# PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

**December 2008**

**This publication was produced by Winrock International under a cooperative agreement for the United States Agency for International Development. The views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.**

# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF ANNEXES

# ACRONYMS

| | |
|---|---|
| ARI | Acute Respiratory Infection |
| ALRI | Acute Lower Respiratory Infection |
| CEPIS | Center for Sanitary Engineering and Environmental Sciences |
| CO | Carbon Monoxide |
| COPD | Chronic Obstructive Pulmonary Disease |
| EAQ | Peru’s National Environmental Air Quality Standards; also ECA (Spanish) |
| ECO | Centro de Ecología y Género (Centro ECO) |
| EHA | Environmental Health Association (“Association”) |
| EHC | Environmental Health Committee (“Committee”) |
| ETHOS | Engineers in Technical and Humanitarian Opportunities of Services |
| GTZ | German Technical Cooperation |
| IAP | Indoor Air Pollution |
| NGO | Non-governmental Organization |
| PAHO | Pan American Health Organization |
| PM | Particulate Matter |
| USAID | United States Agency for International Development |

# EXECUTIVE SUMMARY

Most rural indigenous people of Latin America live in poverty in communities that rely heavily on biomass and other solid fuels for cooking and heating.  Communities at higher elevations in particular are often exposed to severe levels of indoor smoke from inefficient burning of fuels in open fires or rudimentary stoves in poorly ventilated spaces.  Exposure to indoor air pollution (IAP) poses a serious health risk of respiratory infection, causing illness and even death for those who spend the most time in the home cooking environment, namely women and children.

Beginning in 2003, the energy team of USAID's Bureau for Economic Growth, Agriculture, and Trade, and the environmental health team of the Bureau for Global Health jointly supported a cooperative agreement with Winrock International to develop models to reduce indoor air pollution by combining fuel-efficient cooking technologies with behavior change messages and market-based distribution mechanisms. Winrock developed two project models:  a peri-urban model piloted in Bangladesh for poor households and a rural model piloted in the highlands of Peru for indigenous communities.

Field implementation of the Peru "Healthy Kitchen/Healthy Stove" project was led by Centro ECO, a Peruvian NGO, in the rural district of Inkawasi in the northern department of Lambayeque, where 3,000 Quechua-speaking families live at 1,600 to 3,200 meters above sea level. The project involved 33 of the 60 communities in the district and aimed to significantly reduce IAP levels within the kitchens of participating households.  It also aimed to establish a sustainable market for improved and appropriate stoves to avoid the need for subsidies, current or future, and ensure that stoves would be available to the villagers beyond the project period.  Winrock coupled product promotion with a multi-faceted communication campaign to raise awareness about the risks of indoor smoke and to introduce improved stoves and specific behaviors as effective tools for reducing exposure.

The 21-month project resulted in community ownership and management of the production, promotion, micro-financing, and broad dissemination of improved "Inkawasina" stoves.  Environmental Health Committees (EHCs), composed of local leaders and trained promoters charged with educating the public about indoor smoke, improved stoves, and related behavior and environmental health issues, were created in each participating community.  Geographic clusters of committees in turn formed three Environmental Health Associations (EHAs) to oversee and administer the micro-loan fund and to report progress and problems to Centro ECO.

A cadre of 33 promoters from the EHCs was trained to deliver messages directly to families using educational illustrations about the negative impacts of indoor smoke and the benefits and proper use and maintenance of improved stoves.  Radio spots broadcast over a four-month period on a popular radio station reinforced these messages, and various print media were disseminated throughout the communities to raise awareness of the project and elicit participation.  "Healthy Kitchen" competitions motivated participating families to take additional steps to create healthy and orderly kitchen environments.

To maximize access to the stoves, Winrock and Centro ECO developed an animal-based micro-loan system to reflect the region's reliance on barter to exchange goods and services. This was perhaps the most innovative aspect of the project. Despite some challenges in reconciling animal reproduction rates with anticipated repayment plans, the loan system has been largely successful. As of August 2007, 491 families had received their loan of an animal "module" (one male chicken or duck and five females, or one male guinea pig and 11 females). This loan represented 75% of the value of the stove, while the remaining 25% of the value was provided by the family in the form of homemade adobe bricks and labor. The family was then required to pay back 2.4 animal modules to cover the loan principal, the cost of the stove, and the EHA's administrative cost of project management, including technical assistance from project promoters.

This micro-loan system provided income for two new types of entrepreneurs: stove builders and ceramic "elbow" combustion chamber makers. A total of 27 entrepreneurs now get paid in animals or cash by the EHAs, which manage the loan fund.

By September 2007, improved stoves had been installed in 377 of the borrower households. An additional 36 families chose to purchase stoves with cash. Surveys and focus groups confirmed that the majority of families were happy with their stove's performance. The unexpected outright purchases, while still a small percentage of stove acquisitions, underscored the value that families place on having an improved stove.

People were happy with their stoves for a number of reasons, most notably the reduction in indoor smoke and the reduction in fuelwood consumption. Stove monitoring and user feedback showed that the Inkawasina stove was saving over a third of the wood previously used in open fires. Indoor air pollution (IAP) monitoring within 12 months of stove installation showed that indoor concentrations of respirable particulate matter (measured as $PM_4$) and carbon monoxide (CO) were reduced by more than 80% in a large majority of households. A second, post-intervention monitoring conducted up to 24 months after installation showed less dramatic reductions as well as significant increases in IAP levels, in some cases, revealing a possible weaknesses in the ceramic elbows and the need to reinforce messages about effective (and counter-productive) behaviors to sustain the substantial IAP reductions demonstrated by this intervention.

According to household surveys and focus group discussions with families and promoters, the majority of families in the district are now aware of the risks of IAP. Most of those who have acquired the Inkawasina stove have improved the ventilation of their kitchens by keeping doors and windows open while cooking. Some families have invested considerable time, materials, and ingenuity to build new, larger windows and install shelves to store utensils and food. Most families report they now try to keep children away from smoke as much as possible. The implementing team was surprised to discover that a large number of families spontaneously constructed new kitchen rooms in anticipation of receiving their new stoves. These kitchens were for the most part larger and better ventilated than the previous spaces. These families cited pride in their new clean cooking spaces, a dramatic departure from the previous soot-encrusted cooking areas.

While the results of this project have been largely positive, a small portion of families (estimated at about 3% of project participants) have experienced cracking and even collapse of the ceramic elbow combustion chamber, preventing them from using the stove. Of these families, some have fixed the stove while others, unfortunately, have abandoned it. Centro ECO and the promoter team are acutely aware of these problems and are actively seeking appropriate measures to remedy the situation and to reduce the likelihood of elbow cracks.

The overall positive results from this “Healthy Kitchen/Healthy Stove” project have stimulated other organizations to adopt one or more components of its approach. The German aid agency GTZ is using the Inkawasina stove in a 2,750-stove dissemination project in the Bolivian Andes and is focusing on standardized production of the ceramic elbow to improve quality. The Pan American Health Organization (PAHO) has used the IAP monitoring protocol near Cuzco to establish a baseline for a 3,000-stove dissemination project (using the same equipment from the USAID project, loaned to them for this purpose), and has adopted the same focus on local stove entrepreneur development. The SEMBRANDO initiative of Peru’s First Lady is using the Inkawasina stove and negotiating with Centro ECO to expand the project to include another 560 households in Inkawasi. SEMBRANDO’s ambitious goal is to provide 1 million families throughout the Andes region with stoves, latrines, and improved agricultural techniques over the next five years. While the animal-based micro-loan system has generated a great deal of interest and discussion among these groups and elsewhere in Peru, it remains to be seen whether any of these initiatives will adopt this type of market-based approach to ensure sustainable adoption of improved cooking technologies and practices.

# I. PROJECT OVERVIEW

## A. Background

### 1. *Poverty, biomass, and smoke in high-Andean kitchens*

Throughout Latin America most indigenous populations live in rural areas in conditions of extreme poverty. Their communities typically are located in remote, difficult to access areas with limited economic and social development. In countries such as Peru, Ecuador, Bolivia, Mexico, and Guatemala, indigenous populations comprise a significant portion of the total population. According to the Center for Sanitary Engineering and Environmental Sciences (CEPIS), a technical branch of the Pan American Health Organization (PAHO), the majority of indigenous populations in Latin America rely on biomass for cooking and heating.

A significant portion of Peru's indigenous population is exposed daily to heavy levels of cooking smoke in confined kitchen spaces with little ventilation. The situation is particularly severe at higher elevations where solid fuels are the only available options for cooking, and cold temperatures and windy conditions lead people to cook almost exclusively indoors. Daily exposure to high levels of indoor smoke represents a serious health risk for the millions of indigenous poor who inhabit the high Andes, particularly women and children, who typically spend the most time near the fire during meal preparation.

**View of Incahuasi**
*Photo credit: Winrock International*

Mortality rates for the under-five segment of the indigenous population are much higher than the national average; for the Andean populations targeted in this pilot, the rates are estimated in the range of 60-80 deaths per 1000 live births, up to twice the national average. According to the Ministry of Health, acute respiratory infection (ARI) was the leading cause of death in Peru in 2000, accounting for 9,753 cases or 12% of all reported deaths.[1] Acute lower respiratory infection (ALRI) among infants and young children, and chronic obstructive pulmonary disease (COPD) in adults, are estimated to be significant contributors to mortality and morbidity among Peru's indigenous peoples of the high Andes.

Peru's Country Environmental Analysis,[2] a recent study produced by the World Bank, ranks indoor air pollution (IAP) as the fifth most costly environmental degradation issue in the country, after water and sanitation, outdoor air pollution, natural disasters, and lead exposure. According to the study, the negative health impacts associated with IAP cost Peru about US$240 million annually. The report points out that child mortality and illness due to respiratory infections represent 34% and 32%, respectively, of this total cost, while death and illness of adults due to COPD and ARIs together represent 17% of the total cost.

The same report notes that IAP contributes to 25-40% of child ARI deaths in Peru; 20-30% of all ARI-related illness for children under five years of age; 15-25% of all ARI in adult females; and 20-40% of all cases of death and illness due to COPD.

## 2. *The Ayamachay Pilot: 2003-2004*

Although development agencies (private, governmental, and international) have implemented efforts to improve basic living conditions for Peru's indigenous populations by addressing the need for clean water and sanitation, IAP has not been part of the agenda. A unique pilot experience integrating improvements in water and sanitation while tackling IAP was undertaken in 2003 by PAHO and GTZ in the community of Ayamachay, in the district of Inkawasi, department of Lambayeque, in northern Peru. The initial focus of the project was limited to water and sanitation; however, the IAP levels observed in houses in Ayamachay were too severe to be ignored by PAHO and GTZ staff. Improved stoves were

**Infants are usually present when cooking takes place in Inkawasi and are at high risk of ARI.**
*Photo credit: Winrock International*

---

[1] With a 50% report rate. http://www.minsa.gob.pe/estadisticas/estadisticas/Mortalidad/092000DI00.htm

[2] Republic of Peru Environmental Sustainability: A Key to Poverty Reduction in Peru. Country Environmental Analysis. June 2007. Report 40190-PE, The World Bank.

thus incorporated into the pilot under the “environmental health” umbrella.

By 2004 the pilot initiative in Ayamachay had installed latrines, a running water system, and improved wood stoves in 60 households, addressing all basic needs of sanitation and cooking for these rural families. The Centro de Ecología y Género (“Centro ECO”), a local non-governmental organization (NGO) based in the city of Chiclayo, provided training in basic health and environmental issues to the Ayamachay community leaders. The improved wood stove was custom designed by a local engineer. He used mostly locally available materials to create a model that improved energy efficiency and curbed emissions, yet was appropriate and affordable to the community. Project monitoring conducted in 2004 revealed a 90% acceptance rate of the stoves by Ayamachay families, with reported reductions in respiratory illnesses among women cooks. Unfortunately, neither PAHO nor GTZ committed to expanding this experience within the region.

### *3. The Healthy Kitchen/Healthy Stove model: 2005-present*

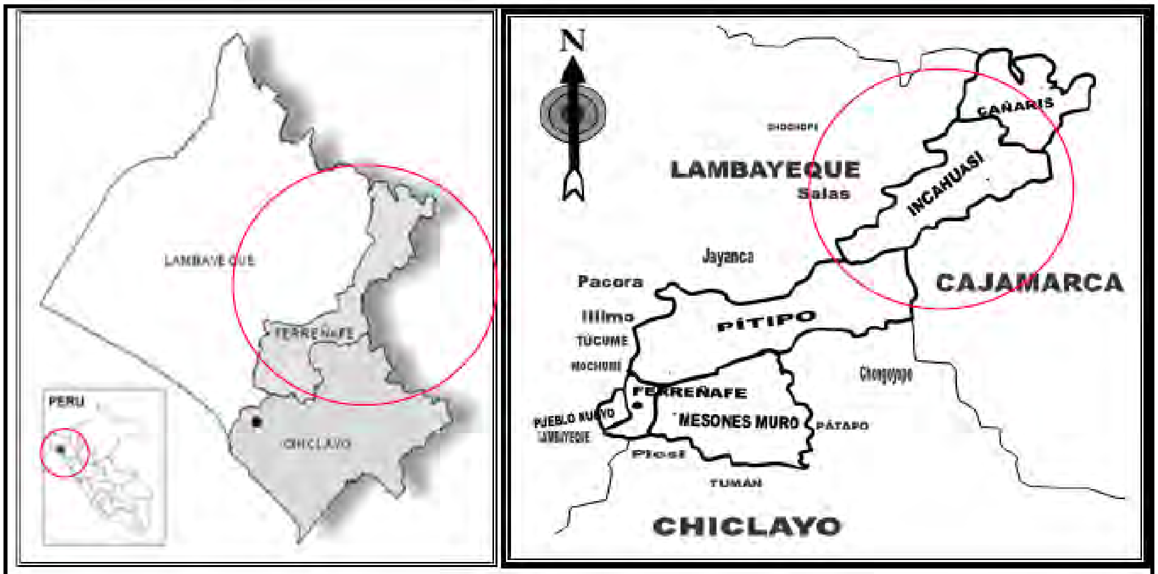
To strengthen this experience and further develop it into a replicable model, the energy team of the USAID Bureau for Economic Growth, Agriculture, and Trade and the environmental health team of the Bureau for Global Health jointly supported the “Healthy Kitchen/Healthy Stove”[3] pilot project on a district-wide scale. The project described in this report developed a unique model for the manufacture and distribution of improved wood stoves among poor rural indigenous communities; creating local organizational capacity for raising awareness about the health risks of indoor smoke among the families of 33 communities; producing and supplying the wood stove technology; and enabling widespread community access through an innovative finance scheme. This project model was developed to be easily coupled with water and sanitation and other environmental health initiatives. The lead field implementer for this project was Centro Eco, the NGO that participated in the previous project in Ayamachay. Centro ECO specializes in community development of environmental projects. Winrock International provided project design guidance, technical support, and administrative oversight on behalf of USAID.

The district of Inkawasi is located in the high-Andean mountains of northwestern Peru, northeast of the city of Ferreñafe within the department of Lambayeque (see maps on next page). It is an indigenous district with 60 villages (approximately 3,000 families) in a mountain landscape that ranges from 1,800 to 3,200 meters above sea level. Quechua is the primary language, with Spanish the secondary language. The economic activities are primarily agriculture based, including cultivation of wheat, potatoes, green peas, corn, timber, and animals such as cows, chickens, guinea pigs, and sheep. Houses typically are built of adobe, roads are unpaved, and electricity service is unreliable and reaches only a small portion of the population. Elementary schools are usually available throughout the

---

[3] “Cocinas” in Peru refers to both stoves and kitchens; thus “Cocinas Saludables” carries the double meaning of Healthy Stoves and Healthy Kitchens.

villages, while secondary-level schooling is available only in the town of Incahuasi.[4] There are health posts and public phones in the towns of Incahuasi and Uyurpampa.



**Maps of Peru, highlighting the Inkawasi district**

## B. Project Objectives

The overarching objective of Healthy Kitchen/Healthy Stove pilot project was to reduce exposure to indoor air pollution among indigenous communities in the high-Andean region through an integrated and sustainable household energy intervention. Women and children were the primary targets, given their traditionally higher exposure to kitchen smoke.

The project aimed to develop a program model for replication elsewhere in Peru and throughout the Andean region, expanding the Ayamachay pilot from one community to at least 20 communities and 600 households in the district. The model also sought to complement the improved stove technology with behavior change communications, the establishment of community institutions, and an innovative finance mechanism to increase the project’s sustainability.

## C. Approach and Activities

The approach taken in this pilot project reflects a present-day understanding of the key elements needed to achieve and sustain adoption of improved technology and behavior change and, in this case, reduce exposure to indoor air pollution. Past interventions have yielded many lessons about the failure of one-size-fits-all, technology-driven “stove” programs to achieve long-term adoption. The greater challenge lies in demonstrating the

---

[4] The district and a town within the district have the same name, which is commonly spelled two ways: Inkawasi and Incahuasi. In this report, Inkawasi refers to the district and Incahuasi to the town.

combination of elements most likely to be effective in the short term for a given population or category of populations—and most likely to be replicated and scaled up over the long term. This project demonstrates an integrated intervention composed of the following core components:

*Local organizational infrastructure*

Establish an organized cadre of promoters and other community leaders trained in the health risks of indoor air pollution, improved stove design and benefits, animal husbandry, and micro-loan management to ensure local capacity to carry on all aspects of the intervention beyond the life of the project. Building formal community structures facilitates initial community buy-in and ultimate ownership and responsibility for long-term results.

*Awareness building and behavior change*

Raise awareness within the target population and among neighboring families about: 1) the risks associated with exposure to indoor air pollution; and 2) technological and behavioral options to reduce exposure. Increased awareness and improved practices are revealed in attitudes and perceptions as reported through surveys, focus group discussions, and promoter feedback. Improved practices are assessed through IAP reductions (or lack thereof) and promoter observations of changes in kitchens.

*Market development*

Build the foundation for a sustainable market through the development of local stove entrepreneurs and a micro-loan mechanism that reflects the region's reliance on barter rather than cash for the exchange of goods and services. The selected stove technology is a locally adapted and accepted wood stove technology utilizing well-tested design principles for reducing fuelwood consumption and indoor air pollution while remaining cost effective.

*Technology adoption*

Distribute energy-saving, emissions-reducing cookstoves adapted to local conditions among a target population of 600 families, or 20% of Inkawasi households, across at least one-third of the district's 60 communities. This target goal of 20 villages was exceeded, and 33 villages ultimately were included in the project area. Successful adoption of the improved stove technology implies that families use the Inkawasina stove exclusively for daily cooking needs (using traditional open fires only *outdoors* for special events) and are satisfied with the new stove's performance. Winrock also promoted adoption of a locally adapted retained heat cooker, or "haybox," in a limited number of households based on the level of interest identified through initial trials.

*Indoor air pollution monitoring*

Verify changes in kitchen concentrations of respirable particulate matter (measured as $PM_4$) and carbon monoxide (CO), with a reduction target of 80%, in a representative sample of 30 households (5% of the target population).

**Annex I** presents detailed information on project indicators. The approach taken for each of these project components is discussed in the next sections.

### *1. Establishing community-level organizational infrastructure*

Securing community ownership or buy-in and building community capacity to manage project components were fundamental steps in sustaining project activities over a long period. The project team agreed that in addition to developing technical and administrative capacity among individual promoters, a governing structure was needed to achieve near-term project objectives as well as the longer-term goals of a locally managed, market-based system.

Centro ECO applied its strong communications and organizational skills, along with its experience in community organization elsewhere in Lambayeque, to mobilize the communities of Inkawasi. These people- and time-intensive activities dominated the first few months of project implementation.

The model developed for Inkawasi involved two levels of organization:

1. **Community level**: Environmental Health Committees (EHCs) for each of the 33 participating villages. These local volunteer-based community organizations were responsible for promoting the project and coordinating implementation activities within each village. Winrock and ECO chose "environmental health" to characterize the committees, with the vision that the scope of their activities could broaden with time to encompass water and sanitation, hygiene, and related environmental health issues.
2. **Regional level**: Environmental Health Associations (EHAs) of EHCs grouped on a geographic basis. The 33 EHCs were divided among three EHAs to cover the wide territory. The EHAs were responsible for overall project administration, coordination, and reporting to Centro ECO.

Each committee is composed of four lead promoters trained in IAP health risks and the behavioral and technological solutions to mitigate them. The leaders include a President, Secretary, Treasurer, and substitute. Winrock urged committees to select women to hold at least one if not two of these posts. The overall mandate of the committees is to promote sound environmental health practices. While the emphasis of this project was IAP reduction, the scope of promoter training—and in turn their awareness-raising activities with target households—included more general kitchen organization and hygiene issues, under the umbrella of "Healthy Kitchen."

Committee members elect leaders to manage the associations. Each EHA is responsible for overseeing the work performed by EHCs within the association. The EHAs also approve EHC work plans, approve new families who want to join the project, and keep records on the number of animal modules delivered and recovered, stoves made, and other data, which is then shared with Centro ECO and the other two EHAs during their monthly joint planning meetings.

Figure 1 on the next page shows the organizational structure of the EHAs, EHCs, and Centro ECO, which worked with local leaders to form these community organizations before transferring overall project management responsibility to the EHAs.

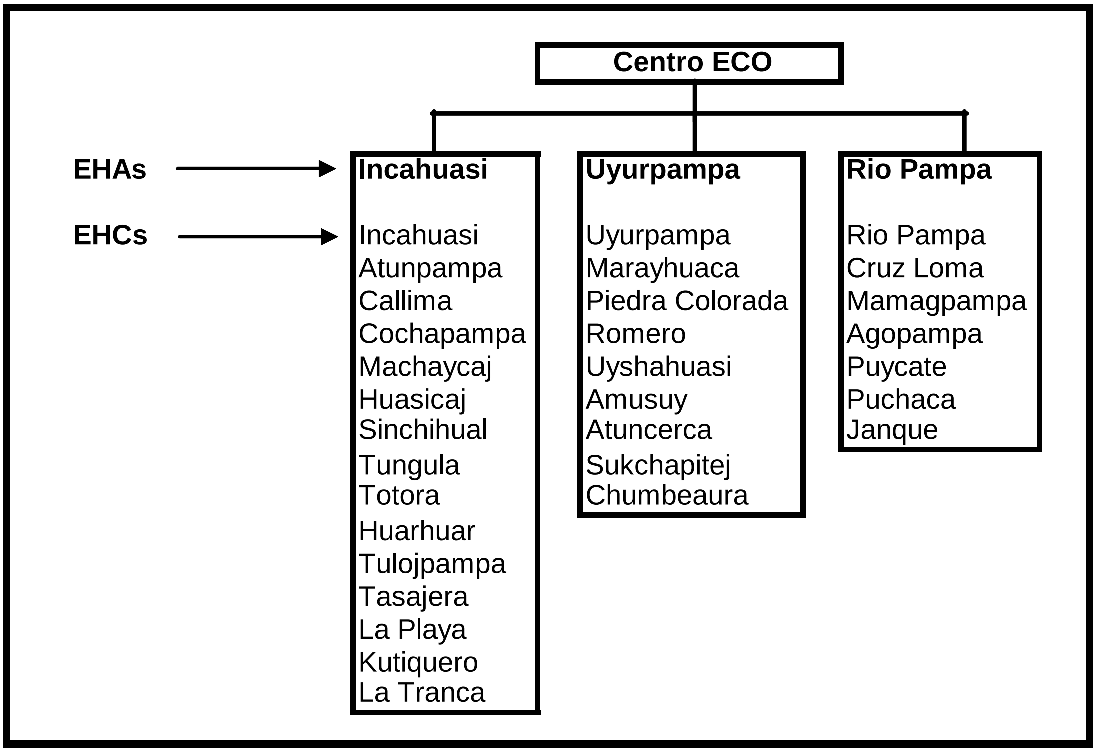


***Figure 1. Organizational structure of EHAs and EHCs in the Inkawasi district***

### *2. Raising awareness and promoting effective behaviors*

The core mission of the Healthy Kitchen/Healthy Stove project was to raise awareness among the population of the Inkawasi district about the risks associated with exposure to IAP from the use of solid fuel for cooking, and to promote ways to mitigate these risks through improved behaviors and technologies. Local buy-in, knowledge, and communications capabilities were central to achieving this mission. Several activities engaged the population at the household, community, and municipal levels.

*Project kick-off and broad-level promotion*

A series of presentations was developed to inform local leaders of the project's objectives and seek their collaboration. First, Winrock's lead implementing partner, Centro ECO, made presentations to provincial authorities and opinion leaders in the city of Ferreñafe, followed by two local meetings with community leaders in the villages of Uyurpampa and Incahuasi. All of the local leaders expressed support for the project. To raise awareness about the project and its objectives among decision makers throughout the country, brochures were produced and distributed by Centro ECO staff at meetings and seminars throughout the region and in the capital city of Lima.

*Message and material development*

Winrock worked with Centro ECO to develop a range of communications materials for use by trained promoters when meeting directly with families or community groups, or for dissemination through a range of local media.  All communications focused on three primary messages—a problem statement and two solutions—to be delivered jointly:

1. Smoke from indoor cooking fires causes serious respiratory illness, particularly among women and children, and can even cause death of children.
2. The Inkawasina stove enables a cleaner and healthier kitchen while reducing the use of fuelwood.
3. Improved kitchen practices, such as ventilation, keeping children away from smoke, and using dry fuelwood can help minimize the health risks of indoor smoke.

Because the Inkawasina stove had already been field tested in Ayamachay, it was promoted from the beginning of this project as a solution to the indoor smoke problem.

Specific materials were developed to encourage behavior change, including:

- Large banners and murals placed centrally in each village to raise awareness of the issues and publicize the project
- Smaller posters for broader distribution around the district, with similar objectives
- Flyers containing information on the project; health impacts of smoke; stove construction, use and maintenance; and animal care were circulated through the villages
- Radio spots featuring local women discussing health impacts of kitchen smoke and the benefits of an improved stove
- A set of illustrations conveying messages about the ill effects of smoke; indoor conditions resulting from an open fire versus an improved stove; images of a well-ventilated, orderly, and clean kitchen; and proper operation and maintenance of the stoves (shown at right).  These materials were aimed at the end user and intended for use by promoters during initial awareness-raising meetings with families, and later to train them in the use of their new stoves.

Messages and graphic images were developed with help from local artists and feedback from focus groups. The materials used both Spanish and Quechua, as appropriate, and were culturally adapted for this high-Andean, Quechua population.  An awareness campaign was launched with the hanging of large murals in each target community; displays of posters depicting key health and fuel-saving messages; and district-wide radio broadcasts of information and educational messages about IAP risks and project benefits. As local leaders were identified and trained as promoters, the direct awareness and promotion activities began through small group discussions and household visits.

*Promoter selection and training*

The project developed a cadre of local promoters to distribute information to families and lead the stove dissemination. Promoter responsibilities included making house visits and leading activities with groups of women at the local community centers to share knowledge about IAP risks, discuss the Healthy Kitchen/Healthy Stove project, and recruit participants.

Centro ECO was responsible for training the promoters, who were selected based on their interest in the project. The project team planned to train equal numbers of men and women as promoters, not only to achieve a gender balance, but because women were expected to be more effective at communicating health risks and stove benefits to other women. At least one promoter was trained in each community.

*Healthy Kitchen competitions*

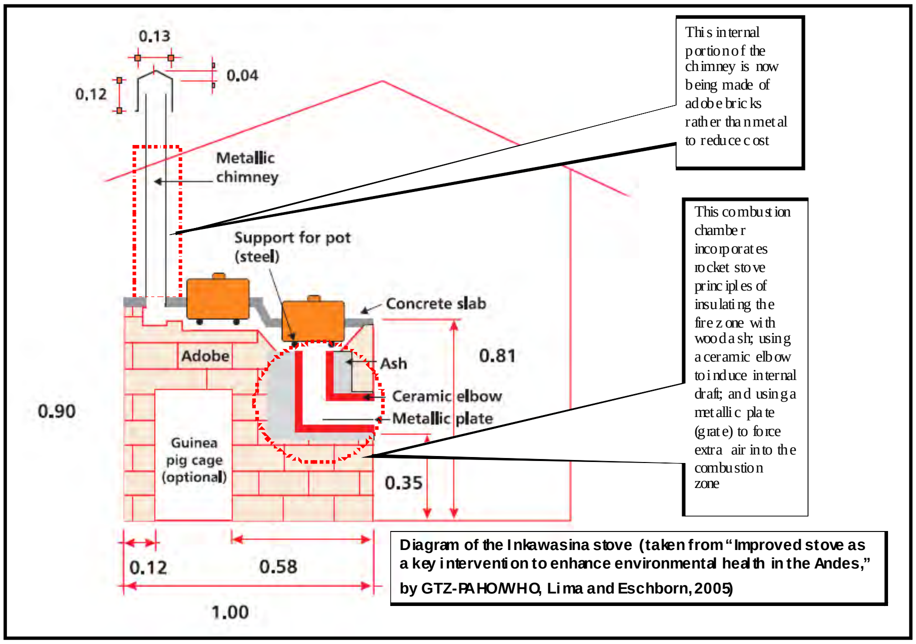
At the recommendation of Centro ECO, a series of “Healthy Kitchen Competitions” was organized among families receiving the improved stoves. The competitions reinforced the concepts of clean air and kitchen cleanliness and provided additional incentives to natural leaders in the community to take pride in their kitchen environment and share their approaches with other women. A total of 22 competitions were held.

### 3. Promoting appropriate technology

The chosen technology for this project was an improved woodstove called the “Inkawasina” stove, developed by Centro ECO engineer José Humberto Bernilla. This stove was field tested by 60 households under a GTZ pilot with excellent results. From the project kick-off meetings with municipal and community leaders to the household-level promotion by community promoters, the Inkawasina stove was touted for its ability to reduce indoor smoke, reduce respiratory disease, and reduce the time and physical drudgery of collecting fuelwood. Based on community acceptance in the Ayamachay pilot, the model was deemed appropriate, with some small improvements, for immediate promotion.

In October 2007, after the project was completed, the GTZ program in Bolivia contracted Aprovecho Research Center to assess the performance of the Inkawasina stove, among many others to be promoted in Bolivia. Aprovecho had the following conclusion about the Inkawasina stove design: “The Inkawasi-based stoves are wonderful. Successful use of sunken pots in a chimney stove is the best way to reduce fuel use and IAP level in a home. The stove design is well done from a heat transfer and combustion efficiency standpoint, and they are appropriate solutions to local needs using local materials. Also the stoves fared quite well in all tests that were conducted.” With reference to the Inkawasina stove dissemination strategy in Peru, the Aprovecho report also noted, “The Peruvian stove dissemination strategy is one of the best I have seen. The strategy and cost for reaching the people with greatest need living in remote areas is excellent. It is encouraged that the designs and performance results of this project be shared with the greater stove community in the hope that a similar strategy can be followed in other areas worldwide."[5]

The Inkawasina stove incorporates clean and efficient combustion concepts, particularly "Rocket"[6] stove design principles, to increase energy efficiency while reducing emissions and indoor pollution. A chimney exhausts the remaining pollutants. The original Inkawasina stove used an all-metal chimney; however, the design was modified under this project to replace the metal with adobe for the indoor portion of the chimney to reduce costs. The stove is built on-site using locally available materials, including adobe bricks, locally fired ceramic "rocket" elbows, and cement (see **Figure 2**).



This internal portion of the chimney is now being made of adobe bricks rather than metal to reduce cost

This combustion chamber incorporates rocket stove principles of insulating the fire zone with wood ash; using a ceramic elbow to induce internal draft; and using a metallic plate (grate) to force extra air into the combustion zone

Diagram of the Inkawasina stove (taken from "Improved stove as a key intervention to enhance environmental health in the Andes," by GTZ-PAHO/WHO, Lima and Eschborn, 2005)

***Figure 2. Detailed sketch of the Inkawasina stove***

---

[5] MacCarty, Nordica. Results of Testing and Existing Stove Design Recommendations: Peru. Aprovecho Research Center. October 2007.

[6] The "Rocket" stove was developed by Aprovecho Research Center. The principles of rocket stove design are incorporated into a wide range of stove designs in numerous countries. Key elements include: an insulated combustion chamber to increase the temperature within the fire zone; a grate to elevate the fuel magazine and allow adequate air (oxygen) to mix with the fuel gases; and an internal chimney that creates a natural draft within the combustion chamber, forcing the hot gases to rise and fresh air to enter the combustion chamber. These features result in a better mix of the fuel gases and oxygen and very high temperatures, such that the combustion is more efficient and generates fewer harmful pollutants. Additional design features, such as adding a "skirt" around the pot or sinking the pot closer to the flame, increase heat transfer efficiency, and thus facilitate a reduction in fuel use.

Winrock and Centro ECO designed a dissemination strategy that would make the Inkawasina stove affordable and accessible to interested families in the district and foster ongoing access in the future. Local artisans produce the "rocket" elbows, and the stoves are constructed by a select group of promoters in each EHC trained as stove builders under this project. Both the elbow makers and stove builders receive payment for their services from their respective EHAs.

To keep the stove cost low and to maximize the engagement or "buy-in" of the stove owner, the family must make the adobe bricks for the stove body, using locally available mud mixed with grass in wooden molds and dried outdoors. Each family must further contribute labor to assist the stove builder when he is constructing the stove in the family's kitchen. This contribution in adobe and labor by each family represents about 25% of the overall stove cost. The stove builders are responsible for buying or preparing other materials such as the cement plate to hold the pots, iron bars, rocket elbow and chimney cap.

The cost of the Inkawasina stove components are shown in **Table 1**, with the family contribution highlighted:

***Table 1. Inkawasina wood stove cost breakdown***

| **Component** | **Cost:** ***soles*** | **US$** | **Notes** |
|---|---|---|---|
| Masonry | 27 | 7.54 | Cost of mason's labor |
| Rocket elbow | 17 | 4.75 | Ceramic elbow |
| Metal parts | 22 | 6.15 | Iron bars, chimney hat and outdoor pipe, chimney paint, wires |
| Other parts | 15 | 4.19 | Cement plate, sand, wood mold for stove parts |
| Adobe bricks | 33 | 9.22 | Adobe, mud, wood ash (all provided by stove owner) |
| Assistant | 5 | 1.39 | Manual labor (provided by stove owner) |
| **Total** | **119** | **33.24** | |

To supply the stoves with the ceramic "elbow" combustion chamber, several local promoters were trained as ceramic artisans. These artisans are now responsible for supplying all stove makers with this key component of the Inkawasina stove.

### *4. Developing a market: establishing entrepreneurs and micro-finance*

At the heart of this project was Winrock's commitment to establishing a self-sustaining system through which residents of the Inkawasi district could obtain and maintain Inkawasi stoves beyond the life of this pilot. Thus the project also aimed to develop local entrepreneurs to provide the stoves, and a micro-loan system to accommodate local barter traditions while generating cash to pay the entrepreneurs.

#### *Local capacity and entrepreneur development*

Developing entrepreneurs required identifying dynamic and motivated leaders among the community promoters already trained in the benefits and basic functioning of the stoves. Centro ECO and the promoters agreed that the work of building stoves and constructing ceramic elbows would most appropriately be conducted by men. Though Winrock aimed to involve as many women as possible at all levels, Centro ECO was persuasive in arguing that both the physical demands and the time commitment away from home would render both jobs inappropriate for women, given local customs and gender roles.

The project aimed to train at least one promoter per community to build stoves, and at least two per EHA to make ceramic elbows. To enable local production of the elbows, the project planned to build one kiln per Association.[7] Centro ECO drew on its experience under the Ayamachay pilot to lead the stove-building training, and benefited from consultations with Winrock's Rogerio Miranda, an expert in rocket stove adaptations. Training on elbow production was led by the ceramist from the lowland city of Morrope (near Ferreñafe) who was responsible for making the elbows for the 60 Ayamachay stoves. After initially producing the elbows in parts on a potter's wheel and fusing the pieces, the ceramist developed a mold for faster production.

*Facilitating access through micro-credit*

The Inkawasi district is relatively isolated from the main cities of Lambayeque province. Located high in the mountains at the end of a winding, narrow, and bumpy uphill dirt road, the local indigenous communities have little mobility and face difficulties in trading with the more prosperous areas of Peru. Their traditional economy thus remains impoverished, based largely on subsistence agriculture and on bartering products among themselves, with relatively little cash exchange.

Centro ECO and Winrock designed a micro-loan mechanism that reflects this economic context, providing capital to enable borrowers to acquire the new and improved woodstove. The micro-loan system is based on animal husbandry: the borrower receives a "module" of several animals that reproduce to generate new "capital" or income with which to purchase the stove and repay the loan.

*Loan conditions*

To participate in this innovative micro-loan system, families needed to meet the following conditions:

1. Express interest in buying an Inkawasina stove to minimize household exposure to IAP.
2. Commit to the terms of the animal loan. Each family received an animal module (usually one male and five female chickens, or one male and ten female guinea pigs). The family had to return around 2.4 times the number of animals it borrowed. This "capital" covered the cost of the stove, repaid the loan principal, and generated an additional 40% for interest and a service fee.[8] Each animal module was valued at about 75% of the price of an Inkawasina stove (US$25)[9],

---

[7] As noted in the Project Results section, a third EHA was created, leading to a total of six elbow makers and three kilns constructed.

[8] This service fee income was used by the EHA to pay the per diem of the technical promoters to assist neighboring villages and also for the EHA leaders to travel to Ferreñafe and Chiclayo to negotiate the sale of animals reproduced.

[9] The micro-loan financed 75% of the stove cost; the remaining 25% was provided through in-kind contributions from each family.

and the total repayment was equivalent to US$60 (the value of 2.4 animal modules). The repayment period was 12-18 months, with some flexibility to account for variation in animal reproduction rates. Once the first module equivalent was paid (U$25), the family was authorized to receive the installation of the stove, and then continued to pay back the remaining loan amount to the EHC.

3. Contribute in-kind by: a) making adobe bricks for the stove; b) providing additional labor to help the stove maker; c) building a secure animal pen with adequate water and appropriate shelter from the elements; and d) committing to care for the animals, providing food and paying for veterinary treatment as necessary.

*Loan management*

Families could choose between ducks, chickens, and guinea pigs for their loan. The EHC promoters monitored the animals' development and health, and tracked repayments.

Promoters were trained by Centro ECO to provide assistance to each family in the proper care of their animals. For a small fee, the promoters also administered basic veterinary services such as vaccinations and other treatments as needed.

## 5 Verifying changes in IAP and other indicators

To determine and demonstrate the effectiveness of the comprehensive Healthy Kitchen/Healthy Stove intervention, Winrock and its partners undertook monitoring of local practices and perceptions, indoor air quality, fuelwood consumption, and health symptoms using pre- and post-intervention surveys, focus groups, fuelwood monitoring, air sampling of $PM_4$ and CO, and spirometry to detect changes in lung function. Given the overarching goal of the project to reduce indoor air pollution, Winrock gave priority to monitoring $PM_4$ and CO to gauge project impact, followed by energy consumption. However, Winrock and Centro ECO also sought to track other impacts, such as time savings, to provide further insight into the project's success in bringing about effective and enduring changes in the cooking practices of Inkawasi families.

Pre- and post-intervention monitoring took place as follows:

- *IAP concentrations:* 24-hour measurement of $PM_4$ and CO concentrations in the kitchens of a >5% sample of intervention households (42 pre-intervention and 32 post-intervention), prior to the first stove installations, and again 12 and 24 months later. This work was conducted by Lima-based Swisscontact.
- *Practices and behaviors:* Surveying of >5% of the district's households (169 households), before intervention and 12 months later. This survey gathered information on awareness about IAP health risks and alternative cooking technologies; cooking practices, including type of stoves and fuel used, number of meals cooked per day; perceptions of how wood smoke affects the family's health; the amount, time, and costs associated with fuelwood collection; and other key information. The survey was developed by Winrock and implemented by Centro ECO with the help of several EHC promoters, who provided translation into Quechua.

- *Fuelwood consumption:* Measurement of household fuelwood consumption patterns (kg/week), conducted in >5% of the intervention households by Centro ECO engineer José Humberto Bernilla, with assistance from EHC promoters, in parallel with the household pre- and post-intervention surveys.
- *Health symptom impacts:* Spirometry (lung capacity) tests coupled with a survey on health symptoms in >5% of the intervention households, conducted by Dr. Jay C. Smith from Dartmouth University, before and after stove installation.

In addition to these measurement and survey tools, feedback from focus groups and trained promoters within the three clusters of Environmental Health Association villages provided additional insights on what has or has not worked, and why.

Local training was included for each monitoring component. For IAP monitoring, Swisscontact trained a field technician from Uyurpampa. For the surveys, Winrock and Centro ECO agreed that both men and women should serve as surveyors; Centro ECO conducted the training on the survey and data gathering procedures. Dr. Smith identified a local female nurse, bilingual in Spanish and Quechua, to facilitate the health symptoms survey, and a male assistant to administer the spirometry tests.

## D. Project Team

Winrock International was the lead implementing organization for the project, guiding the design of the project and activity implementation, and providing technical assistance. Two local partners supported Winrock's work. The Centro de Ecología y Género (Centro ECO) was the lead field implementer for this project and supported all local implementation and much of the project monitoring and coordination. Swisscontact led the IAP monitoring component of the project. Dr. Jay Smith undertook health symptom testing and surveying before and after the stove installations. The full team is listed here:

Lisa Büttner, Winrock International
Rogerio Miranda, Winrock International
Dante Díaz, Centro ECO
José Humberto Bernilla, Centro ECO
Axel Krause, Centro ECO
José Reto Timaña, Centro ECO
María Vázquez, Centro ECO
Aida Figari, Swisscontact
Adrián Montalvo, Swisscontact
Dr. Jay C. Smith, Health symptom monitoring volunteer
Nelly Huaman, Nurse and translator
Luis Ferronay, Veteranarian
Victor Eduardo Bautista Carrasco, Graphic artist

# II. PROJECT RESULTS

## A. Summary

This pilot project reached a significant portion of its goals and surpassed several targets, as summarized in Table 2. Additionally, the project was able to gather data over two years, including pre-intervention, post-intervention, and one year after the end of implementation, which was both extremely helpful in project evaluation, and highly unusual for projects of this sort. The project achieved its primary objective of significantly reducing IAP among target households of the Inkawasi district. While the total number of installed stoves fell short of the target (largely due to slower than expected rates of animal breeding and loan repayment), as of August 2007 60% of the target number had been installed, with indications that dissemination would continue sustainably. Twelve-month post-intervention monitoring demonstrated the potential of this intervention for reducing indoor pollutant concentrations–there was an average IAP reduction of 84% in households where any reduction was noted (a majority of households monitored). A subsequent monitoring survey in July 2007 revealed lower reductions in 50% of the households, while the other 50% experienced no change or increases. This slippage was due to a combination of stove elbow failures, ill-fitting pots, and a tendency of some cooks to leave coals smoldering throughout the day. Both Winrock and Centro ECO believe they can remedy these problems with further follow-up to ensure the sustainability of the earlier–and significant–reductions in indoor smoke.

**A project beneficiary with her Inkawasina stove.** *Photo credit: Centro Eco*

Meanwhile, survey results showed that the vast majority of participating families were satisfied with their improved stoves. Many families invested their own time and materials to construct new kitchen rooms to accommodate the new stove, and have undertaken additional kitchen improvements to yield a more orderly and healthy environment. Fuelwood monitoring showed a reduction of 32% in fuelwood consumption, while many families perceived an even greater reduction.

During implementation, the project team and USAID recognized that the number of installed stoves was not the most telling indicator of long-term success. Indicators of the likelihood that local capacity, community organization, and financial mechanisms would endure over time were ultimately given greater weight. In this regard, the project has demonstrated success. By the end of the project, 527, or 88% of the target number of households, had acquired or committed to acquiring an Inkawasina stove (93% utilizing the micro-loan mechanism and 7% paying for the stove in cash); 68% of the original value of loans made had been recovered; and project surveys, focus groups, and anecdotal feedback indicated that a large majority of households in the district now understand the risks associated with IAP and are aware of measuresthey can take to reduce these risks.

The direct purchase by 36 families of Inkawasina stoves was surprising. This suggests that the IAP messages and appreciation for the advantages of the Inkawasina stove are spreading beyond the target population to an unexpected segment that both values the benefits and has the capacity to pay for the improved stoves without the assistance of a loan.

Since the close of the project implementation period in September 2007, the activities initiated in Inkawasi have continued and even picked up speed, with both increased stove demand, and increased promoter and manufacturer capacity to meet the demand. By September 2007 about 380 improved stoves had been purchased and installed and more than 400 animal modules had been distributed on loan. Since then project activities have continued without external funding. By March 2008 the Environmental Health Associations had supported the adoption of about 700 improved stoves, and loans of more than 800 animal modules. This continued success demonstrates the sustainability of the project, which relied on local organizations, developers, and community leaders influencing their neighbors and friends about the importance and benefits of the improved stoves.

***Table 2. Quantifiable results of Healthy Kitchen/Healthy Stove project***

| **INDICATORS**<br>(Household = hh) | **Totals (as of August 20th 2007)** |
|---|---|
| IAP reduction 2006: average for 42 hh | 70% |
| IAP reduction for 30 hh w/ decrease | 84% |
| IAP reduction 2007: average for 32 hh | -10% (increase) |
| IAP reduction for 16 hh w/ decrease | 64% |
| Inkawasina stoves installed | 377 |
| Animal modules loaned | 491 |
| Value of animal modules loaned (*Soles*/US$) | S./40,262<br>(US$ 12,388) |
| Value of animal modules recovered (*Soles*/US$) | S./26,881 (US$ 8,271) |
| Direct sale of stoves | 36 |
| Environmental Health Associations formed | 33 |
| Cadre of community promoters trained in IAP, stoves | 60 |
| Stove makers trained (men) | 21 |
| Ceramic artisans trained (men) | 6 |
| Women trained on use & construction of retained heat cookers | 35+ |
| Murals installed | 33 |
| Posters distributed | 600 |
| Radio spots broadcasted | 290 |
| Flyers circulated | 2,100 |

| **INDICATORS**<br>(Household = hh) | **Totals (as of August 20th 2007)** |
|---|---|
| Pictorial materials developed for household awareness and end-user training (# people) | 1,000+ |
| Healthy Kitchen competitions held | 22 |
| Professional meetings where project results were presented | 8 |
| Houses surveyed for practices/perceptions (pre & post) | 169 |
| Houses monitored for IAP | 42 |
| Average % of fuelwood reduction | 32 |

## B. Detailed Results

Based on these results and the lessons learned from this project, Winrock expects that the IAP reduction model developed in Inkawasi can be scaled up and replicated elsewhere in the region. This section provides a more detailed discussion of the results obtained through each of the project components.

### *1. Community organizations established*

*Promoters created and empowered*

Centro ECO approached one community at a time to familiarize local leaders with the Healthy Kitchen/Healthy Stove project and seek interested and dynamic individuals to assume the role of community promoters. This process started in April 2005 and continued for several months as ECO reached out to a total of 33 communities. During initial project planning, Winrock had discussed a goal of working in 23 of the 60 communities in the district. Reaching approximately one-third of the district's communities would provide good coverage, without being too heavy a logistical and administrative burden on Centro ECO. As planning progressed, however, ECO proposed including 25 communities; in the end, ECO included even more communities in response to growing interest throughout the district. Thus, 33 promoters were identified and trained, one for each of the participating villages.


**Promoters receiving training about IAP messages at Centro ECO's headquarters.** *Photo credit: Centro Eco*

As of June 2007, ECO's 20 training sessions for promoters had attracted about 533 attendees.[10] The sessions covered the basics of IAP and associated health risks and how to avoid the risks by using

---

[10] Number of registered participants in all sessions organized by ECO. Many promoters attended more than one session.

improved wood stoves, improving ventilation, and adopting new habits to minimize IAP exposure. In addition, these promoters received training in five sessions (with about 70 attendances) on proper use and maintenance of the improved stove, as well as training in animal care and veterinary practices (nine sessions with about 179 attendances).

These volunteers were extremely effective as the primary promoters of the project in Inkawasi. They dedicated 10-15 hours a week to this work, receiving compensation in the form of new skills received through the training sessions, material goods (a hat, a bag, and promotional materials), and the pride and status of being recognized as an important member of their community. Promoters who provided veterinary care for the families also received a small fee for services performed (e.g., vaccination or medicine administered). As can be expected in any development project, some promoters dropped out of the project, often due largely to other time pressures. As of August 2007, 52 of the 60 trained promoters and stove builders were still active in Inkawasi.

In the identification of promoter candidates, Winrock and ECO discussed including both men and women as community promoters, including the possibility of pairs of promoters (one man, one woman) to maximize the effectiveness of message transmission, as well as the comfort level of women receiving visits in their own households. Both Winrock and ECO assumed that women promoters might be most effective at communicating health risks and cooking benefits to other women. Nevertheless, involving women as promoters turned out to be more difficult than anticipated. Of the 33 project promoters, about one-third were women. One reason for the lower than desired number of women participants was the significant time that promoters must spend away from home.

**Training sessions on retained heat cooker (or "haybox") construction at Uyurpampa. Easily available cardboard was used to frame the haybox, which was insulated with locally available materials such as rice husks or wool and covered with plastic to protect against humidity. The haybox cover was a small pillow of cloth and insulating material. At the end of each training, the hayboxes built during that session were raffled off to participants. Recipients liked the hayboxes but found the Inkawasina stoves more exciting.** *Photo credits: Winrock International*

On the other hand, women were successfully targeted and trained in how to build and use retained heat cookers, or hayboxes, which ECO introduced and tested with a handful of interested women after the majority of stoves were installed. As of June 2007, more than 35 women had been trained in the construction and use of retained heat cookers.

*Institutions established*

To provide logistical and long-term support to the project, including post-project support, Centro ECO built local institutional capacity to manage the project by helping the local communities form their own Environmental Health Committees (EHCs). In turn, Centro ECO organized the committees into associations to consolidate the management of funds, planning, and reporting by geographic region. Thus, the first two Environmental Health Associations (EHAs) were established with headquarters in Uyurpampa (on the west side of the watershed) and Incahuasi (on the east side). As the project developed, a third association was established in Rio Pampa to encompass communities at lower elevations in the southern part of the district.

The village-level committees assumed responsibility for promoting the project messages and components within each community. The most competent and available promoters were given the title of Technical Promoters and assigned by the EHAs to visit neighboring communities to supervise and assist local EHCs with priority tasks, for which they received a modest per diem from the association as an incentive (S/.6 per day). The funds used to pay the Technical Promoters came out of the 40% "interest" that families paid on their loans.

At the onset, the project aimed to establish 23 EHCs; however, as the project progressed and the publicity reached more villages, leaders from several additional communities approached Centro ECO asking to be included in the project. In the end, Committees were formed in 33 communities. In an example of the strength of the EHAs' capacity, eight of the last 33 Committees formed were created by the leaders of the three Associations, following the same methodology used by ECO to evaluate community interest and potential.

Centro ECO's previous successful experience with developing community organizations and promoters in the low-lying community of Jayanca greatly contributed to motivating the promoters of Inkawasi. ECO has worked for eight years in Jayanca to form local committees and associations, train promoters, and create a conservation and environmental health development agenda in that community. To maximize the sharing of experiences, ECO on several occasions brought lead promoters from Jayanca to Inkawasi to share their knowledge and provide training to promoters from Inkawasi. In turn, ECO also brought key promoters from Inkawasi to Jayanca to learn first-hand about the environmental committees and animal micro-loans in operation in that community.

**A planning meeting between Centro ECO and the EHA of Uyurpampa.**
*Photo credit: Centro Eco*

Centro ECO's high level of organization in planning, accounting mechanisms, and reporting schedules also contributed significantly to building solid community-based management through the EHCs and EHAs. Communications and project tracking benefited from monthly meetings between ECO and the EHAs, along with visits with specific EHCs to review and discuss:

- Progress reports by the EHCs to the EHA[11] and ECO on: new families wishing to join the project; new animal loans made; stoves installed and new stoves requested; animals recovered; and any other information relevant to that EHC.
- Funds requested by the EHA from ECO to cover new animal modules to be loaned, stoves to be installed, and promoter per diems. ECO kept control of the revolving fund until late 2006, when this responsibility was transferred to the Associations.

In total, ECO conducted 46 planning and review meetings with the EHAs and EHCs, which had 1,175 registered attendances.

Centro ECO also held meetings with local and municipal government representatives to secure cooperation and support for the project, and keep them posted on project progress, planning, and results. Meetings with regional leaders resulted in project results being incorporated into the Regional Environmental Commission's action plan. Centro ECO also met with Peru's First Lady, Mrs. Pilar Nores de García, providing an update on project methodologies and experiences, as well as the materials and tools to scale up the project to a national level.

*Local management strengthened*

Centro ECO began transferring responsibility for promoting project goals and administering the micro-loan funds to the EHAs in early 2007. Between January and June 2007, Centro ECO reduced field visits and staff time dedicated to project administration. During this phase, EHA leaders traveled to Chiclayo on a monthly basis to meet with ECO to report on progress and receive guidance as necessary. The EHA leaders volunteered their time for this effort; travel costs were covered by the interest on the micro-loan fund, for which they assumed full responsibility.

To reinforce the EHAs' capacity to assume full responsibility for fund management and project replication, Winrock provided a modest extension to the sub-agreement with Centro ECO to provide additional training to the EHAs. The training responded to needs identified by ECO through feedback and by Winrock during focus group discussions held in late 2006 at the EHA headquarters. In addition to improved financial and animal management, ECO expected the follow-up training to help mitigate the loss of promoters who chose to leave the project. While drop-outs were not a major problem (52 of 60 trained promoters and stove builders are still active) and the motivation and dedication of the promoters remains high, personal circumstances have led some promoters to leave the project to concentrate on their crops, studies, or other family or work matters. As the EHA recruits replacements, more in-depth training may provide the needed incentive to attract good candidates.

---

[11] On average, each member of the EHA dedicates three to five hours per week for meetings with EHCs and a monthly meeting with ECO.

*Financial management training*

This training focused on basic accounting to strengthen the leaders' understanding of the importance of cash flow planning, shorter loan recovery periods (and associated animal management issues), and charging and scaling interest as a function of time to discourage drawn-out repayment periods. Focus group discussions revealed that although the leaders of the EHA were motivated and engaged in the project, they lacked a degree of entrepreneurial vision. The additional training for the EHA leaders aimed to instill this business sense and strengthen the promoters' skills in managing loan funds so they would grow, and not dissipate, over time. With Winrock's assistance, ECO designed a simple financial plan to ensure a sustainable cash flow into the future. The plan included monthly estimates of animal modules to be loaned and recovered, as well as the number of stoves to be built, so that the EHAs can balance their finances and have capital available for new participants. This plan was shared with the EHAs as part of the training.

*Veterinary training*

ECO provided promoters with training in basic veterinary care, so that the promoters could better assist families in properly caring for their animals and, consequently, repay their loan as quickly as possible. A core objective of this training was for the EHAs and EHCs to develop a clear understanding that the health of the animals was directly related to their working capital, and that the animals must be well-tended in order for the EHAs to be able to maintain an ongoing financial capacity to promote stoves and pay the technical promoters and stove builders for their services.

### 2 Awareness raised and behaviors changed

Evidence from field trips, household surveys, and focus groups – and the ongoing demand for the Inkawasina stove – suggest that families throughout the district have become much more aware of the health risks of IAP and steps they could take to mitigate the risks. During the focus groups, which consisted of members of households in which stoves were installed, women stressed that they were happy with their new stoves and didn't want to use open fires indoors anymore; rather, they would reserve cooking over open fires for special occasions when they needed to cook for larger groups, and they would do so outdoors. The post-intervention practices and perceptions survey showed a similar increase in awareness in the general population: in response to a question about how to avoid indoor smoke, around 51% of the interviewees suggested acquiring an

**"My new baby does not tolerate being around a smoky kitchen, as she was born after my new Inkawasina stove was installed. She cries out loudly when there is smoke in the kitchen," says Silvia Aurora Carlos de la Cruz, beneficiary of the Healthy Kitchen project in Uyurpampa.**
*Photo credit: Winrock International*

improved stove, 32% recommended improving ventilation, and 15% recommended having a kitchen that is separate from the rest of the house. These responses showed marked increases over the respective 18%, 15%, and 8% of interviewees who suggested these measures during the baseline survey.

The overall social marketing approach thus appears to have been fairly effective. It began with local workshops among community leaders (Uyurpampa and Incahuasi) and at the municipal level (in the capital, Ferreñafe), followed by a mixed-media campaign using radio announcements, posters, and word-of-mouth through trained promoters. The social marketing approach ended with the "Healthy Kitchen" competitions to stimulate additional awareness and motivation among families with stoves and their neighbors.

As anticipated, based on Centro ECO's experiences with similar beneficiary groups elsewhere, initial engagement was slow due to the uncertainty of beneficiaries about project intentions. As the project rolled out, however, people became more confident, began participating in activities, and enlisted in the project. Similarly, the process of training promoters was ongoing as ECO approached communities and identified promoter candidates. Based on post-intervention survey results, the most effective means of raising awareness appears to have been the household and village-level visits of the promoters. Centro Eco's emphasis on personal contact with the target groups helped bring about widespread interest in the new stoves.

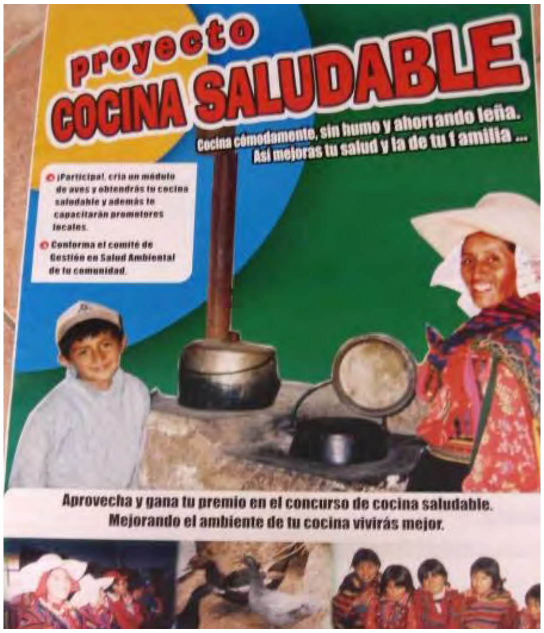
**The initial murals were painted on walls throughout the first communities.**

### *Mixed media in public spaces*

Centro ECO designed and produced 300 posters announcing the project. With the help of promoters, these posters were distributed widely throughout the district, along with large murals posted in central locations in each of the 33 EHC communities.

The first poster (shown at bottom right) announced the project to the Inkawasi district: *"Healthy Kitchen/Stove Project. Cook comfortably, without smoke and with less wood. Improve your health and that of your family."* The language continues: *"Seize the opportunity to win your prize in the healthy kitchen competition. Improve your kitchen environment and live better. Get informed by the Environmental Health Committee of Uyurpapma or Inkawasi."*

*Photo credits: Winrock International*



*Radio spots*

Centro ECO developed four radio spots using both Spanish and Quechua in the same spot, and each was broadcast for one month. The first message, delivered by ECO, announced the project and invited participation (see dialogue box on next page). The subsequent three spots were formatted as a dialogue between Inkawasi residents.[12] The 30-second radio spots were broadcast on the local station Radio JHC between 6:00 and 7:00 pm, repeated three times during the hour, every day for three months. Information on the best time of day and preferred radio station for broadcasting to Inkawasi families was identified through the baseline survey. This was the hour during which husbands and wives would typically be home together listening to the radio. It is also common for men throughout the district to walk with their radios hanging around their necks.

## Healthy Kitchen Radio Spots

***Dialogue 1***
**Voices:** Two women—a Healthy Kitchen promoter visiting the house of her friend Virginia
**Synopsis:** While visiting, the promoter observes that Virginia's children are coughing near the open fire. She explains to Virginia that wood smoke causes respiratory illness, eye irritation, and shortness of breath, potentially leading to death, and that a new project in Inkawasi is facilitating new improved woodstoves that are much cleaner and more efficient for cooking. She invites Virginia to join the project and offers to facilitate her contact with the EHC.

***Dialogue 2***
**Voices:** Virginia and her husband
**Synopsis:** After joining the project, Virginia and her husband attend a meeting of the EHC. Virginia mentions that she has raised guinea pigs to buy the improved woodstove. Now that she has the stove, she says her kitchen is much cleaner without smoke, and her family's health is much better as they no longer suffer from respiratory or eye illnesses. The couple mentions to the group that the new stove also uses less fuelwood, and that raising animals doesn't take much time, so the improved stove can be obtained rather quickly. They invite the listeners to join the project and to seek their nearest EHC to obtain more information on how participate.

***Dialogue 3***
**Voices:** Male promoter and Mrs. Silvia, a project beneficiary
**Synopsis:** Before asking Mrs. Silvia how she likes her new stove and how easy it is to use and maintain, the promoter points out that her kitchen is clean and smoke-free, with good ventilation due to an open window. He also mentions that 150 other families in Inkawasi have improved stoves. Mrs. Silvia responds that before she had the Inkawasina stove, she could not even see her pots due to the thick smoke, that her eyes always watered a lot, and now her stove saves energy by using smaller pieces of wood and cooking faster. Mrs. Silvia also points out that the stove is easy to clean, as she learned from the promoters. Finally, the interviewer invites the listeners to hurry and join the project, and to visit their neighbors who already have new stoves to see for themselves how happy they are with the Inkawasina stove.

---

[12] The dialogue format was proposed based on the effectiveness of social marketing materials developed for USAID's Kenya Indoor Air Pollution Reduction Initiative (KIAPRI) project: Helping Women Entrepreneurs Commercialise Low-Cost Cooking Products in Peri-Urban Settlements.

The radio messages spread initial information about the project quickly. The spots appeared to have been particularly useful in prompting several leaders of communities reached by the radio messages to approach the EHAs and ask to join the project and form EHCs. However, the post-intervention survey conducted by Centro ECO suggested that the radio spots were less influential than direct visits by promoters in raising awareness among typical households about the project and its messages, perhaps due to their limited broadcast time. Future radio campaigns should be run for at least six months, and in the local language (Quechua, in this case) for maximum impact.

*Household and village-level visits by promoters with illustrated materials*

In the post-installation survey, 54% of the interviewees reported that the family visits, women's gatherings, and village-wide visits by the promoters were the most effective promotion techniques.

Centro ECO developed a set of educational materials depicting core messages about the health effects of IAP, the benefits and use of improved stoves, fuel preparation and maintenance, and related topics. Centro ECO engaged a local artist and communications expert and used an interactive process to develop the materials based on feedback from focus groups and input from Winrock. Each promoter received his/her own set of materials to use with the families. The materials depicted health effects that included coughing, runny noses, shortness of breath, and death of young children. Pictures featured the Inkawasina stove in a clean kitchen; proper operation of the stove, including covering the pots and cook holes; splitting and drying the fuelwood and lighting the stove; as well as stove maintenance, with particular emphasis on removing the ash and cleaning the chimney. Other pictures suggested opening windows for better lighting and ventilation, and finishing walls and using shelves for a cleaner and more orderly kitchen. With no text, the pictures were particularly effective for educating illiterate community members.

**A promoter points to illustrations on the kitchen wall of a beneficiary household depicting proper stove operation and maintenance.**
*Photo credit: Winrock International*

In addition to using the materials to raise general awareness throughout the community, promoters used them to train users when their stoves were completed and lit for the first time. Beneficiary families received small versions of the illustrated messages to hang on their kitchen walls. The complete set of illustrations is included in **Annex II**.

*Healthy Kitchen competitions*

The Healthy Kitchen competitions proved to be extremely useful in getting the attention of the communities. A total of 22 competitions were held within the district to raise the visibility of the Inkawasina stove and complementary kitchen improvements undertaken voluntarily by families. The competitions were designed to spotlight role models within the communities and infuse a sense of ownership and pride in having an improved stove and creating a healthy kitchen space.

**This family won one of the competitions for a healthy kitchen, by making a new window, drying firewood, and building a shelf for orderly storage of kitchen items, in addition to using the Inkawasina stove properly.** *Photo credit: Winrock International*

Competitions were held in communities with a minimum of five families with Inkawasina stoves; the corresponding promoters identified the families interested in participating. A committee of judges (lead promoters) was formed within each EHA; this committee was responsible for visiting at least 15 participating families across two to three communities. During these visits the judges observed overall kitchen organization and cleanliness; whether the Inkawasina stove was operating properly,[13] and the level of lighting and ventilation. The judges awarded kitchen utensils such as new pots, pans, and silverware to the five best kitchens in the competition area.

### 3. *Market system developed for sustainability*

*Local entrepreneurs trained to supply the stoves*

A core factor in developing a local market for the Inkawasina stove was the identification and development of local entrepreneurs. This capacity was divided into two basic roles due to the requirement of distinct skills: ceramic combustion chamber (elbow) making and in-situ stove building. Six ceramic artisans were trained to make the rocket elbow combustion chambers, and 25 people were trained to make stoves, of which 21 remain committed to providing their commercial services to the 33

**Engineer Jose Humberto Bernilla (right) and a ceramic artisan trained to produce rocket elbows in Uyurpampa stand in front of a newly built ceramic kiln.** *Photo credit: Winrock International*

---

[13] Although the stove did not necessarily have to be lit at the time of the visit, the judges looked for evidence of its proper use.

communities. Both the elbow makers and the stove builders are paid a fee for their services, and this fee is included in the cost of the stove. Most of these men are farmers earning very little from their primary occupation, and so their stove-building activities provide a much-needed second income.

**Posters with the names and photos of the stove makers trained by ECO were disseminated throughout Inkawasi.**

*Photo credit: Winrock International*

*Stove construction*

Centro ECO closely supervised the first stoves made by each stove maker and facilitated corrections as necessary to ensure adherence to a standard design. ECO was very strict with the stove design and cautioned against any modifications that might inadvertently reduce the stove's efficiency. Experience around the world has shown that over time, as stove makers gain confidence in their skills, they often introduce what they believe to be "improvements" to the design that in fact result in worse performance.

To raise the visibility of the stove makers, Centro ECO prepared a poster with photos of the entrepreneurs and their names. These 300 posters were distributed for display around the district, so that people would recognize the stove makers and consult them about the stoves. In addition, a sign was hung outside each stove maker's house to advertise his services.

*Micro-loan system established*

Centro ECO's micro-loan scheme was based loosely on Heifer International's "Passing on the Gift" model of animal husbandry. Winrock provided ECO with seed capital to provide 600 micro-loans, reflecting the project's target of introducing improved stoves to 600 families. Each loan was in the form of a "module" of animals, which was equivalent to 75% of the total value of an Inkawasina stove or S./82 (US$ 25). By August 2007, 491 loans had been made, for a total value of S./40,262 (US$ 12,388), of which 68% had been recovered. The loan portfolio was 45% guinea pigs, 39% chickens, and 16% ducks.

*Ducks, chickens, or guinea pigs for stoves?*

At the onset of the project, Centro ECO recommended using ducks for the animal modules, due to its successful earlier experience reproducing ducks in lowland communities. However, the ducks reproduced much more slowly than expected in Inkawasi, apparently due to poor adjustment to the higher altitude. In addition, the lack of experience among families in raising ducks led to higher mortality rates than expected. Centro ECO was slow to respond to this problem, believing that better veterinarian training could address it. After nearly six months had passed with little improvement in reproduction rates, the Winrock team directed ECO to stop promoting ducks. Instead, ECO was encouraged to consider using animals better adapted to the Inkawasi area, such as chickens and guinea pigs. In November 2005, ECO ceased promotion of duck modules for the higher elevations and began promoting guinea pigs and chickens instead.

The original plan, designed jointly with ECO's veterinarian, called for families to reproduce and pay back to ECO[14] the complete animal module loan within nine months of receiving the initial set of animals. However, this payback period had to be extended to reflect the poor adaptation of the ducks and lower rates of reproduction among the chickens and guinea pigs, which initially suffered from inadequate animal care. Winrock observed that many animals were lost and reproduction delayed due to preventable diseases, predation by other animals, and exposure to cold and malnutrition, all of which should have been avoidable. The families themselves acknowledged their problems during the focus group discussions. However, in some cases families purchased animals to replace those that were lost, sometimes buying only females and borrowing successful males from the promoters, in order to breed stronger animals.

***Unexpected Result: Direct Sales***

The promoters of Rio Pampa EHA have been extremely effective in motivating families to tackle IAP and invest in a stove. Although Rio Pampa's EHCs are among the most recently created, this region has already surpassed Uyurpampa (among the first EHCs created) in number of stoves installed and also in the number of animals recovered. Moreover, to the surprise of Winrock and Centro ECO, roughly 20% of all families who have committed to having a stove have purchased the stove directly with cash. Despite the expectation that the families of Inkawasi are too poor to pay directly for the Inkawasina stove, a total of 36 families around the district did just that. Of these, 28 were sold in Rio Pampa. This suggests some unanticipated market segmentation within the district. It is possible that the residents of Rio Pampa are on the whole better off than villagers at higher altitudes, and perhaps less used to receiving international aid. The cash sales may also indicate a more effective awareness-raising campaign by Rio Pampa EHC or an overestimate of the need for micro-credit in this particular area.

An unintended consequence of the animal module delays was the delay in stove installation.[15] The project thus faced difficulty in gaining momentum early on, since the installation of Inkawasina stoves was key to stimulating interest and motivation among both the promoters and general public. To avoid more serious delays, in October 2005 Winrock and ECO agreed to modify the repayment plan and allow the first phase of stoves to be installed before families had fully repaid the first module.[16] The first stoves

---

[14] During the project implementation phase, ECO was responsible for administering the micro-loan fund (the equivalent of 600 animal modules). In the close-down phase of the project, ECO transferred this responsibility to the EHAs.

[15] In order to have the stove installed, each family should have first paid back a complete animal module, equivalent to the value of the stove.

[16] ECO's experience with the Inkawasi people instilled trust that they would ultimately honor their loan commitments.

were installed in the homes of the project promoters, who were the first families to participate in the project. ECO believed their experience would provide effective testimony on stove performance, and the associated reduction in both IAP and firewood consumption.

*Repayment patterns*

Of the total 491 modules loaned by August 2007, the EHAs had received repayment for the equivalent of 328 modules, or S./26,881, loaned as of August 2007. Rather than paying a full module at once, families paid back incrementally, with one or a few animals at a time, as they became available. As a result, the 328 module-equivalents repaid to date actually represent repayment by about 440 families (out of 491 borrowers) of less than a full module, while 51 families have repaid the full module, though with some delay.

**Project promoters check on the progress of animal reproduction with a beneficiary family.**
*Photo credit: Centro Eco*

In the absence of a penalty for late payments, promoters had to be patient, accommodating the needed time for animals to reproduce and families to pay back the animals. However, Winrock anticipates that eliminating the duck modules and providing better training to promoters in animal care will result in greater success with reproduction and thus fewer delays in repayment. A penalty or interest charged on late payments may further facilitate timely payments.

*Conversion of animals to currency*

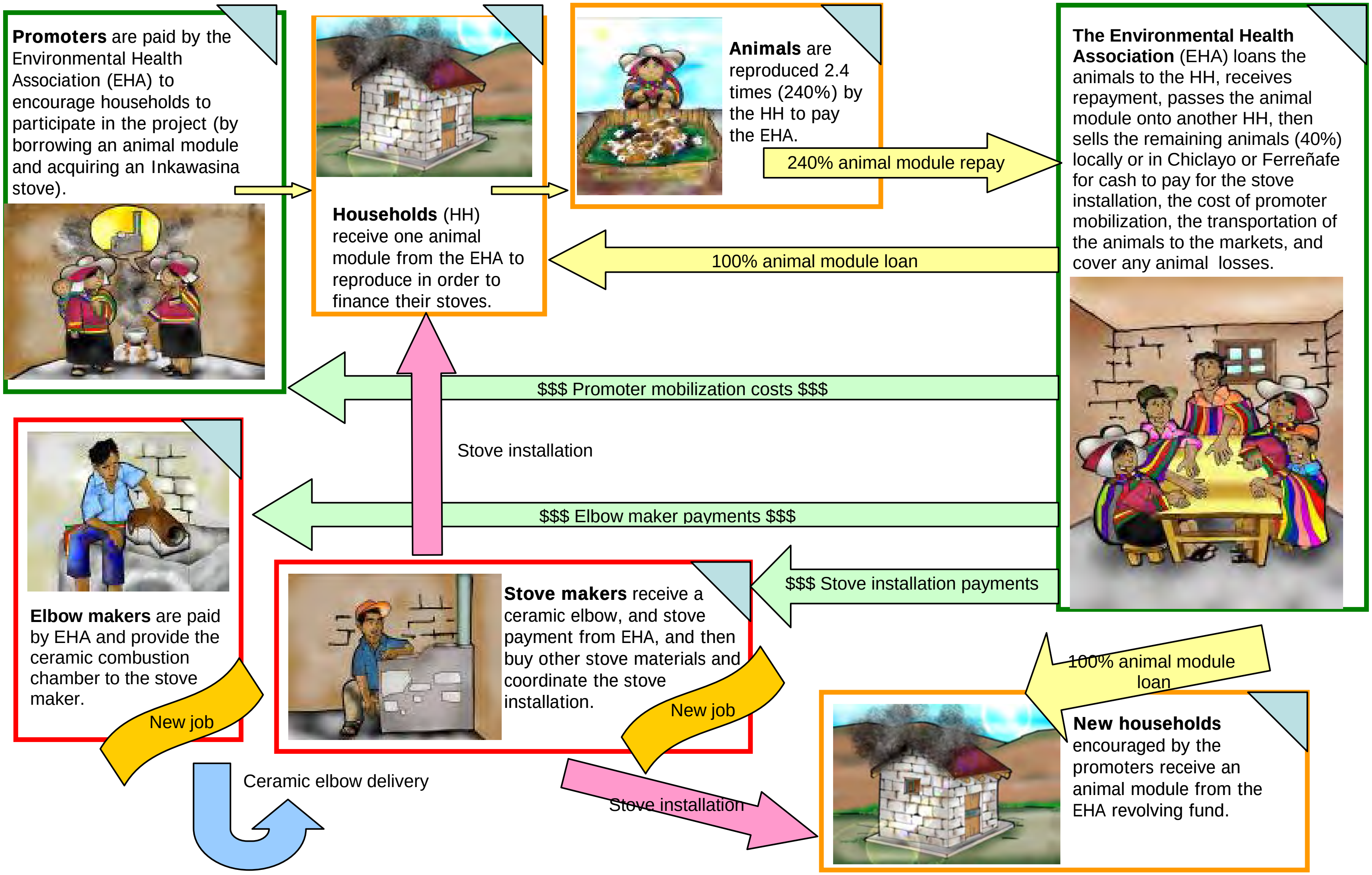
The micro-loan system was designed to enable families with little or no cash to pay for their stoves, while generating a range of jobs with cash income. **Figure 3 on the next page** illustrates the flow of animals and cash in this micro-loan system.

The animal modules were thus planned to be utilized in the following ways:

- As part of a revolving loan fund, transferred to the next families/borrowers in line.
- Sold within local markets, including Inkawasi’s limited cash market, or more active markets in Ferreñafe and Chiclayo (approximately 80-100 kilometers, a 3-4 hour drive away) to generate cash to cover the costs of the stove and pay promoters for promotion work and veterinary services.

One interesting development was a contract between Centro ECO and Marako’s, one of Chiclayo’s largest barbecue restaurants. The restaurant created a new barbecue dish using guinea pig meat, and it agreed to pay a premium price for the Inkawasi meat because it is being produced under a social development project. Marako’s is paying S./13 per animal, over 40% above the market rate for guinea pig meat in Chiclayo (S./9 per animal). Marako’s has been buying about 10 guinea pigs per week from the EHAs. This amounts to roughly 6 kg of meat per week or 24 kg per month, with a **total income value of US$160 per month**. To facilitate on-demand supply to

Marako's, Centro ECO set up a holding pen on a small farm near Chiclayo belonging to one of its members.  The meat is also prepared for delivery at this location, according to orders from the restaurant.



**Promoters** are paid by the Environmental Health Association (EHA) to encourage households to participate in the project (by borrowing an animal module and acquiring an Inkawasina stove).

**Households** (HH) receive one animal module from the EHA to reproduce in order to finance their stoves.

**Animals** are reproduced 2.4 times (240%) by the HH to pay the EHA.

**The Environmental Health Association** (EHA) loans the animals to the HH, receives repayment, passes the animal module onto another HH, then sells the remaining animals (40%) locally or in Chiclayo or Ferreñafe for cash to pay for the stove installation, the cost of promoter mobilization, the transportation of the animals to the markets, and cover any animal losses.

**Elbow makers** are paid by EHA and provide the ceramic combustion chamber to the stove maker.

**Stove makers** receive a ceramic elbow, and stove payment from EHA, and then buy other stove materials and coordinate the stove installation.

**New households** encouraged by the promoters receive an animal module from the EHA revolving fund.

*Figure 3. Animal module-based micro-loan scheme*

### *4. Appropriate technology adopted*

As of August 2007, Inkawasina stoves had been installed in 377 homes. Though this number falls short of the project's goal of 600 stoves, other indicators suggest that satisfaction with the installed stoves is high, and that despite early delays in animal reproduction (and thus stove installation), a solid momentum has been established and demand for stoves continues to be strong.

In 2007, ECO reported a few cases of cracking of the combustion chamber elbows, and eventual collapse in some cases. During field visits Winrock investigated the elbow failure issue and found this indeed to be a problem. Elbow collapse was also apparently a problem with households that participated in the original pilot in Ayamachay, and in general is a common weakness of stoves with low-cost ceramic combustion chambers around the world. To minimize failure, ceramic liners must be reinforced. Most importantly, however, users must be aware of the problem and be careful when feeding the fire. At project onset, Winrock made recommendations to Centro ECO to reduce cracking, including reinforcing the elbow by tying it with stainless steel wires, and making three artificial vertical crack lines to control the cracking. Although Centro ECO piloted these recommendations, some combustion chamber problems persisted.

Under the current project in Inkawasi, the EHAs claimed that the elbow failure problem was manifested in about 3% of the stoves installed. Some promoters blamed the breakage on user behavior, claiming that a minority of cooks continued the habit of feeding large trunks of wood, in some cases forcefully, into the combustion chamber, thereby fracturing the fragile ceramic. Other feedback claimed that the elbows that failed were all made at the same location, suggesting that there were problems with either the materials or the firing technique (or both). Some of the households whose elbows failed requested a replacement ceramic elbow (and were willing to pay for it), while others did not make such a request and unfortunately ceased to use the stove.[17]

Regardless of the specific shape or reinforcement, robust and crack-resistant elbows require a source of good clay and production techniques that include proper temperature firing and the addition of refractory materials to the mix. Furthermore, stove users' awareness of the fragility of the elbow and careful use also needs to be reinforced. Centro ECO is keenly aware of the impact that elbow problems could have on broader perception of the product within the district, and is eager to confirm the primary causes of the failures and both take corrective action to fix the damaged stoves and reinforce the training for both elbow makers and stove users to mitigate further occurrence of this problem. For example, the stove engineer began recommending to the ceramic artisans that they reinforce the elbow by thickening the areas most likely to crack, and exploring the idea of using a square combustion chamber made of six tiles, which would allow for easy replacement of the broken piece. Centro ECO did eventually switch to the square tile chambers, which has eliminated the cracking problems. Some of the broken elbows have since been successfully replaced with this alternate combustion chamber model.

---

[17] The exact number of households that have abandoned their stoves is not known by ECO, but it is within the 3% estimated group of breakages.

Results from ECO's post-installation surveys and focus groups generally reflect happy customers who are pleased with the reduced indoor smoke and reduced time spent gathering wood, and who feel the loan system is an appropriate mechanism for paying for the stoves.

### *Installation dynamics*

Stove distribution went relatively well. The process followed these basic steps:

- An EHC identified at least five families ready for stove installation. Readiness criteria included repayment of a full animal module and preparation of the adobe bricks. As discussed earlier, however, the module payback criterion had to be relaxed to speed up installation. As animal and financial management improve, the original payment scheme is expected to resume.
- The EHC requests the respective Association's authorization to install the stoves. After reviewing each case, the EHA authorizes the stove installation.
- The Association hires the nearest available stove builder(s) to install the stoves in the community in question.
- The stove builder visits the homes to discuss installation dates, stove location, and labor and materials needed from the family (adobe bricks, mud, and wood ash).
- The beneficiary families prepare their inputs, typically one to two weeks prior to the agreed date.
- The EHA provides the stove builder with the balance of materials (the ceramic elbow, the cement to make the cooking plates, iron bars, and the metal chimney top and cap).
- The EHA pays the ceramic artisan for the elbow and the stove builder for on-site construction.
- The homeowner provides labor to assist with construction.

ECO planned the majority of stove installations during the dry season (April through November), given the virtual impassability of the muddy mountain roads during the rainy months and the need for uninterrupted periods of sun to make the sun-dried adobe bricks. Thus, although stove installation began in October 2005, it quickly slowed down in December, resuming speed again in April 2006. During the rainy months, ECO conducted limited project activities in the lower-altitude communities that their vehicles could still reach. The broader project promotion activities continued during this time. Project community leaders (EHA representatives) traveled by foot and public transportation to meet monthly with the Centro ECO team at ECO's office in Chiclayo.

### *Stove performance: IAP reductions*

Initial post-intervention monitoring revealed significant IAP reductions: 70% for respirable particulate matter, and 71% for carbon monoxide, on average, across 42 households. These results are discussed in greater depth in the next section. While these results are quite encouraging and come close to the project's goal of 80% reductions, the Winrock/ECO team believes, based on field observations and experience with other stove designs, that further reductions can be achieved with minor modifications to the

Inkawasina stove. The most obvious drawback of the Inkawasina model is the tendency of smoke to escape around the pots when set into the pot holes. This "pot hole" design was chosen for a few reasons, including cost first and foremost, and because heat transfer efficiency is greater when the pots are sunken and have greater contact with the flames and hot gases.

Stove builders build the pot holes in diameters that correspond to the cooks' most commonly used pots. However, because cooks in the region use up to five different diameters of pots and kettles, inevitably the two pot holes do not properly fit all pots used in that kitchen. Using a kettle without any adjustment to the pot hole results in significant smoke leakage. ECO's engineer Bernilla thus designed a metal plate fashioned out of large oil cans commonly found in the region, cutting a hole the size of the kettle (or smaller pot) to block the gap between it and the larger hole. The metal plate can also be used without a hole as a cover for the pot hole and to place the kettle or small pot on top of it (as shown at right). It is uncertain at this point how many of the households with kettles have been shown this technique, however, and how effective the metal plate is in reducing smoke leakage.

**Inkawasina stove user, properly using the stove. Although the front pot hole is larger than the kettle, she is using a metal plate to cover the gap to prevent smoke leakage.** *Photo credit: Winrock International*

*Stove performance: efficiency*

In response to Centro ECO's post-intervention survey, stove users have anecdotally reported about 60% savings in fuelwood. Though data suggests this figure may be inflated, two-thirds of users also report that the time needed for cooking each meal has been significantly reduced, from over two hours to between one to two hours, on average.[18]

To verify fuelwood savings, Centro ECO monitored fuelwood use among 42 households both before stove installation and after stoves had been installed for a minimum of 30 days (much longer, in many cases).

Centro ECO's engineer Bernilla coordinated the monitoring with the support of local promoters. Each household was monitored every day for a week. The fuelwood was weighed using a simple scale (the type commonly used in farmers' markets). The promoters separated enough fuelwood to be used for each family for more than one day; and on the following day they would measure the amount used the previous day, and then add and weigh a new amount to the pile for next day's consumption. Moisture content

---

[18] The perception of time savings is not based on real time measurements.

was not included in the calculation. However, the pre- and post-intervention monitoring sessions were conducted at roughly the same time of the year (around August) to avoid seasonal variation in ambient air humidity.

This monitoring showed a notable reduction in fuelwood consumption after the installation of a new stove. On average, these families consumed 66 kg/week using a traditional open fire, prior to the intervention. Their consumption dropped to an average of 45 kg/week using the Inkawasina stove, a savings of roughly 32%.[19] Since a secondary function of stoves in Inkawasi is space heating, there was some concern that the stove might not serve this purpose adequately. However, to date no beneficiary has complained that her kitchen is now too cold as a result of installing the Inkawasina stove.

Winrock and Centro ECO believe that greater energy efficiency can be achieved through additional technology and behavioral improvements. As these improvements are made, ECO will have the capacity to repeat the fuelwood monitoring to verify any efficiency increases.

*Design improvement: comparison of stove variations*

In order to explore other stove models that could further reduce IAP, Winrock helped Centro ECO build and test two other stove designs and compare them with both the Inkawasina model and an open fire in terms of efficiency, IAP levels, and user preference.

The two alternative models had the same insulated ceramic “elbow” combustion chamber as the Inkawasina stove, but modified heat transfer systems. In both cases, an iron plate replaced the concrete “pot hole” frame of the Inkawasina stove. The first alternative design had two pot holes with three graduated-diameter metal discs to accommodate pots of different sizes. This is similar to the heat transfer system of traditional wood stove designs in Europe and the United States. The second alternative design used a solid metal griddle cooking surface, similar to the Ecostove.[20] The griddle surface has the advantage of eliminating smoke leakage from the cooking surface and enabling the simultaneous use of multiple pots and/or direct grilling of tortillas or other foods.

***This Inkawasi resident tested the Ecostove for five months in Uyurpampa.***

*Photo credit: Winrock International*

---

[19] The thermal efficiency coefficient of about 27% obtained at this time by engineer Bernilla for the Inkawasina stove is comparable to the 28% obtained for the Inkawasina stove during the Ayamachay project phase under GTZ in 2003.

[20] The Ecostove is a popular stove being produced in Nicaragua, Honduras, and Brazil, and uses a rocket stove combustion chamber and a flat solid metal griddle for the cooking surface.

To compare the performance of the three stove models with each other and a traditional three-stone open fire, Centro ECO set up a testing room in Uyurpampa in which all four options were installed. This set-up enabled comparison of IAP concentrations in a controlled environment. ECO conducted an energy efficiency test for each stove, and Swisscontact measured the resulting IAP concentration levels. The results suggested that the griddle surface reduces CO emissions more dramatically than the Inkawasina, but is less energy-efficient and more expensive due to the use of elaborate metal work (griddles with soldered undersides). To date, however, only a single test has been performed for each stove, and thus the results are not conclusive. Further trials are needed to compare the relative performance of these models.

In addition to these "lab" comparisons, Winrock built a portable Ecostove for ECO to try out. The wife of one of the project promoters used the stove for about five months alongside the Inkawasina stove. She preferred the Ecostove because of its cleanliness, as it produced no smoke and left no soot on the pots. However, the particular benefits of this stove model need to be weighed against the higher cost of a solid metal griddle over the cement stovetop of the Inkawasina model.

### *5. IAP reductions achieved*

Swisscontact conducted measurements of respirable particulate matter ($PM_4$) and carbon monoxide (CO) concentrations in August/September 2005, prior to the intervention, and again in October 2006, after the Inkawasina stoves were installed. A third round of monitoring was conducted in July/August 2007 to verify any changes from the post-intervention values obtained in 2006.

Of the original sample of 48 households, valid data for both pre- and post-intervention measurements was obtained for 42 households in 2006. Data was obtainable for 32 households in 2007; as the target sample size was 30 households (5% of the 600-household intervention goal, but almost 10% of the stoves actually installed), the initial sample size was sufficient to allow for dropout. (See **Annex III** for the IAP monitoring protocol and **Annex IV** for detailed results.)

#### *Baseline conditions*

The baseline measurements revealed extremely high indoor pollutant concentrations, with an average 24-hour concentration of 680 $\mu g/m^3$ for $PM_4$–exceeding Peru's Environmental Air Quality (EAQ) ambient standard for $PM_{2.5}$ by more than 10 times–and reaching a maximum of 3,880 $\mu g/m^3$. The median concentration for $PM_4$ was 322 $\mu g/m^3$. CO concentrations were similarly elevated, typically dropping below the average hourly standard only between 11 pm and 5 am.

#### *Impacts achieved*

The 2006 post-intervention results demonstrated that the intervention had reduced particulate matter by an average of 70% and CO by 71% across the 42 households. Surprisingly, 12–or almost 30%–of households experienced little change or an increase in contaminants. Possible contributing factors are discussed in the section on lessons learned. For the 30 households that demonstrated drops in PM and CO, the average reduction was 84%. This result confirms that the Healthy Kitchen/Healthy Stove intervention has the potential to significantly improve indoor air quality. Few improved stove interventions have shown reductions of 80% or more.

**Clockwise from top left: Kitchen smoke levels before and after stove installation; filters from monitoring equipment before and after monitoring; monitoring equipment and staff.**
*Photo credits: Swisscontact*

At the time of post-intervention monitoring in August 2006, some stoves had been installed for only a few weeks. Because optimal stove performance is user-dependent, reductions were expected to improve as cooks got better at managing the fuel and the fire. Winrock thus requested that Swisscontact conduct a final round of monitoring in July 2007 to confirm IAP reductions after a longer adjustment and learning period.

**Figures 4** and **5 on the next page** show the extent of IAP reductions achieved as of September 2006.

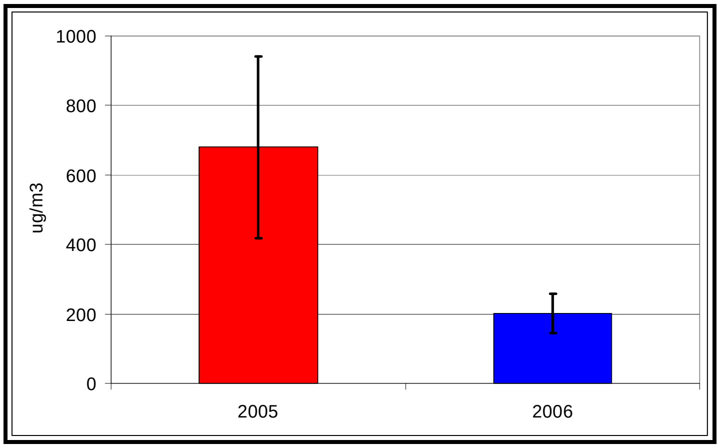


*Figure 4. Average 24-hour $PM_4$ concentration and confidence intervals before (2005) and after (2006) installing improved stoves (n=42)*

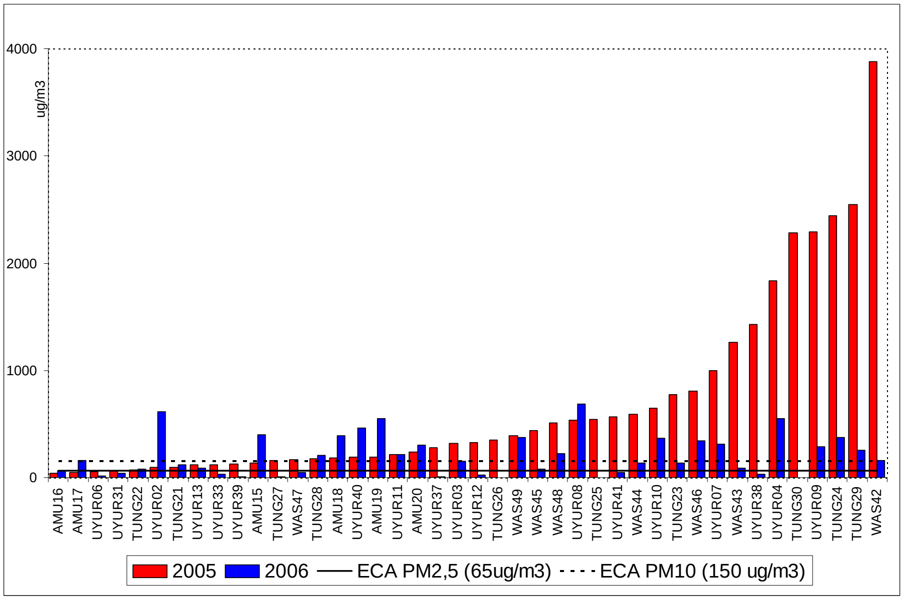


*Figure 5. 24h $PM_4$ concentration in µg/m3 before (2005) and after (2006) installing improved stoves, by household identifier codes*

**Figure 4** shows the significant decline in overall average $PM_4$ concentrations before and after installing the improved stoves. **Figure 5** shows the significant difference between the highest $PM_4$ concentrations recorded before and after the intervention by household. While the maximum recorded value in the baseline sampling was 3,880 µg/m$^3$, the maximum recorded value post-intervention was only 688 µg/m$^3$. The 2005 peak value was reportedly in a kitchen with no ventilation, where three meals/day were cooked, and the cooking time was longer than average (five hours, compared to the average of four hours). It is unclear whether additional factors would explain this extreme particulate concentration. The 2006 peak value was recorded in a kitchen where a pot smaller than the stove's hole was used, leaving room for smoke to escape into the kitchen. Even so, the maximum post-intervention $PM_4$ value recorded is up to five times lower than the maximum level recorded in the baseline. Note that “ECA” is the Spanish acronym for Peru’s ambient air quality standards. As mentioned earlier, although substantial reductions were achieved in the majority of households, some households had fairly low baseline levels but higher post-intervention levels. This chart reveals these results clearly.

The IAP analysis included examining the relationship between concentration levels and the number of meals cooked and the type of roof ventilation in the home. The importance of both these factors became apparent following the baseline monitoring. The monitoring took place during a harvest period, when many families were in the fields during the day and no cooking took place in the kitchen at lunchtime, thus eliminating a mid-day pollutant peak, which may be part of the reason for higher readings after stove installation in some homes. Other possible factors include deteriorated stove elbows, changes in user behavior that exacerbate smoke levels (such as leaving the stove burning all day to avoid having to re-light it at mealtime), mismatches between pot and burner sizes, and a lack of proper stove and chimney maintenance. Further discussion of these issues is included in **Annex IV**, which covers reporting by Swisscontact on the IAP monitoring.

As for the ventilation parameters, Winrock observed during a pre-intervention field visit that some homes had created a roof escape for smoke. Some households had rudimentary holes cut out above the ground-level open fire, while others had very carefully designed hoods placed over elevated cooking platforms, leaving only a couple of feet between the open fire and the hood. The baseline monitoring confirmed that the average contaminant level in the homes with hoods was less than half the level in homes with simple openings, and less than a third of the level in homes with no roof openings. Even with hoods, however, the average indoor concentrations exceed guideline values.

***Unexpected Result: New Kitchens***

Among the unanticipated findings was that a significant portion of homes decided to construct a new kitchen area for the Inkawasina stove, leading in most cases to a larger space with better ventilation. These factors likely contributed to reductions in IAP concentrations. Anecdotal statements from women indicated that if they got a new, cleaner stove, they wanted a new, cleaner kitchen as well. Some families in Inkawasi delayed the installation of the new stove until a new kitchen space was constructed. A Winrock partner in Central America, Proleña/Nicaragua, has observed similar behavior. The delays in stove installation—and in some cases of the IAP monitoring—were outweighed by the positive impact that these kitchen improvements represented for Inkawasi women and their families. These improvements were strong indicators of the value families placed on their new stoves, and the commitment they were prepared to make to create and maintain a healthy kitchen environment.

Based on the second post-intervention monitoring, which shows less dramatic reductions as well as some significant IAP increases, Winrock concludes that there is a need to address possible weaknesses in the ceramic elbows and an even greater need to reinforce messages about effective (and counter-productive) behaviors to achieve the substantial IAP reductions demonstrated in many project households.

### 6. *Other monitoring: practices, perceptions, and health symptom measurements*

**Focus group meeting in Rio Pampa, facilitated by a local Quechua-speaking teacher.**
*Photo credit: Winrock International*

To gain insight into the project's achievements and constraints, in December 2006 Winrock staff conducted three focus groups in Inkawasi with 56 members of the beneficiary communities throughout the district, including new stove owners as well as those who did not own stoves. The focus groups were based on a set of 20 questions designed to prompt participants to speak out on all aspects of the project, specifically: 1) by which communication means they had learned about IAP; 2) their present level of awareness about IAP; 3) their level of satisfaction with the stoves; 4) difficulties they encountered with the animal modules; and 5) their overall perceptions of project implementation by the EHA. The focus groups were conducted by a local teacher in Quechua, through open questions to the groups in a dialogue format, while Winrock staff made notes following translation of the answers into Spanish.

In early July 2007, Centro ECO staff conducted another round of consultations using the same questions through two approaches: one focus group discussion in Spanish with 25 project promoters; and a quick survey of 36 households (18 households with stoves and 18 households that did not participate in the project). The households surveyed were in the communities of Rio Pampa, Sukchapitej, Huasicaj, Chumbeaura, and Sinchihual, and the questions were posed with the help of a Quechua translator.

*Practices and perceptions*

The baseline household-level survey to gather information about cooking practices and health perceptions of Inkawasi households included 88 questions and took approximately 45 minutes to administer. For the post-intervention survey, Centro ECO eliminated several questions judged to be least useful, thereby shortening the time burden on families participating in the survey.

The sample for the pre-intervention survey was a randomly selected 169 households. Of this number, 166—nearly 6% of the district's total number of households—participated in the follow-up. Centro ECO trained a local team to administer the survey.

**Annex V** includes detailed results of the household cooking practices and perceptions survey. The feedback led to the following primary conclusions:

- Before the Healthy Kitchen/Healthy Stove project raised awareness about indoor smoke, the perception among Inkawasi housewives was that IAP was “the way life is,” and they had no hope of changing the situation.
- Overall, the communities were happy with the Healthy Kitchen/Healthy Stove project, which had significantly improved the quality of life among beneficiary families. The main benefits mentioned were much less smoke in the kitchen, savings of firewood and time, having a modern stove, and, consequently, improved family health.
- In general, the beneficiary families were more aware of the health risks of being exposed to wood smoke, and they now sought to minimize and restrict the use of open fires indoors, using open fires only outdoors for special occasions.
- The ways to reduce IAP exposure mentioned by most people included buying an Inkawasina stove, opening windows and doors, making kitchens larger, and keeping children out of the kitchen to the extent possible.
- The participating families found it relatively easy to comply with the requirements of the project (repaying the loan and modifying their cooking practices).
- Raising the animals was very interesting to the families, both as a potential additional source of food, as well as a valuable good that could be exchanged for other products or sold to obtain money in moments of necessity.
- However, mortality among the animal modules was relatively significant; beneficiaries acknowledged that this problem was due in large part to their own carelessness about the animals’ health, and they desired more assistance with animal care.
- Focus group participants reported that the 10-12 month loan repayment period was too short, especially given that the ducks were slow to breed and some animals were occasionally stolen, or eaten by other animals. These groups recommended that the time period for completely repaying the loan (240% repayment) be extended to between 12-18 months.
- The main suggestions for improving the stoves included making different sizes of pot rings to accommodate different pot diameters, making a bench of adobe so the cook could rest, making a tray to collect the wood ash, and building stronger ceramic elbows.
- The families revealed that they could easily recognize the stove makers within their communities.
- Many families had not yet engaged in the project because they had not been directly approached and informed by an EHC promoter, although they had heard of the project through a friend, a family member, or even the radio. Some of them felt uncomfortable about making a commitment to borrow the capital through an animal module.

**Assessing lung function in one home.**

*Photo credit: Centro Eco*

*Health symptom monitoring*

Although exposure to smoke from the burning of biomass fuels is known to be associated with death and disability, the degree to which exposure must be reduced to prevent respiratory ailments is still unknown. To explore this question, health symptom and lung function data (FEV1%—a frequently used spirometry measure to assess airway obstruction) were collected from individuals in households before and 15 months after installation of the Inkawasina stoves to complement the collected IAP data. (This was not a core component of the project, which lacked the funding to do a full health impact study, and the data is indicative only.)

Before stove installation, spirometry data were obtained from 82 individuals from 49 households where stoves were to be installed. Of these 82, 57 test results were valid and met the criteria for reproducibility. However, valid test results could be collected from only 17 of these individuals 15 months after stove installation. Also, two of these individuals lived in households where IAP monitoring was not done both before and after installation. Therefore, only 15 individuals had FEV1% spirometry data meeting all test validity criteria and complete IAP results.

Extrapolating from a recent study on the impact of ending exposure to tobacco smoke, the study team predicted that reduced exposure to cooking fire smoke would lead to a 2.78% average increase in FEV1% in the follow-up period. Surprisingly, FEV1% among the 15 valid observations *declined* by 1.38% rather than increased. However, there were marked differences in IAP reduction in the households of these 15 persons.

By dividing the 15 observations into two groups–those with good respirable particulate reduction (defined as reductions over 64% *and* post-installation concentrations under 100 µg/m3) and those with poor particulate reduction–and removing two outliers, Winrock found that the change in FEV1% was significantly better ($p < 0.01$) for persons in households with good IAP reduction. Furthermore, while the 95% confidence interval for the mean change in FEV1% was large, it was entirely positive for those with good particulate reduction and included the hypothesized 2.78% improvement.

Detailed results of health symptom monitoring are found in **Annex VI**. These results supported Winrock's general hypothesis that individuals in households that greatly reduce respirable particulate exposure from cooking smoke will have less progression of chronic lung disease. Much more extensive and rigorous study would be needed to relate such exposure reductions to decreased incidence and severity of acute lower respiratory tract infections in infants and small children.

# III. KEY OBSERVATIONS AND LESSONS LEARNED

The Winrock team made a number of observations and formulated the following lessons learned about the Healthy Kitchen/Healthy Stove project through ongoing discussions with the Centro ECO team; several field visits to Inkawasi, including interviews with households; Centro ECO's household surveys; the IAP monitoring conducted by Swisscontact; and focus group discussions with the project promoters and beneficiary families conducted by Winrock and Centro ECO.

**The Inkawasina culture is very socially oriented. Here, after a promoters' meeting with ECO, participants share their food in a community meal.** *Photo credit: Winrock International*

## A. Reduction of Indoor Smoke

This project model substantially reduced indoor air pollution with the Inkawasina stove and improved cooking practices. The monitoring results showed that, on average, the intervention reduced IAP levels by 70%, clearly demonstrating the intervention model's potential to achieve significant reductions in IAP exposure.

The final post-intervention round of IAP monitoring in July/August 2007 made clear, however, the importance of quality control of stove components and of the cooks' fuel management practices. Without close attention to production quality and reinforcement of key stove usage behaviors, much of the smoke reduction achievable with proper stove performance can be lost.

## B. Establishing Local Institutional Capacity

Despite the challenges of working in a cash-poor region with low literacy rates, the ECO staff and the communities of the Inkawasi district demonstrated remarkable leadership in embracing the objectives of the Healthy Kitchen/Healthy Stove project and corresponding responsibilities. Winrock believes community initiative and leadership are important indicators of a strong enabling environment for future replication of this model in similar communities.

- Centro ECO's previous community organizing experience proved critical in motivating community leaders and creating a trusting relationship between the NGO and project promoters. Future project implementation should seek to incorporate similar solid experience with community organizing.

- Personal connections within the district facilitated access to households. The lead technical engineer was born and raised in Uyurpampa and not only spoke the local language and knew many families, but was intimately familiar with daily life and customs. Future initiatives should aim to involve one or more champions from within the target population.
- Pride, status, and the opportunity to learn and improve community conditions were strong motivators for promoters to become active in the project. Interested and committed individuals were not hard to identify. It appears quite possible to engage indigenous rural communities from this region in volunteer work to promote projects with a social focus. Sufficient training must be provided, however, to ensure that promoters have absorbed the messages and gained the skills needed for proper management of all project components.
- Expanding the project's geographic scope to maximize the number of communities risked spreading project administration and associated resources too thin. Establishment of more EHCs should be resisted until the existing structures have demonstrated that they can operate autonomously. Future efforts should avoid too much breadth before sufficient depth of involvement is established in each participating community, and behavior change, technical promotion, and micro-credit activities are working satisfactorily.
- Demonstrated community leadership and initiative are important indicators of a strong enabling environment for future replication of this model in similar communities.

## C. Raising Awareness and Changing Behaviors

The social communications campaign conducted in Inkawasi appears to have been effective in educating the majority of families engaged in the project about the risks associated with indoor smoke and convincing them to adopt new practices and behaviors that reduce exposure.

- Direct promotion through household visits has been very effective in raising awareness, motivating participation in the project, and prompting behavior change. The simple, locally oriented educational materials developed for use by the promoters were useful tools for communicating key messages.

**Messages about healthy kitchens have also been passed to children, who are the main beneficiaries of the new behaviors and practices.**
*Photo credit: Winrock International*

- Many families voluntarily invested time, resources, and ingenuity to improve their kitchen environments to complement the improved stove, from installing shelves to constructing completely new kitchens. This level of commitment suggests that the improved stoves are highly valued, and that this population is eager to invest in improving its living conditions.

## D. Establishing Micro-Loans for Cash-Poor Communities

The micro-loan mechanism based on animal husbandry has been perhaps the most innovative aspect of this project, but also proved the most challenging. This financing approach has drawn attention from many other development organizations interested in learning how it works and how the model could be applied in other poor rural communities throughout Latin America.

This type of non-monetary micro-finance system is well suited to the local trading customs of cash-poor populations, including the Inkawasi, and appears to offer a long-term mechanism for household-level income generation. However, the system requires a significant amount of local capacity building before it can be implemented successfully. The lessons identified here are currently being addressed by community leaders in coordination with Centro ECO.

- As participants were dependent on animal reproduction rates to pay back their loans, overall financial planning was more difficult in this non-monetary model—for both the loan administrator (in this case ECO and the EHCs) and the borrowing families—than in a strictly cash-based model.
- The micro-loan system was hampered by the high rate of late animal module payments. In turn, stove dissemination was slowed down to reduce the impact on cash flow within the loan fund. To avoid cash flow bottlenecks and ensure a sustainable finance mechanism, greater attention should be paid during project planning to the key factors influencing animal reproduction rates.
- Ensuring success with animals requires both that appropriate animals be selected (i.e., of appropriate species and stock), and that adequate veterinary training be provided to project promoters as well as to borrower families. Judgments on the appropriate animals for a micro-loan program in a specific community should be left to veterinarians with experience in the target area.
- Tracking of module payments should include the total numbers of animals repaid (and their

**Guinea pig husbandry is well known by the families of Inkawasi, although training in better care techniques is needed to improve growth and survival rates.**
*Photo credit: Winrock International*

monetary value), as well as the number of families who have repaid entire modules.

- The mechanism should incorporate a late fee penalty as a motivator for better animal care and quicker repayment.
- Local loan managers require solid training to ensure they have sufficient skills and understanding of factors affecting repayment. Achieving repayment goals will be greatly facilitated by working with an implementing partner with strong business sense and skills.
- Realistic milestones should be set for future projects to enable proper evaluation throughout all stages, and allow for corrective actions sooner to avoid compromising the sustainability of the animal micro-loan fund.

## E. Introducing Appropriate Technology

The Inkawasina wood stove has proven to be a suitable model for the Inkawasi population. It is affordable, uses primarily local materials, is more energy efficient than traditional open fires, significantly reduces indoor smoke, and is accepted and liked by local families. The commercialization strategy established in Inkawasi with a network of stove makers and ceramic artisans has been responsive to local needs and to the demand for stoves from the Inkawasina families.

- Additional IAP reductions of 5-15% could be achieved with modest improvements to the stove design, combined with attention to occasional installation flaws (e.g., short chimneys) and reinforcement of basic behavior changes (e.g., covering pot holes when not in use). Although some of these adjustments involve minor additional effort, others involve higher costs, such as metal griddles and more intense promoter follow-up on end-use behaviors.
- Ceramic elbows have been notorious for cracking in stoves in a number of countries. Though cracking does not necessarily result in reduced performance, this factor should receive close attention and follow-up. Producing fool-proof stove components requires continued research for appropriate local solutions; solid training of local artisans; adequate materials; and training and technical assistance in construction of local kilns. Follow-up by Winrock and Centro ECO with the ceramic artisans has led to more rugged elbows for Inkawasi, which can also be offered to residents of Ayamachay to rehabilitate their stoves. Careful follow-up should be undertaken to ensure that the elbows in Inkawasi continue to permit satisfactory stove performance. In the meantime, Winrock and Centro ECO should continue their research efforts and seek opportunities to incorporate tips from other projects on more robust ceramic “recipes” to improve elbow performance.
- Stove users must be made aware of the stove weaknesses and limitations and receive reinforced training on proper use of the stove. With time and experience, users will understand the importance—and efficiency benefits—of feeding the combustion chamber carefully.

- A design modification to accommodate varying pot diameters will significantly improve the ability of the Inkawasina stove to reduce IAP more consistently. A one-size pot hole approach cannot fit all families. Winrock has given ECO more flexible options to consider and experiment with, to better accommodate different family needs and pot sizes. These options can be complemented by a greater focus on educating families about using a reduction ring or cooking over a pot hole covered by a metal sheet.

## F. IAP Monitoring

As indicated earlier, the Healthy Kitchen/Healthy Stove intervention achieved substantial average reductions in indoor smoke. The reductions can be expected to surpass the targeted 80% reductions with the correction of installation flaws and cracked elbows in some households and more effective use of the stoves.

Winrock considers this degree of smoke reduction to have significantly improved the lives of Inkawasi families, including notably reducing health symptoms aggravated by smoke exposure. Winrock recognizes, however, that claiming the project has achieved specific health outcomes, such as a reduced incidence of infant pneumonia or of COPD among women, would be premature. A complex, long-term, and prohibitively expensive study would be required to support such claims. Nevertheless, Winrock believes the IAP monitoring was worthwhile for establishing a relative measure of pollutant reduction achievable through this intervention. This measure will enable comparison with similar interventions around the country and with improvements to the Healthy Kitchen/Healthy Stove model, as they occur.

The actual IAP monitoring process also revealed some specific areas of concern:

- Despite the involvement of a strong analytical partner experienced in ambient air monitoring, the partner still needed time to become familiar with IAP protocols and monitoring equipment.
- The monitoring equipment is not fail-safe, and requires special considerations (e.g., battery charging) for use in remote settings where electricity is unavailable or unreliable. The PM monitors were not designed to measure such extreme levels of particulates and sometimes clogged in less than 24 hours. Equipment failures in the field can cause significant delays in monitoring. Despite local capabilities to clean, repair, and recalibrate this equipment, the extreme conditions in which it is used may lead to premature failure, at which point Peruvian groups will need to decide whether to invest in new equipment for future monitoring.
- The variation of stove installation dates within the sample likely led to misinterpretation of the data, and in this case may have led to lower estimates of the intervention’s ability to reduce indoor concentrations of particulates and CO. Future projects should aim to coordinate installation of the stoves in the households to be sampled within a short window (e.g., within a month of one another).

- At a minimum, follow-up monitoring should be conducted 12 months following the installation date; if budget and logistics permit, pre-and post monitoring during another season (e.g., the rainy season, six months apart from the dry season) would be even better.
- In addition to confirming the potential of the Inkawasina stove to achieve substantial (>80%) IAP reductions, the monitoring was valuable in detecting common problems with stove use and prompting follow-up solutions and innovation to mitigate the problems, such as using metal plates to reduce smoke leakage between pots and pot holes of unequal size. The monitoring also indicated the importance of user experience in influencing a stove's performance, and impact on both smoke production and leakage.

## G. Other Monitoring: Household Practices & Perceptions and Health Symptom Monitoring

Winrock aimed to gather enough useful data before and after the intervention to detect changes in household cooking practices and perceptions about specific health impacts resulting from the intervention. Winrock envisioned integrating some of the household survey data with the IAP data and, if possible, the health symptom data, to form an even more complete picture of changes brought about by the Healthy Kitchen/Healthy Stove project.

These expectations were too optimistic for a project of this scope. Adapting the survey for the Inkawasi context was itself a time-consuming task, requiring multiple translations and adjustments after the initial field trial. ECO faced time constraints while training a survey team, which in turn led to less than full confidence in the results. Because of Swisscontact's experience with data management and statistical analysis, Winrock charged the team with integrating the household and health symptoms data with the IAP data. However, significant delays in the processing of household and health data rendered such integration infeasible. Departure of key ECO personnel exacerbated these delays, reducing the time available to review and discuss the results.

- Though the tight budget led Winrock to keep the household survey in-house (administered by ECO), it ultimately might have cost less, detracted less from ECO's principal implementation responsibilities, and yielded more valid results had this task been contracted out to an experienced team of field researchers. This would also have reduced any possibility of a bias factor influencing the monitoring results and analysis.
- Although the health symptom monitoring was not a core component of this project, spirometry tests may be worth conducting on a larger scale to assess an intervention's impact on lung function among adults. If such an activity is planned, however, the research team should demonstrate fluency with local languages, expertise in COPD and statistical analysis, and adequate familiarity with local customs and potential barriers to conducting these medical tests. Moreover, any health symptom survey should be peer reviewed and field tested before final application.

## H. Dissemination of Project Model

Winrock has sought numerous opportunities to disseminate information on the Healthy Kitchen/Healthy Stove project model to targeted audiences throughout the course of the project. Project partners collaborated on several occasions to make presentations on the project's approach and results, to share the experience with other implementing groups, and to increase visibility of indoor air pollution and mitigation measures. These dissemination events included:

**Participants at the seminar on IAP and stoves, jointly organized by PAHO and Winrock in Lima, December 13-14th 2006.** *Photo credit: Winrock International*

- September 2005, Lima, Peru: Healthy Housing Initiative seminar, sponsored and organized by WHO/PAHO. Winrock presented on overall IAP and environmental health integration model development for both Peru and Bangladesh; Centro ECO presented the methodology and overall project status; and Swisscontact presented the IAP monitoring plans.
- January 2006, Seattle, USA: ETHOS[21] conference. Winrock presented project methodology and status.
- October 2006, Brasilia, Brazil: First Brazilian IAP and Improved Stoves seminar, sponsored by USAID/Brazil and Shell Foundation, and co-organized with Winrock International. Winrock presented project methodology and status.
- December 2006, Lima, Peru: IAP and Health seminar. Winrock initiated and co-organized this event with PAHO. Centro ECO presented an update on the results of the stove dissemination and micro-credit system, while Swisscontact presented preliminary results of the reductions achieved in IAP.

---

[21] ETHOS (Engineers in Technical and Humanitarian Opportunities of Services) is a non-profit organization that holds annual meetings among stove and IAP experts from around the world to discuss the latest advancements in stove technologies, IAP monitoring, and related issues. The presentations from the meetings can be downloaded from http://www.vrac.iastate.edu/ethos/proceedings.php.

- January 2007, Seattle, USA: ETHOS conference. Winrock presented the preliminary IAP monitoring results.
- February 2007, La Paz, Bolivia: GTZ sponsored an improved cookstoves workshop. Winrock presented the micro-loan animal modules scheme as a way to finance improved cookstoves.
- March 2007, Bangalore, India: 3rd Biennial Partnership for Clean Indoor Air Forum. Winrock presented a poster on the preliminary IAP monitoring results.
- June 2007, Managua, Nicaragua: Central American Wood Energy and Improved Stoves Meeting. Centro ECO presented the project approach and overall results.
- Publication of the project's baseline IAP monitoring results in the World Bank's Country Environmental Analysis report, which assesses the costs to Peru of indoor air pollution, among other factors of environmental degradation.[22]

Each of these events and discussions has generated significant interest in the Healthy Kitchen/Healthy Stove model. The components of this model that stand out when presented alongside other projects are the efficiency and smoke-reducing aspects of the stove design (i.e., the incorporation of rocket stove design principles); the inclusion of indoor air pollution and health risks in education and awareness-raising materials; and the micro-credit scheme that increases access by the poor and offers an alternative to ineffective and unsustainable subsidies.

Within Peru, the most significant event was the December 2006 seminar specifically focused on household energy, IAP, and health. Winrock engaged PAHO/Peru in organizing this seminar, which brought together–for the first time in Peru–several key actors engaged in stoves and/or indoor air pollution and health issues. Three contractors of the USAID/Peru mission also participated: Caritas and ADRA, which spoke about dissemination of improved wood stoves within the PL-480 food security program in Peru; and Management Sciences for Health (MSH), which spoke about stove dissemination through the Healthy Municipality project under USAID/Peru's health program.[23]

Among the notable outcomes of the event were the following:

- PAHO was particularly impressed by the IAP monitoring results and has since committed to IAP monitoring of a 3,000-household project it is initiating in Cuzco with Japanese funding. For this monitoring, PAHO contracted Swisscontact to train a staff member and facilitate field measurements and analysis, with equipment borrowed from USAID/Winrock.
- Peru's First Lady, Mrs. Pilar Nores de García, took great interest in the Inkawasina stove model and the micro-credit scheme. In 2006, the First Lady became very active in promoting the SEMBRANDO program, a major high-profile initiative targeting marginalized, high-Andean indigenous communities.

---

[22] Republic of Peru Environmental Sustainability: A Key to Poverty Reduction in Peru. Country Environmental Analysis. June 2007. Report 40190-PE, The World Bank.

[23] Presentations given at this seminar can be downloaded at http://www.per.ops-oms.org/talleres.html.

SEMBRANDO has since formed a partnership with Centro ECO and Fondo de las Américas (FONDAM[24]) to expand the dissemination of Inkawasina stoves throughout the Inkawasi district, and also with other NGOs that participated in the seminar.

- GTZ invited Winrock to present the animal micro-loan scheme at its February 2007 seminar in La Paz, Bolivia, and the Ministry of Mines and Energy of Nicaragua invited Centro Eco's stove engineer to present the stove technology at its June 2007 meeting in Nicaragua.

Winrock has worked with Centro ECO to explore ways to replicate and scale up the Inkawasi experience. ECO successfully negotiated with FONDAM and SEMBRANDO to replicate the Healthy Kitchen/Healthy Stove project in six other communities of Inkawasi. ECO has also worked with private entities to further dissemination activities, including the construction of around 300 stoves to date along with home rebuilding in Chinca, south of Lima, which was devastated by a 2007 earthquake.

## I. Considerations and Recommendations for Replication and Scale up

The integrated household energy, indoor air pollution, and health intervention model piloted by the Winrock/Centro ECO team in the Inkawasi district shows promise for self-replication throughout the district, as well as replication on a greater scale elsewhere in Peru and the high-Andean region. Winrock suggests the following factors warrant careful consideration in replicating this model.

### *1. The integrated model*

Based on the Healthy Kitchen/Healthy Stove experience, complementing technology intervention with a market-based approach, multi-media communications, and a strong team of local promoters is appropriate and effective for long-term adoption of cleaner and more efficient cooking technologies and practices in Peru, particularly where indoor smoke is a chronic problem. Integrated models are by nature more complex than simpler, single-faceted interventions, however, and thus require more investment in up-front planning and training.

### *2. Factors for success*

At a minimum, the following factors are critical to replicating the Healthy Kitchen/Healthy Stove intervention model:

- A solid local champion to lead the intervention with experience and credibility in the project region; strong project management experience and accounting and communications skills; and, preferably, experience and skills in small business management.

---

[24] FONDAM: Fund of Americas, a grant award organization which was jointly created by the US and Peruvian governments.

- Clear and reasonable milestones for accomplishing objectives, and enough time to make adjustments to reach the overall project goals.
- A dynamic, motivated project manager or key technical advisor based in the field who can lead the project or provide valuable support in the field and be responsive to the interests of the donor, and provide clear project guidelines.
- Up-front training of savvy community leaders who can manage the project at the community level, and who share a business vision for financial sustainability to ensure greater benefits to the communities.
- A skilled veterinarian with experience in the project region.
- Field-tested communications materials, with emphasis on pictorial materials for end-user training.
- An in-depth promoter recruitment and training program, phased such that promoters are well-versed in the topics prior to installation of the first stoves, and sequenced with some repetition and review to accommodate new recruits, reinforce learning, and update knowledge as promoters become familiar with user preferences and complaints.
- An in-depth elbow and stove builder training program, phased such that artisans are adequately skilled prior to installing the first stoves.
- Access to good clay and adherence to the best-known local “recipe” for durable ceramic elbows.
- A micro-loan system that utilizes animals appropriate for the region and starts with good stock. There must be an existing market for these animals, moreover.

### *3. Constraints*

The lessons learned from this project suggest that there are some areas that need special attention. Some of the constraining factors affecting the progress of the Healthy Kitchen/Healthy Stove pilot project include:

- A high reliance, at least in the early stages, on direct promoter outreach, which implies significant investment in promoter training and follow-up, as well as a limit to the rate at which households can be reached for a given density of promoters.
- Limited knowledge of and experience with financial systems among target populations and communities.
- A payback system dependent on animal reproduction rates, which can be variable.
- Lack of motivation to repay loans among communities with a legacy of subsidized projects.
- Remoteness of communities, lack of communications infrastructure, and absence of housing for visitors.

The approach this project took was very successful in raising awareness about IAP and health impacts, creating demand for improved stoves, establishing a sustainable market for the stoves, and developing a sustainable micro-credit model for stove payment. The reductions in IAP in target homes was lower than expected for a variety of reasons, including deteriorated stove elbows, changes in user behavior that exacerbate smoke levels (such as leaving the stove burning all day to avoid having to re-light it at mealtimes), mismatches between pot and burner sizes, and possibly a lack of proper stove and chimney maintenance. Future interventions should aim to replicate the awareness raising, capacity building, market development, and micro-credit aspects of the Healthy Kitchen/Healthy Stove pilot approach, with additional attention to the factors noted here, including the need to reinforce messages about effective (and counter-productive) behaviors to sustain the substantial IAP reductions demonstrated by this intervention.

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX I – Project Indicator Table

## **Annex I** – Project Indicator Table

| **INDICATORS** | **EHA Incahuasi** | **EHA Uyur-pampa** | **EHA Rio Pampa** | **Totals (as of August 20, 2007)** | **Target** | **% of target goal** |
|---|---|---|---|---|---|---|
| *Households (hh) directly benefiting—and contributing* | | | | | | |
| IAP reduction by 2006: average, 42 hh | | | | 70% | 80% | 88% |
| IAP red'n by 2006 for 30 hh w/ decrease | | | | 84% | 80% | 105% |
| IAP reduction by 2007: average, 32 hh | | | | -10% (increase) | | |
| IAP red'n by 2007 for 16 hh w/ decrease | | | | 64% | | |
| Inkawasina stoves installed | 173 | 91 | 113 | 377 | 600 | 63% |
| *Micro-credit system established* | | | | | | |
| Animal modules loaned | 209 | 157 | 125 | 491 | 600 | 82% |
| Value of animal modules loaned (*Soles*/US$) | - | - | - | S./40,262 (US$ 12,388) | S./48,600 (US$14,954) | 83% |
| Value of the animal modules recovered (*Soles*/US$) | S./12,345 | S./5,608 | S./8,928 | S./26,881 (US$ 8,271) | 100% | 67% |
| Direct sale of stoves | 8 | - | 28 | 36 | 0 | - |
| *Community organizations established* | | | | | | |
| Environmental Health Associations formed | 15 | 8 | 10 | 33 | 23 | 143% |
| Cadre of community promoters trained in IAP, stoves | - | - | - | 60 | 50 | 140% |
| *Local entrepreneurs established* | | | | | | |
| Stove makers trained (men) | - | - | - | 21 | 25 | 84% |
| Ceramic artisans trained (men) | - | - | - | 6 | 4 | 150% |
| Women trained on use & construction of retained heat cookers | - | - | - | 35+ | 32 | 110% |
| *Awareness materials and activities developed and utilized* | | | | | | |
| Murals installed | 15 | 8 | 10 | 33 | 23 | 143% |
| Posters distributed | - | - | | 600 | 300 | 200% |
| Radio spots broadcasted | - | - | - | 290 | 720 | 40% |
| Flyers circulated | - | - | - | 2,100 | 3,000 | 70% |
| Pictorial materials developed for household awareness and end-user training (# people) | | | | 1,000+ | *na* | |
| Healthy Kitchen competitions held | - | - | - | 22 | 15 | 147% |
| Professional meetings where project results were presented | - | - | - | 8 | 3 | 266% |
| *Monitoring results* | | | | | | |
| Houses surveyed for practices/ Perceptions (pre & post) | - | - | - | 169 | 150 | 126% |
| Houses monitored for IAP | - | - | - | 42 | 30 | 140% |
| Average % of fuelwood reduction | - | - | - | 32 | 40 | 80% |

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX II – Training and Awareness-Raising Materials

This annex contains graphic illustrations used as stove use and maintenance communications materials.  These illustrations convey messages about the ill effects of smoke; indoor conditions resulting from an open fire versus an improved stove; images of a well-ventilated, orderly, and clean kitchen; and proper operation and maintenance of the stoves.  These materials were aimed at the end user and used by promoters during initial awareness-raising meetings with families and community groups, and later to train families in the use of their new stoves.  The images were also used on banners, posters and flyers.

Not included in this annex, as they are available only in Spanish, but used in project activities include the Peru Healthy Kitchen/Healthy Stove Pilot Project Informational Brochure, and a guinea pig care manual.  The brochure was produced to raise awareness about the project and its objectives among decision makers throughout the country.  The brochures were distributed by Centro ECO staff at meetings and seminars throughout the region and in the capital city of Lima. The guinea pig care manual was created for use in training promoters in basic animal care, who would in turn assist and guide each family in the proper care of their animals.

# ANNEX II – Training and Awareness-Raising Materials

Graphic illustration demonstrating the need for small twigs and logs cut into small pieces for use in Inkawasina improved stoves

Graphic illustration demonstrating proper use of a small amount of firewood at a time in an Inkawasina improved stove

Graphic illustration depicting the smoke that is released into the room when one hole of the stove is left uncovered

Graphic illustration depicting the proper release of smoke outside the house through the chimney when the second stove hole is properly covered

Graphic illustration demonstrating proper chimney maintenance techniques

Graphic illustration demonstrating proper regular ash removal from the combustion chamber of the stove

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX III – Indoor Air Pollution Monitoring Protocol

# **ANNEX III.** Indoor Air Pollution Monitoring Protocol

**July 2005**

Compiled by:

Winrock International

# I. Monitoring Methods and Measurements

**Objective:** To monitor the changes in indoor concentrations of Respirable Suspended Particulates ($PM_4$) and carbon monoxide (CO) before and after the Healthy Kitchen/Healthy Stove household energy intervention in the kitchens of 40 families in the Inkawasi district, at approximately 12-month intervals to ensure similar conditions exist for the measurements. Swisscontact will conduct a baseline diagnosis to determine the current air quality situation, and follow-up measurements to produce an assessment of the percentage of $PM_4$ and CO concentration reduction in the kitchens after one year.

The PM monitoring will be conducted using the gravimetric pump-and-filter approach, and a real time, data-logging CO sampler for area concentrations. Based on recommendations from WHO, US EPA, and the UC Berkeley team, personal CO monitoring will not be conducted.

Pump type : Buck VSS -5
Filter type : PVC, 5 μm, 37mm
Flow rate : 2.2 l/min ± 5%
Flow rate calibration : M-5 Mini-Buck calibrator
Cyclone type : BGI (HD type), 50% cut-off at 4μm
CO sampler : T82 real time Datalogger
Area sampling location : area sampling at height 1.3m, and distance 1.3m away from stove
Area sampling duration : 24 hrs (with a filter change between 2 sessions; see section II)

Notes:

1. Volume sampled will be calculated using initial and final flow rates measured by the Buck calibrator and time recorded by an external watch. Flow rates, times, and volumes recorded by the pump are to be used only as cross-checking measures.
2. Filter weighing QA/QC: 1 in 10 filters to be used as lab blank and 1 in 10 filters to be used as field blanks. Lab blanks (in cassettes) are to be left in the custody of the designated weighing laboratory. Field blanks will be taken to the field and returned after all 30 houses have been surveyed. Thus we will have 6 lab blanks and 6 field blanks. The laboratory will be requested to give us all raw data (e.g., if a filter is weighed three times, then we need all three readings and not just the average). The laboratory could weigh in batches of 12 – the 11th filter is to be a lab blank and the 12th filter to be the field blank. Filters with more than 2 mg dust loading will be rejected.
3. Data downloaded from T82 to be carefully archived in the laptop. Each file to be labeled in a manner that it is easy to understand which household it relates to. In the first round of analysis we will use only 24-hour averages. But in the second round we will need to look at the time-series profile.
4. Ideally, try to begin monitoring at approximately the same time of day in each house and at least half an hour after the last time cooking occurred in the house.

## II. PM and CO Equipment

Two “kits” (equipment cases) have been packed with the following equipment:

- 1 pump (AP Buck, VSS-5)
- 1 respirable dust cyclone
- 2 “triple charge” batteries (VSS/Basic Battery Pack)
- 1 “Fast One” battery charger with “alligator clips” (for charging pump battery from car battery)
- 50 filter and 50 support pads, pre-loaded into the 3-part cassette cases with blue and red end plugs (filters to be pre-weighed and assembled by Supervisor)
- 1 T82 CO monitor with leather case

**Case I holds the following additional equipment:**

- 1 calibrator (AP Buck) with charger, plastic tubing, and calibration soap bubbles

**Case II holds the following additional equipment:**

- Bottle of 100 shrink bands for filter cassettes
- T82 Datalogging kit with cable, cradle, and software

**Equipment to be acquired locally:**

- Two (2) car batteries, with the following specifications: DELCO, 50 Amp-hour (Ah). Battery life calculations are based on 50 Ah; if other battery capacity is used, please inform Winrock.
- Two 12 Ampere chargers for charging the car battery from 110 Volt, AC source (if this is not easily available, please inform Winrock).
- A jumper cable if there will be no access to a 110 Volt AC electricity source, so that the car battery may be charged with the battery in a truck or other vehicle.
- Materials for securing the pump, cyclone, and T82 in suitable position in the home.
- Watch or clock for recording start/finish time. NOTE: be sure to synchronize with the equipment to avoid discrepancies!
- Tape measure for proper location of equipment.
- Flashlight(s).

## III. Monitoring Session Scheduling

The supervisor must schedule the timings of the two sessions such that **one of them does not include any cooking activity** (typically, this will start late in the evening after dinner and end the next day early morning before breakfast). This will provide important information on the background level of particulates. It is not necessary that both the monitoring sessions be of 12 hours duration (meaning that the filter need not be changed exactly after 12 hours).

For example, suppose these are the likely timings as reported by a cook:

**Day 1**

| | |
|---|---|
| Breakfast | 6-7 AM |
| Lunch | 11 AM - 12:30 PM |
| Dinner | 8-9 PM |

**Day 2**

| | |
|---|---|
| Breakfast | 6 –7 AM |
| Lunch | 11 AM -12:30 PM |
| Dinner | 8-9 PM |

In this case the supervisor should schedule the monitoring as follows*:

Start the first session on Day 1 at 5:30 AM
End first session on Day 1 at 9:30 PM

Start second session on Day 1 at 9:30 PM **(30 minutes after cooking has ended)**
End second session on Day 2 at 5:30 AM

**NOTE 1: For this case, the duration of first session is 16 hours and duration of the second session is 8 hours. This is acceptable. The two durations can be unequal as long as they add up to 24 hours (other than a few minutes that are required to change the filter).**

**The one risk of this schedule in kitchens with very high concentrations of smoke is that the filters will become quite clogged or even saturated after the 3 (or more) cooking sessions. This can cause back-pressure on the pump, which will make the pump work harder to keep the flow rate constant, and will draw down the battery more quickly. If the back pressure is sufficiently high, the pump may stop. The supervisor should be attentive to this possibility, and should revert to a 12 hour/12 hour monitoring session breakdown in the case of pump stoppage.**

***NOTE 2: Monitoring session scheduling is further influenced by battery charging requirements, as discussed in the next section.**

# IV. Battery Charging Protocol

**Operating Parameters:**

- The "triple pack" batteries for the pumps **should be re-charged after every 24-hour monitoring period.** Using the car battery and the "fast charger," this can be done in approximately 4.5 hours.
- Assuming the car battery is of 50Ah capacity, it can recharge the triple packs 10 times before it will need to be recharged from either:
    1. A 110 volt/AC electricity supply. (This will take approximately 4 hours with a 12 Ampere charger, or about 12 hours with a 4 Ampere charger.) **OR,**
    2. Another car battery. In order to avoid draining the charged car battery, this should be done with the vehicle running, and will take approximately 1 hour.

**Recommended Charging Regimen:**

1. For every 24-hour monitoring period, use two triple charge batteries to run the pumps. During this time, charge the other two triple charge batteries, one after another, for 4.5 hours each, using the Fast Charger with one of the car batteries. The green LED light on the fast charger will light up when charge is complete. *NOTE: it is important to disconnect the fast charger from the batteries at this time; otherwise, it will continue to draw current and reduce the available energy in the car battery*.

2. After 10 charges with the first car battery, take it for recharging, preferably to a place with access to an electric line. If none is accessible, use a vehicle to recharge the battery. (Follow parameters outlined above). Meanwhile, use the second car battery for recharging the triple charge pump batteries.

**NOTE: In the event of a "bad"/defective triple charge battery (unlikely, but possible!): The fast charger can be used *while the pump is running during monitoring*. Connect the fast charger directly to the battery in the pump (has adaptor plug). This will take longer than when the triple charge battery is not in use, likely 6 hours. *Remember to disconnect the charger as soon as the green light turns on to save the car battery's energy!***

**Other topics affecting monitoring schedule:**

- Consistency of start time (see section III). The start time should remain as consistent as possible from house to house. However, it will not be possible to start exactly at the same time every day, due to transition time between houses, pump calibration, etc. It is recommended that the start time remain within approximately a 1 hour bracket, prior to breakfast or first lighting of the fire. For example, if the first lighting of the fire typically happens at 6AM, the monitors should ideally be installed and started between 4:30 and 5:30AM (or as early as 4AM if necessary, or as late as 5:45AM, before lighting of fire).

- Pump calibration. See instructions in Appendix C.

## V. Filter Cassette and Cyclone Preparation

1. Refer to Appendix B for proper filter and cassette assembly.
2. Record the two cassette serial numbers that you have selected onto the data form.
3. Check that for each cassette the plastic clip is in place and the cassette bag sealed ("ziplock" bags recommended): record this information on the data form.
4. Place the cassettes (in their bags) in the equipment case: the cassettes for the two periods will be inserted into the cyclone in the field.
5. Make sure you include in the equipment case the **same cyclone that you calibrated the pump with.**
6. **ENSURE THAT THE CYCLONE GRIT CAP AND INTERIOR ARE CLEAN.**

## VI. CO Monitor Preparation

**Before sampling for the first time:**

1. Click on DataLink logo on computer screen desktop to open program.
2. Check room CO- monitor is OFF.
3. Put monitor into cradle, making sure the three dots on the monitor line up with three points on the cradle & monitor clicks into position.
4. Click "Connect to the T82," then click on ON – monitor will beep once.
5. Click "check/set instrument settings."
6. Click "change."
7. Click TWA time base and change to 24 hours and set Lo, Hi, TWA, and STEL alarms to 999.
8. Click "set" – wait for set of blue bars to show it has been done.
9. Click "Exit."
10. Click "Clear data."
11. There is no need to open the "Download preferences" as they should be left as set currently.
12. Click "disconnect."
13. Click "exit."

>>>**Performing a zero check at supervisor's office**<<<

1. Switch on the instrument.
2. Ensure that the air around is clean and/or keep the inlet tightly covered.
3. Observe if the display is showing zero.

# VII. Equipment Set-up

## *A. PM monitor set-up*

1. Record serial number of cassette on Data Collection Form (Step 3) and on household correlation table. *It is vital that this information is recorded correctly as this is the only way of knowing which sample comes from which house*.
2. Check chart provided in Appendix A of this manual for the filter cassette serial numbers for each house.
3. Select the filter cassette with the correct number for the first monitoring session (should be prepared ahead of time).
4. Enter the filter cassette serial number onto the data collection form.
5. Remove the plastic clip, replace clip in bag and reseal the bag. Place the cassette into the cyclone the right way up (the word "TOP" is printed on the top), and close the cyclone securely, without over-tightening.

*Positioning the pump and cyclone:*

1. Connect cyclone to pump, and ensure cyclone lid securely tightened, and pipes well connected.
2. Identify a suitable site for the **cyclone**. This must be in the kitchen, **1.3m above floor level, and 1.3m from fire, and away from smoke rising directly from fire**. Avoid a location that is close to (less than 1 meter away from) windows, doors, and other openings.
3. When you have identified a suitable location, fix the pump and cyclone securely. Ensure that the cyclone is upright. Check alignment of the filter holder and cyclone in the sampling head to prevent leakage.
4. Record the location on the data collection form, **providing enough detail to ensure that the same location can be selected for all subsequent rounds of air pollution monitoring.** Put an "X" on the layout drawing for the kitchen to identify the location of the monitor.

## *B. CO monitor set-up*

1. The T82 room monitor should be fixed securely next to the cyclone.

## VIII. Equipment Start-up

### *A. Starting the pump for sampling PM*

The pump has been prepared and calibrated by the supervisor, and should be ready to start sampling.

- Switch on the pump in the RUN mode by pressing "ON" and then "ENTER."
- Record the temperature displayed by the pump.
- Check that the flow rate is in the range **2090 – 2310 ml/minute**.
  - If flow rate is in range, proceed.
  - If flow rate is not in range, the pump must be re-calibrated by the supervisor (see Appendix C for pump calibration procedure).

### *B. Sampling CO*

- Switch on T82 CO monitor by pressing and **holding the switch until it gives one beep,** and watch to see that the display goes through the following sequence:
  - "On"
  - CO – this is what is it going to measure
  - A series of bars to show the condition of the battery in a 3-2-1 pattern (if it is less than 3-bars, let the IAP consultant know at once)
  - r 2.2 – this is the software which is needed to download the measurements
  - A red light and backlight to the display
  - A countdown set of numbers: 5-4-3-2-1
  - It will then indicate the level of CO in the room (which may be zero, so do not be concerned if it shows 0….the important thing is that there is a number on the screen). It is now working.

## IX. Mid-Monitoring Filter Change and Equipment Check

### *A. Filter replacement*

If all has gone well, all that is required following the first monitoring session is to check the pump, replace the filter cassette, and then re-start the pump.

NOTE:

1. While replacing the filter cassette always hold the cyclone upright and **never invert the cyclone at any time.**
2. If the pump has stopped before you arrive, it is important to find out why.

The following procedure should be followed:

*Procedure for checking and then temporarily stopping the pump*

Case 1: If pump is **still running**, follow the steps below.

1. Record the following:
    - ☐ Flow rate
    - ☐ Temperature
    - ☐ Time elapsed (minutes)
    - ☐ Total volume sampled (liters)

2. Then press ON/HOLD (for a few seconds).

3. Remove the filter cassette. While replacing the filter cassette always hold the cyclone upright and **never invert the cyclone at any time.** Put the sealing clip on the cassette, then place the cassette into the plastic bag and close the seal.

4. Locate the second filter cassette and enter the serial number on the form. As you did for the first cassette at the start of monitoring, remove the plastic clip, replace this in the bag, and re-seal the bag. Place the cassette into the cyclone the correct way up (see reminder box), and close the cyclone securely without over-tightening.

**Make sure the cassette is the correct way up! [“Inlet” and “Outlet”]**

5. Press “ENTER” again to restart for the second session.

Case 2: If pump has **stopped running**, proceed as follows:

1. Check display. The reason for pump stoppage should be displayed (e.g. "flow interrupt" if the filter is blocked). If the display has gone, you will need to press ON/HOLD.
2. Record the reason for the pump stopping.
3. Record the data displayed on: **Time Elapsed and Total Volume Sampled**.

NOTE: If the pump has stopped, the monitoring in that house should be abandoned and the pump taken back to the field office to be checked thoroughly, and to establish exactly what the problem has been. Advise the householder that you are making checks on the equipment, and with her permission you would like to arrange to repeat the sampling on another day. Please ensure that she does not think that she is in any way responsible for problems such as these.

### *B. Check CO monitors*

Make sure that the kitchen CO monitor is still working by checking that there is a value on the display (this may be zero – that is OK). **Do not make any adjustments** to the CO monitors.

## X. Equipment Shut-down, Data Recording, and Recalibration

### *A. Checking and then stopping the PM pump*

<u>If pump is **still running**:</u>

1. Record:
    - ☐ Flow rate
    - ☐ Temperature
    - ☐ Time elapsed (minutes)
    - ☐ Total volume sampled (liters)
2. Stop pump by pressing "ON/HOLD" for a few seconds then pressing "OFF" again for a few seconds.
3. Do not switch on pump for any reason until reviewed by the supervisor.
4. Ensure that the filter cassette is stored and transported with exposed side up and does not suffer any shocks (to the extent possible).
5. Proceed to "flow rate measurement…" section C below.

<u>If pump has **stopped running:**</u> the reason should be displayed (e.g. "flow interrupt" if the filter is blocked).

1. If the display has gone, you will need to press ON/HOLD.
2. Record the reason for the pump stopping.

**NOTE:** If the pump has stopped, the monitoring results in that house will not be used. The pump will need to be checked to establish exactly what the problem has been. Advise the householder that you are making checks on the equipment, and with her permission you would like to arrange to repeat the sampling on another day. Please ensure that she does not think that she is in any way responsible for problems such as these.

### *B. Switching off the T82 CO monitor:*

1. Depress and hold down the function switch on the room CO monitor **until the instrument <u>beeps 5 times</u>.** Check that the display is now blank. The machine is now off.

### *C. Data download from CO monitor (Steps 7 & 8 of the data collection form):*

1. Check room CO- monitor is OFF
2. Put monitor into cradle, making sure the three dots on the monitor line up with three points on the cradle & monitor clicks into position & beeps once.
3. Click "Connect to the T82" – monitor will beep once. You will see "Communication link with instrument is established."
4. Machine will indicate "1 session available to download" – click on "Download data."
5. You will be asked to give the file a name. Give a name and save the file. **Do not clear at this stage.**

6. Click on Disconnect. You will see "instrument data were not cleared (1 session). Do you wish to do so before exiting?" Click "NO."
7. Then "file open" and check that the data is there, and that the date and the times are those that you expected them to be for the house (s) you monitored. You will find this by opening the "Summary/Comments" page (which is the first icon on the left of the opened file).
8. Once you are **absolutely sure that you have downloaded all the data successfully –** connect the T82 Datalogger again.
9. Click "Clear data."
10. Click "disconnect" - monitor will beep once.

**BACKUP**

11. **Please remember that this is the only record that we have of CO levels.**
12. Click on "File open" – highlight the file you have just created.
13. Right-click and select "Send to" and choose $3^1/_2$ Floppy (A).
14. Save onto a labeled floppy disc.

### *D. Flow rate measurement and filter cassette handling on completion of monitoring (Step 6 of the Data Collection form)*

1. Connect the **calibration cassette** between the pump and calibrator. Press ENTER and RUN.
2. Switch on calibrator and wait for 2 minutes for pump flow rate to stabilize. In the meantime wet the glass chamber with many bubbles.
3. Take 3 readings of the flow rate.
4. Switch off pump by pressing ON/HOLD and later OFF.
5. **THIS IS THE END OF THIS SESSION.**
6. Clean the cyclone grit cap and the interior of the cyclone by unscrewing the 4 screws.

**NOTE: The most important checks that you need to make on the filter cassettes when these are brought back from the house are:**

- **You have the correct cassettes for the house just sampled.**
- **The cassettes are correctly sealed with the plastic clip and bag.**

Accordingly, inspect the cassettes and:

7. Record (a) the number, and (b) the condition and packing of the cassette on the data form.

### *Checking Interviewer Data Collection Forms (Step 9 on the data collection form)*

At the end of each house visit (for interview and monitoring), the supervisor should check through the forms that have been completed by the Interviewer. Check that all fields have been completed (that is, none have been omitted), and that the entries appear correct and consistent.

All omissions and possible incorrect entries must be checked with the interviewer, and corrected. If there is any uncertainty about an entry, a return visit to the house should be made by the supervisor should be made.

Record checks on the forms, together with remedial action taken for corrections.

## XI. Post-Monitoring Questioning

These questions will be asked **after the completion** of the air monitoring. All questions refer to what happened **during** the time that the monitors were measuring smoke.

- **Cooking meals**

Note that these questions refer only to the preparation of meals for the family, not the preparation of food or other products for sale, or for any other uses (see section below if this applies).

- **Timing of meal**

Please note that information collected on the first meal refers to the first meal after the monitors were set up and started working and NOT necessarily the first meal of the day (in the event that 12hr/12hr monitoring sessions need to be used). Similarly questions are asked about the second, third, and fourth meals (where appropriate) after the monitors were set up and started working.

For Questions H 1.3 and H 1.4, record approximately how long it took to cook (to nearest quarter of an hour, if possible).

- **Types of food and drink cooked**

Please record food using local names, also hot drinks prepared for the mealtime. We may need some guidance on how the types of food should be recorded (hard/soft, etc.) and in what detail for this to be used in an effective way in the analysis.

- **Other uses of the fire/stove**

This question is to be used for use of the fire/stove in the preparation of food or other products for sale, or for any other use.

If food and/or other products were prepared at the same time as one or more of the meals for the family, try to find out how much of the fuel used on the day of the monitoring was used in income-generating and “other” activities. This will show how important fuel is to people’s earning power.

- **Time-activity information**

In this case, air pollution monitoring began at 08.00 hrs (8 o’clock in the morning). The fire was not lit until 5.30 AM, and went out at about 10.00 AM. It was lit again at 1.00 PM, and was kept alight (smoldering) during the afternoon, until cooking began again at 5.30 PM. The fire was used for cooking and sitting round in the evening, and finally went out at (probably) 1 AM when the family was asleep – in this case the mother and child were sleeping in the same room as the fire.

- **Comments and observations**

**From the INTERVIEWEE**

Ask if the interviewee has any more comments that she would like to add about the issues that you have discussed, or related issues. If the interviewee does not obviously have more to add, there is not need to press her for further comments.

**From the INTERVIEWER**

Record here any observations you wish to make about the interview, and any other relevant observations.

**PLEASE TAKE CARE TO ENSURE THAT NO EQUIPMENT HAS BEEN LEFT AT THE HOUSE.**

## APPENDIX A. Chart for correlating filter cassette serial numbers with households

----------------------------------------------------------✂---------------------------------------------------

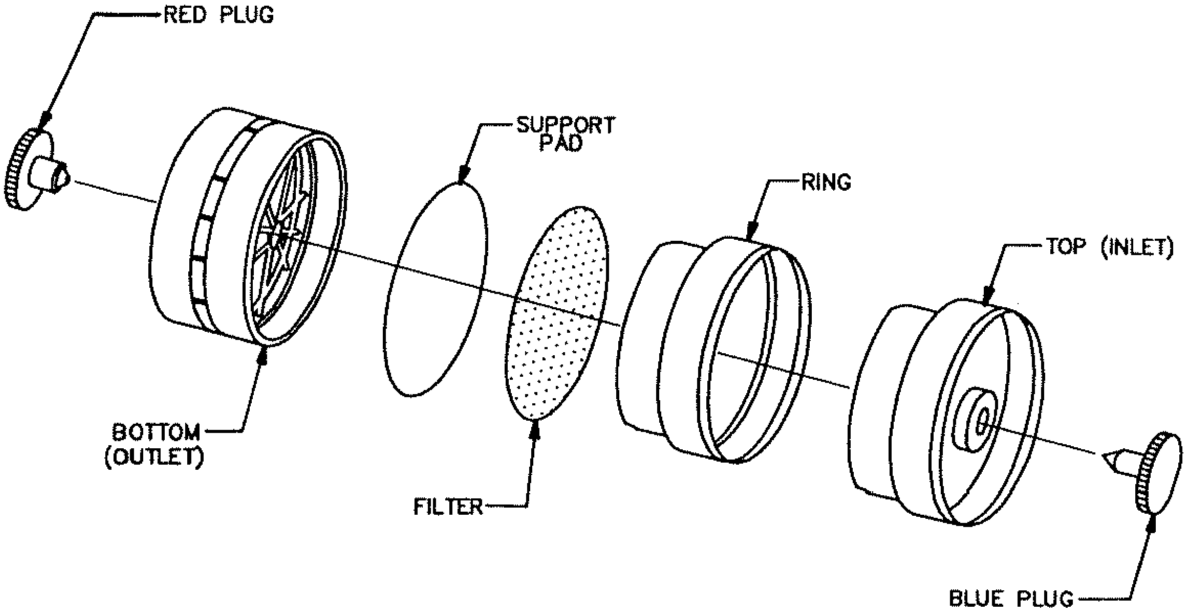
## Chart: Household Numbers, Name of Cook and Identifier and Serial Number of Cassette

| Round number = 1 Peru | | | | |
|---|---|---|---|---|
| House Number | Identifier | Name of woman | Serial number of first cassette | Serial number of second cassette |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## APPENDIX B: Filter cassette configuration diagram

# 37mm Filter Cassette Configurations

*Zefon* offers 37mm cassettes as convenient pre-loaded and assembled units that are ready to use OR as empty cassettes that can be loaded with the filters of your choice. They are manufactured in numerous plastic housing materials and have a large selection of compatible filters. The two most common styles are the 2 and 3 piece clear styrene models, the latter of which is highlighted below.



---

## 37mm 3-piece Cassette Configuration

3-piece cassettes can be used for both “open face” and “closed face” sampling as well as connect to cyclones. The main disadvantage would be that 3-piece cassettes have more static charge than 2-piece cassettes, resulting in more potential for sample loss.

The term “closed face” sampling refers to using a 37mm cassette with the inlet in place and only the plugs removed. Alternatively, “open faced” sampling refers to using a 3-piece cassette and removing the inlet piece, thus creating an “open face.”

## APPENDIX C: Pump calibration procedure

# PUMP PREPARATION AND CALIBRATION

## Step 2 of the data collection form

***Figure 1:*** *Place a few drops of soap solution into the bubble chamber through the lower opening.*

### Items required

- Calibrator
- Pump and power supply
- Tubing (2 lengths of ~0.5m)
- Cassette, containing clean filter (the calibration cassette)
- Cyclone

### I. Preparation

Check that the calibrator has a *small amount* of soap solution (about 1 teaspoonful or 5ml) in the bottom of the glass cylinder (enough to cause a bubble to form around the glass). If not sufficient, top up through the lower tube (see Figure 1).

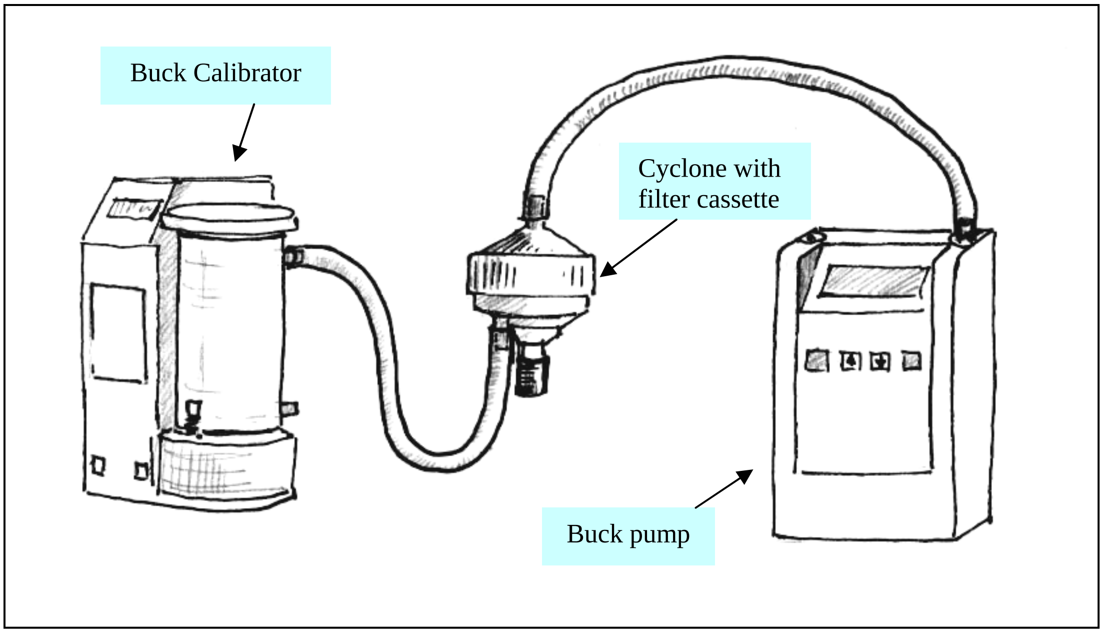


***Figure 2**: Connection of pump and cyclone to the Buck calibrator. The tube between the pump and cyclone should be the length normally used when sampling in the home, and the cyclone must have the (clean) **calibration** filter cassette installed.*

1. Place the calibration cassette (with a blue tape) in the same cyclone assigned to the household being surveyed, ensuring it is the right way up. (TOP is shown on the cassette.) Remove and clean the cyclone's grit cap. Ensure that the cyclone lid is securely tightened to avoid leaks (but do not over-tighten), and that the O-ring in the upper part of the cyclone is in place. Connect the cyclone outlet (top, horizontal pipe) to the pump, and the inlet (lower vertical pipe) to the Buck calibrator as shown (Figure 2). Note that the cyclone inlet should be connected to the upper tube on the calibrator (Figure 3).
2. Place the equipment on a flat stable surface.
3. Connect the pump to its power supply **(+)** to the red and **(-)** to the black. Note that the calibrator has an internal rechargeable battery, estimated operating time of 6-8 hours, and there is a low battery indicator. Battery should be kept adequately charged.

***Figure 3**: Tube to cyclone connects to upper outlet of calibrator.*

## II. Clear current pump settings:

4. Switch "ON" pump.
5. Move arrow to RESET and press ENTER.
6. Sampling data to be cleared? Use arrow to YES and press ENTER. (You will see "sampling data erased.")
7. Run battery life: No. Press ENTER.
8. Menu goes back to initial display.

***Figure 4:** Depress the button to release a soap bubble.*

## III. Check and calibrate the pump flow rate:

9. Move arrow to calibrate "CAL."
10. Clear current calibration – move arrow to YES and press ENTER.
11. Warning "Will Erase." Move arrow to YES and press ENTER.
12. You will hear the pump run.
13. If display shows 2200 press ENTER. If display is not showing 2200, then use arrows to change it to 2200. This is our target flow rate.
14. Switch on the Buck calibrator unit. Display should show 0000.
15. Keep pump running for 2 minutes to allow it to stabilize.
16. In the meantime, wet the glass chamber by releasing many bubbles (Figure 4 and Figure 5).

***Figure 5:** Soap bubble moving up the chamber. Make sure it reaches the top freely before starting measurements.*

17. After 2 minutes are over, check the flow rate of the pump as follows:
    a. Release a bubble to obtain a reading on the calibrator and record this on a paper. Repeat until you obtain THREE CONSECUTIVE READINGS all within 100ml (0.1 on the calibrator display).
    b. Wait until the calibrator display stops flashing before releasing the next bubble).
    NOTE: The readings on the calibrator are in liters/minute – please ignore the decimal point to produce readings in ml/minute (e.g., 2.197liters/minute =2197ml/minute). An example is given in Table S1 (below):

**Table S1: 3 Consecutive flow rates meeting calibration criteria**

| **Reading** | **Value (ml/minute)** | |
|---|---|---|
| 1 | 2186 | These are *acceptable* results |
| 2 | 2204 | |
| 3 | 2193 | |

Set the pump to the correct flow rate if it is not already doing so:

18. The criteria for a correct flow are that the average of the 3 measurements should be close to **2200** ml/minute, and that all three **must be in the range 2090 to 2310** ml/minute. Fill up section 5, 6, 7 of the supervisor manual.
19. If the criteria for the flow rate **ARE ACHIEVED** (Step 14), adjust the flow rate display (see Section IV, below – "Adjusting the Display").
20. If the criteria for the flow rate are **NOT ACHIEVED** (Step 14), and an example where criteria are not met is provided in Table S2, adjust the flow using the UP and DOWN arrow keys on the pump. You will hear the pump slowing down or speeding up and see the % change on the display. Allow 20-30 seconds for the pump to stabilize after each change you make in the flow rate. Carry out a further three test readings with the calibrator, and check whether these meet the criteria. This procedure needs to be repeated, by "trial and error" until the criteria are met.

**Table S2: 3 Consecutive flow rates NOT meeting calibration criteria**

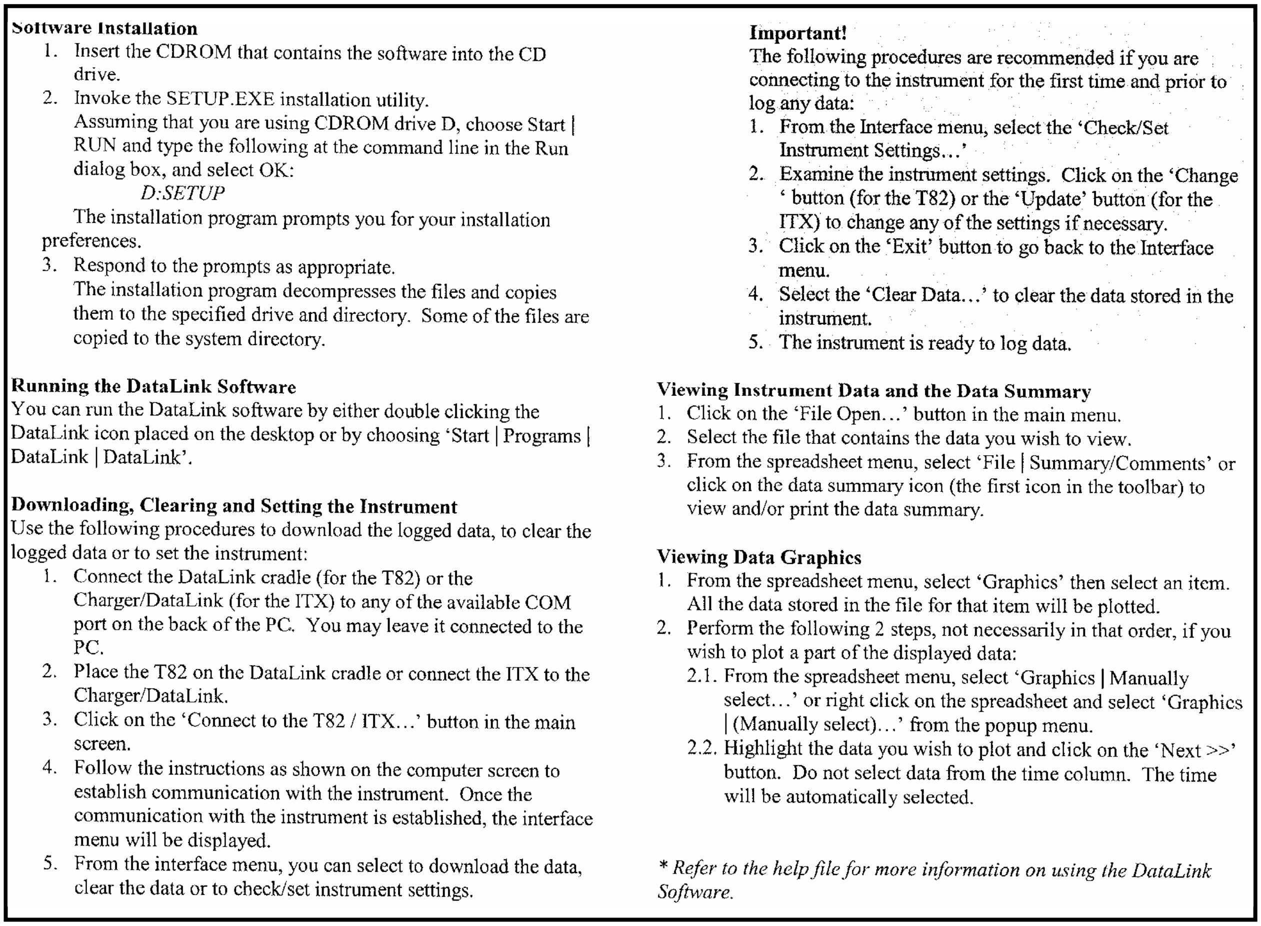
| **Reading** | **Value (ml/minute)** | |
|---|---|---|
| 1 | 2103 | These results are NOT acceptable |
| 2 | 2086 | |
| 3 | 2135 | |
| **Average** | **2108** | |

21. Note that the final three readings (that you enter on the data sheet) must be within 20ml/minute of each other. If this precision cannot be achieved, check all connections, and that the grit pot is in place on the cyclone. If this level of consistency is still not achieved, contact Dr. Subida and we will get in touch with suppliers.

## IV. Adjusting the display on the pump:

22. Press ENTER. You will see “Calibration flow rate 0000 cc/m.”
23. You will now adjust the four-digit display on the pump to read the average of the final three readings, which have been entered on the data sheet. Each digit will flash in turn, starting with the left hand one. Use the up and down keys to set the number. Press ENTER to move on to the next digit (which will then start to flash), until all are correct. Then press ENTER again – the pump will stop and menu goes back to initial main menu.
24. Press ENTER on RUN. Flow should be 2200. If not, use arrow to set it to 2200 and then press ENTER.
25. Switch off pump by pressing “OFF” for a few seconds. DO NOT SWITCH ON PUMP TILL ACTUAL MONITORING BEGINS.
26. The pump is now calibrated and ready for survey work.
27. Place the pump and cyclone (with calibration cassette removed) into the house survey kitbag.

## APPENDIX D: CO datalogging “Datalink” procedure



**Software Installation**

1. Insert the CDROM that contains the software into the CD drive.
2. Invoke the SETUP.EXE installation utility.
   Assuming that you are using CDROM drive D, choose Start | RUN and type the following at the command line in the Run dialog box, and select OK:
   *D:SETUP*
   The installation program prompts you for your installation preferences.
3. Respond to the prompts as appropriate.
   The installation program decompresses the files and copies them to the specified drive and directory. Some of the files are copied to the system directory.

**Running the DataLink Software**

You can run the DataLink software by either double clicking the DataLink icon placed on the desktop or by choosing ‘Start | Programs | DataLink | DataLink’.

**Downloading, Clearing and Setting the Instrument**

Use the following procedures to download the logged data, to clear the logged data or to set the instrument:

1. Connect the DataLink cradle (for the T82) or the Charger/DataLink (for the ITX) to any of the available COM port on the back of the PC. You may leave it connected to the PC.
2. Place the T82 on the DataLink cradle or connect the ITX to the Charger/DataLink.
3. Click on the ‘Connect to the T82 / ITX…’ button in the main screen.
4. Follow the instructions as shown on the computer screen to establish communication with the instrument. Once the communication with the instrument is established, the interface menu will be displayed.
5. From the interface menu, you can select to download the data, clear the data or to check/set instrument settings.

**Important!**

The following procedures are recommended if you are connecting to the instrument for the first time and prior to log any data:

1. From the Interface menu, select the ‘Check/Set Instrument Settings…’
2. Examine the instrument settings. Click on the ‘Change ‘ button (for the T82) or the ‘Update’ button (for the ITX) to change any of the settings if necessary.
3. Click on the ‘Exit’ button to go back to the Interface menu.
4. Select the ‘Clear Data…’ to clear the data stored in the instrument.
5. The instrument is ready to log data.

**Viewing Instrument Data and the Data Summary**

1. Click on the ‘File Open…’ button in the main menu.
2. Select the file that contains the data you wish to view.
3. From the spreadsheet menu, select ‘File | Summary/Comments’ or click on the data summary icon (the first icon in the toolbar) to view and/or print the data summary.

**Viewing Data Graphics**

1. From the spreadsheet menu, select ‘Graphics’ then select an item. All the data stored in the file for that item will be plotted.
2. Perform the following 2 steps, not necessarily in that order, if you wish to plot a part of the displayed data:
   2.1. From the spreadsheet menu, select ‘Graphics | Manually select…’ or right click on the spreadsheet and select ‘Graphics | (Manually select)…’ from the popup menu.
   2.2. Highlight the data you wish to plot and click on the ‘Next >>’ button. Do not select data from the time column. The time will be automatically selected.

** Refer to the help file for more information on using the DataLink Software.*

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX IV – Indoor Air Pollution Monitoring Report

# **ANNEX IV.** Indoor Air Pollution Monitoring Report

## Reducing Exposure to Indoor Air Pollution through Household Energy and Behavioral Improvements among Families of the High-Andean District of Inkahuasi-Ferrañafe, Peru

**June 2007**

Submitted by:
Swisscontact

## Summary

In the framework of the cooperation agreement between USAID and Winrock International, in April 2005, the “Healthy Kitchen/Healthy Stove” project was launched to reduce indoor air pollution by implementing improved stoves for better household energy use. The project was implemented in the Inkahuasi district, province of Ferreñafe, department of Lambayeque, in Northern Peru’s Andean region, at approximately 3,000 meters (9,842 ft.) above mean sea level. The district has a population of 13,316 living in extreme poverty. The project proposes the introduction of improved stoves to develop a needs-based local market, with a goal of 600 households in the district’s communities.

Three institutions have come together to work on local activities: Centro ECO, in charge of the logistics, implementation of improved stoves, and identifying the households that will take part in the intervention; Swisscontact, in charge of monitoring indoor air quality and data management; and Dr. Jay C. Smith, M.D., M.P.H, in charge of evaluating health symptoms and breathing tests associated with indoor air pollution.

The project monitoring was divided into two stages:

- Pre-intervention stage (August-September 2005): Centro ECO completed a survey based on the Inkahuasi district about the population’s practices and perceptions. Information was collected about the types of kitchens and use of firewood, among other data. Swisscontact sampled indoor air quality inside 48 kitchens to set a pollutant baseline prior to the implementation of improved stoves. Finally, Dr. Jay Smith collected health data from 78 individuals representing 44 households.

- Post-intervention stage (August-September 2006): After installing the improved stoves, indoor air quality was sampled in 44 kitchens with newly installed improved stoves. Along with the sampling, a survey was completed to gather information about the kitchen and food cooking process on monitoring day. Furthermore, Centro ECO completed a survey and fuel use study to determine changes in the behaviors and firewood consumption resulting from the use of the new technology. A year after the stoves were implemented, a second air quality sampling was completed (August 2007). In this last sampling only indoor air quality was measured, and a survey was conducted in 32 of the households included in the intervention. Centro Eco conducted a perception survey about the improved stoves.

This report includes the baseline information obtained prior to the implementation of the improved stoves and the results obtained in terms of air quality after installing the stoves.

## *I. Component 1: Practices, perceptions and socio-economic impacts*
## *Institution in charge: Centro ECO*

During the months of May and June of 2005, a baseline study was conducted on the practices, perceptions and socio-economic context for the Inkahuasi population. Centro ECO completed a survey with 169 households in 23 communities, as shown in Table 1.

***Table 1. Survey intervention***

| Group | Community | Number of households per group | Sample size |
|---|---|---|---|
| I | Canchachala | 52 | 5 |
| | Amusuy | 44 | 10 |
| | Uyshahuasi | 53 | 5 |
| | Atuncerca | 25 | 2 |
| II | Uyurpampa | 171 | 29 |
| | Chumbeara | 40 | 3 |
| | Romero | 41 | 3 |
| | Piedra Colorada | 33 | 2 |
| III | Marayhuaca | 100 | 9 |
| | Piedra Parada | 100 | 9 |
| | La Tranca | 40 | 3 |
| | Tasajera | 63 | 6 |
| IV | Totora | 60 | 5 |
| | Tungula | 60 | 13 |
| | La Playa | 58 | 5 |
| | Huarhuar | 60 | 5 |
| V | Sinchihual | 90 | 8 |
| | Huasicaj | 134 | 19 |
| | Machaycaj | 48 | 4 |
| VI | Inkahuasi | 78 | 6 |
| | Atumpampa | 95 | 8 |
| | Callita | 56 | 5 |
| | Cochapampa | 60 | 5 |
| **Total** | | **1,561** | **169** |

*Source: Centro ECO*

According to this baseline survey, only 24% of the population in this district has at least some elementary school education. About 90% of the families are farmers, while 3% produce textile crafts or have small businesses.

In over 90% of the households, it is the women who cook; girls 10 and older oftentimes help or even take over their mother's cooking duties. Meals are cooked 2 or 3 times per day, for a total average of 4 to 5 hours. During this time, children under 5 keep their mothers company.

In 61% of the households, the kitchen is a separate room within the house, while in 27% of the cases, the kitchen is a separate building. Only in 8% of households do people cook in the same room used also as a living or sleeping area, and in 4% people cook outdoors.

As for the cooking technology used, 66% of the surveyed households use three-stone open fires, due to low costs and because the fires are also used to heat the room. However, close to 80% of those surveyed said they didn't like cooking on three-stone fires, particularly because of the smoke that builds up in the room. The 23% of the households using three-stone open fires also have some other type of stove, most frequently a semi-closed wood stove without a chimney. Households not using a three-stone stove use semi-closed stoves without a chimney (38%), improved stoves with a chimney (33%), and improved stoves without a chimney (29%).

The most commonly used fuel is firewood, identified as the main fuel in 100% of the households. Over 90% of those surveyed identified dry leaves as the second most common fuel. Firewood is mostly collected by women, with the help of their children and husbands. This activity is carried out twice per week (in 50% of the households surveyed), every other day (21%), every day (20%), or less frequently (9%). The firewood used is generally dry, to prevent smoke generation. Other fuels used on a smaller scale are charcoal and kerosene.

## *II. Component 2: Indoor air quality*
## *Institution in charge: Swisscontact*

During the month of August 2005, respirable particulate matter ($PM_4$) and carbon monoxide (CO) concentration levels within the cooking environment was monitored in 48 households in 4 communities of the Inkahuasi district, representing over 5% of the 600 households targeted in the intervention. After installing improved stoves, indoor air quality was sampled twice in the households targeted in the intervention: The first sampling was conducted in October 2006, a few weeks after the stoves were implemented, with pollutant concentrations being measured in 44 homes (of the initial 48). The second sampling took place in August 2007, as a follow-up on how the users were operating the stoves, and the efficiency and strength of the stoves over time. During this sampling, $PM_4$ and CO from 3 models of improved stoves and a three-stone stove installed in the same room and operated on different days were measured in 32 of the homes in the original intervention.

### 2.1 Methodology

Winrock provided Swisscontact with a protocol for IAP monitoring based on the method used by Intermediate Technology Development Group (ITDG, now Practical Action) in monitoring interventions in Kenya, Sudan, and Nepal. In early 2005, this method was the most accepted and accessible method for use by an implementing NGO. This protocol uses the "gold standard" pump-and-filter method for measuring respirable particulates, and real-time datalogging CO monitors, mounted together at a standard distance from the fire. This approach assumes that $PM_4$ measurements represent the levels of breathable particles and are a good indicator of the levels of $PM_{2.5}$ and smaller particles, which dominate biomass gas combustion distribution curves.

Measurements were made for 24 hours to determine the $PM_4$ concentrations, divided in two back-to-back sampling sessions: a 16-hour period during which meals were cooked, and an

8-hour period at night during which no cooking took place.[1] Carbon monoxide was measured on an ongoing basis (recording every minute[2]) for a 24-hour period and kitchen environment temperature was measured while monitoring indoor air quality. The IAP monitoring equipment was provided by Winrock International, while Swisscontact provided devices for temperature measurement.

For reference purposes, this analysis uses the values established as Peru's National Environmental Air Quality (EAQ) Standards. While not established as occupational health or indoor air quality standards, Peru's EAQ standards serve as a framework to evaluate pollution levels in the sampled kitchens. For particulates, as shown in Table 2, the EAQ reference value for particulate matter $PM_{2.5}$ is used as reference to analyze the $PM_4$ values quantified in this study.

***Table 2. Particulate matter (PM) and carbon monoxide (CO) Environmental Air Quality (EAQ) Standards for Peru (according to Supreme Decree 074-2001-PCM)***

| **Pollutant** | **Period** | **EAQ** |
|---|---|---|
| $PM_{10}$ | 24 hours | 150 μg/m$^3$ |
| $PM_{2,5}$ (reference) | 24 hours | 65 μg/m$^3$ |
| CO | 1 hour | 30,000 μg/m$^3$ (26.2 ppm) |
| | 8 hours | 10,000 μg/m$^3$ (8.7 ppm) |

In 2005, the World Health Organization published a worldwide update to air quality guidelines. For particulate matter, the new guidelines confirm the fact that a low threshold cannot be set for this pollutant at which there would be no health effects from exposure, and that said effects happen both in short-term exposures (24 hours) and long-term exposures (one year). Even though a value cannot be set to offer complete protection against particulate-related health effects, the WHO set new guideline values in 2006, as shown in Table 3.

***Table 3. WHO guidelines for particulate matter (2006)***

| **Pollutant** | **Period** | **WHO Guideline** |
|---|---|---|
| $PM_{10}$ | 24 hours | 50 μg/m$^3$ |
| $PM_{2.5}$ | 24 hours | 25 μg/m$^3$ |

The new guideline for 24-hour average concentrations of PM2.5 (25 μg/m$^3$) is thus now significantly lower than Peru's current standards (65 μg/m$^3$), reflecting a recognition of the seriousness of the health impacts of smoke exposure even at low levels, and creating a more challenging target to meet in typical developing country kitchens, given extreme baseline conditions.

---

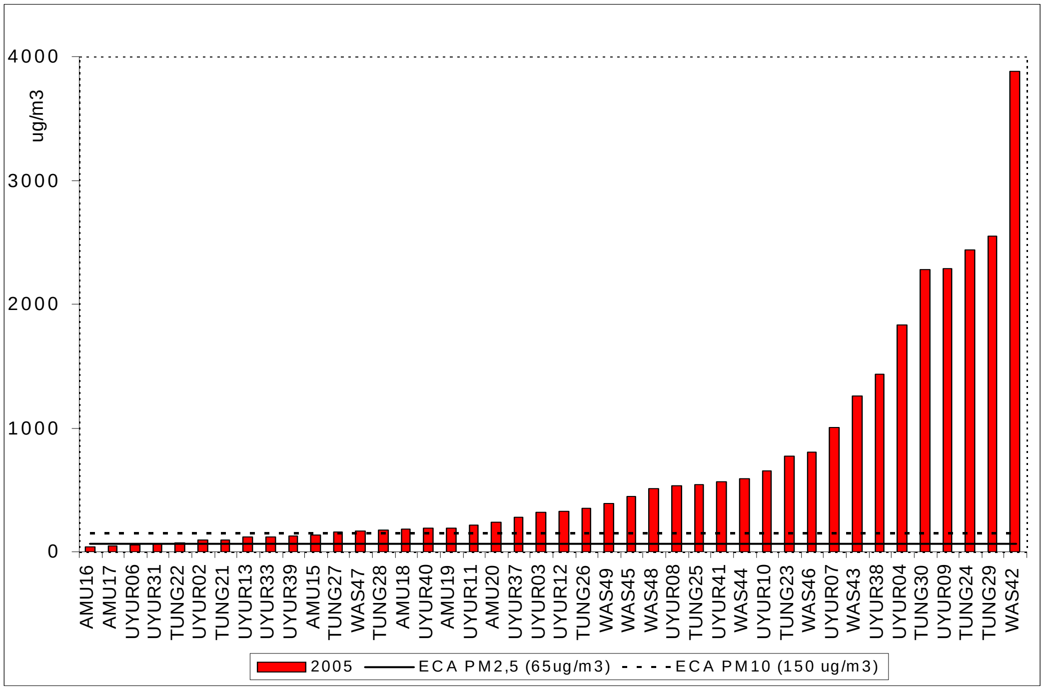
[1] To measure $PM_4$, a gravimetric method in which air is filtered using a pump and filter (A.P. Buck) for 24 hours was used. In this case, measurements were taken for two consecutive periods of 16 and 8 hours. Particles were captured in special filters that were weighed before and after exposure to determine pollutant mass. The result is the average $PM_4$ concentration for a 24-hour period.

[2] CO measurements were taken with a real-time device (Industrial Scientific Corporation) that recorded the concentration every minute for a 24-hour period. The hour values are estimated by averaging all the minute values in one hour and the eight-hour values are estimated by averaging the hour values. To consider the valid value, at least 75% of the data required to estimate the average should be available.

## 2.2 Results: Baseline

In general, the $PM_4$ and CO concentration levels found in the environments used for cooking were high. The overall $PM_4$ average reached 680 µg/m$^3$, more than **ten times** the EAQ reference value for $PM_{2.5}$. 93% of the kitchens had particulate concentrations exceeding this reference value (**see Figure 1.** (n=42)
). The maximum recorded concentration, in a kitchen of the village of Wasicaq, was 3,880 µg/m$^3$.

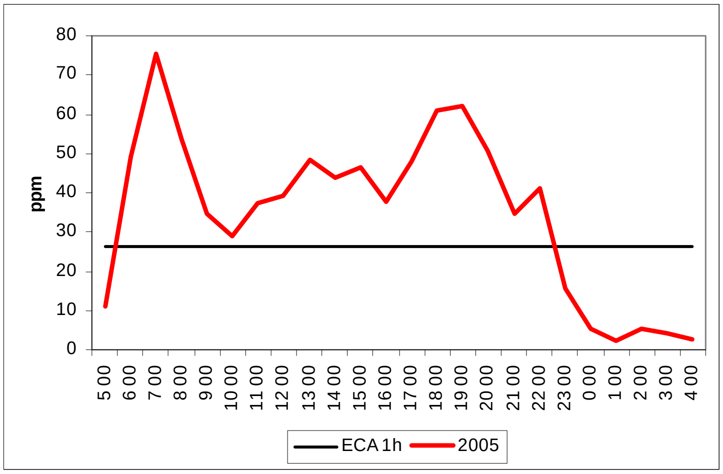
***Figure 1. $PM_4$ concentration (in µg/m$^3$) in the kitchens sampled prior to installing the improved stoves (n=42)***



Note: “ECA” in these figures refers to the Spanish acronym for Environmental Air Quality (EAQ) standards.

For carbon monoxide, average hourly concentrations from 06:00 to 22:00 hours continuously exceed the 1-hour CO EAQ (**see Figure 2**). The mean maximum value recorded in one hour was 176 ppm, over **6 times** the carbon monoxide EAQ for 1 hour. Likewise, the mean maximum 8-hour recorded value is 74 ppm, more than 8 times the corresponding EAQ value.

*Figure 2. Average hourly concentration prior to installing the improved stoves (n=42)*



### *Influence of number of meals cooked*

Since the sampling coincided with crop harvest days, in 12 of the 48 households sampled only 2 meals were cooked per day: breakfast and supper. During the day, household members were out working on their land. This made it possible to analyze $PM_4$ and CO concentrations under harvest-time conditions. Results show that the hourly CO concentrations have peaks that coincide with the hours when the kitchen was used for food preparation (**see Figure 3 and Figure 4**). In households where 2 meals were cooked, the average CO concentration between meals (represented by the blue line) fell below the hourly guideline value of 26 ppm, while in households where 3 meals were cooked, the hourly guideline value is exceeded all day long, and it only goes down at night. Though no data are available as concrete evidence, it can be assumed that in kitchens where lunch is cooked, the fire is not completely extinguished, and remnants of the fuel continue to burn or smolder between meals, which accounts for the elevated CO levels. On the other hand, in kitchens where lunch isn't being cooked, the fire is extinguished completely until it is time to cook supper, which brings CO values below the standard during that period of time. In Figure 4, the dashed line represents two-meal averages, including homes where the fire is stoked after dinner.

*Figure 3. Average hourly CO concentration in kitchens where three meals were cooked*

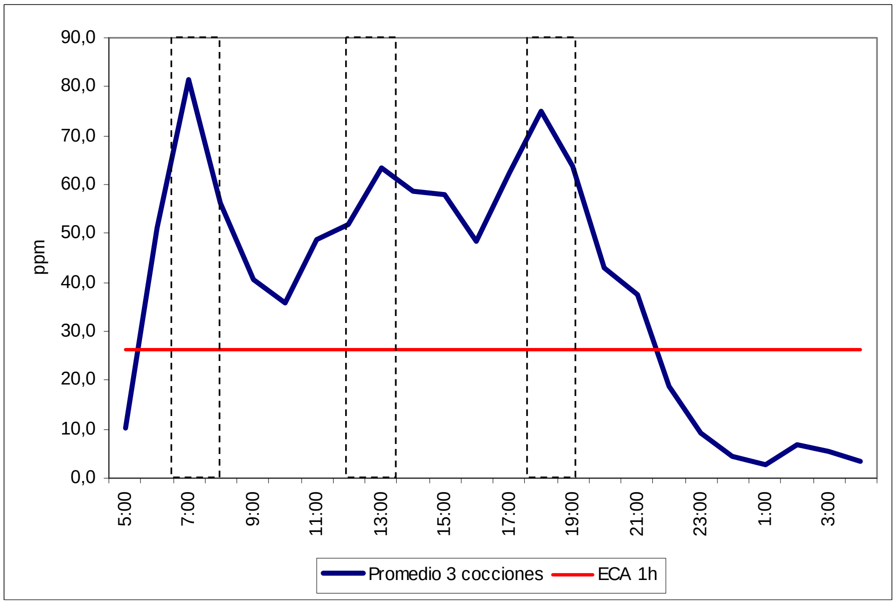
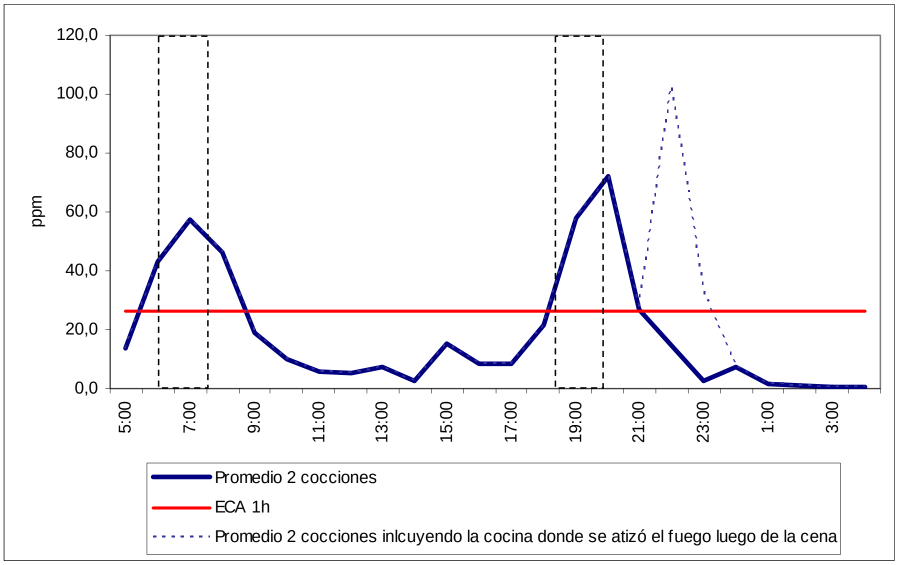
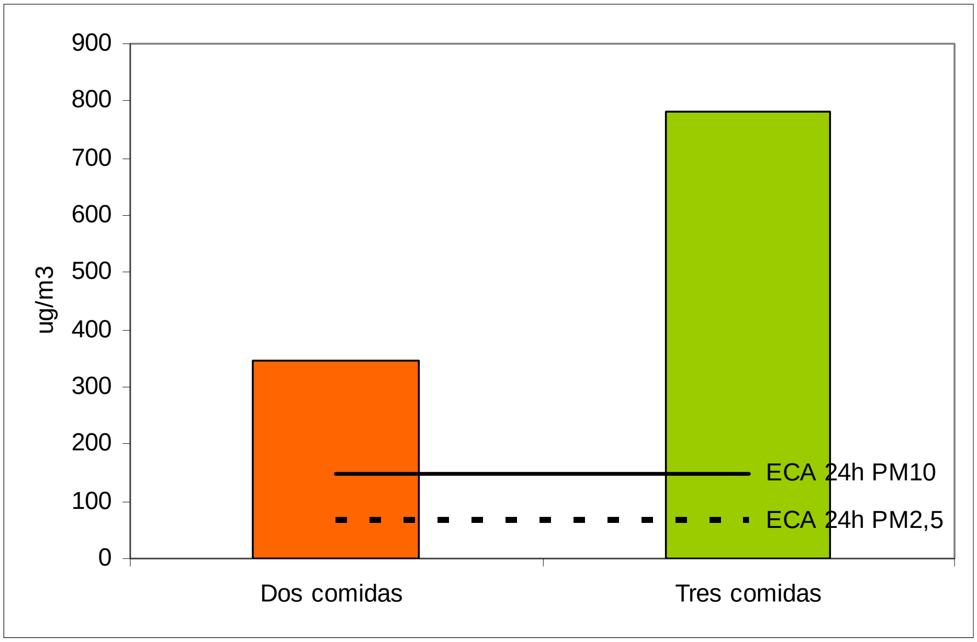


*Figure 4. Average hourly CO concentration in kitchens where two meals were cooked*



Similarly, as shown in **Figure 5**, the average 24-hour $PM_4$ concentration in the houses where 3 meals were cooked is substantially higher than in kitchens where only 2 meals were cooked. In both cases, the particulate values recorded far exceed the reference EAQ value for $PM_{2.5}$, reaching on average more than 4 times the standard in the 2-meal kitchens, and about 12 times the standard for the 3-meal kitchens.

*Figure 5. Average 24-hour $PM_4$ concentration in kitchens where two and three meals were cooked per day*



### *Influence of ventilation*

At the time the IAP monitoring was being planned, significant differences in roof ventilation were not anticipated. However, a pre-monitoring visit by Winrock and Centro ECO revealed that a number of households had either a rudimentary hole cut-out located in the roof directly over the floor-level open fire, or a carefully constructed hood combined with an elevated cooking platform. The latter finding surprised even the local engineer from Centro ECO who was not familiar with these hoods. Several of these stove hoods were observed, and they were skillfully constructed using the same design, with the material appearing to be a combination of mud and a local fibrous material. The platform consisted of a stack of adobe bricks, enabling the cook to stand while cooking, while the smoke exited easily through the vent.

The monitoring sample was thus adjusted to include a subset of households with hoods/"exhausts." Results showed that the monitored houses that use kitchens with exhausts had the lowest baseline $PM_4$ concentrations, while the kitchens with no roof opening had the highest concentrations (**see Figure 6**), roughly 3 times that of the kitchens with hoods. The blue bar refers to kitchens without exhausts but with roof openings. Nevertheless, even with hoods, the average indoor concentrations exceed guideline values. The average CO concentration also shows differences. In kitchens with no roof venting, the average hourly CO concentration during the day remained above the appropriate EAQ, except at dawn. On the other hand, kitchens with exhausts exceeded the EAQ in the early morning hours (coinciding with breakfast) after which concentrations dropped significantly, remaining below the EAQ for the rest of the day (**see Figure 7**).

*Figure 6. Average 24-hour $PM_4$ concentration by type of venting on kitchen roofs*

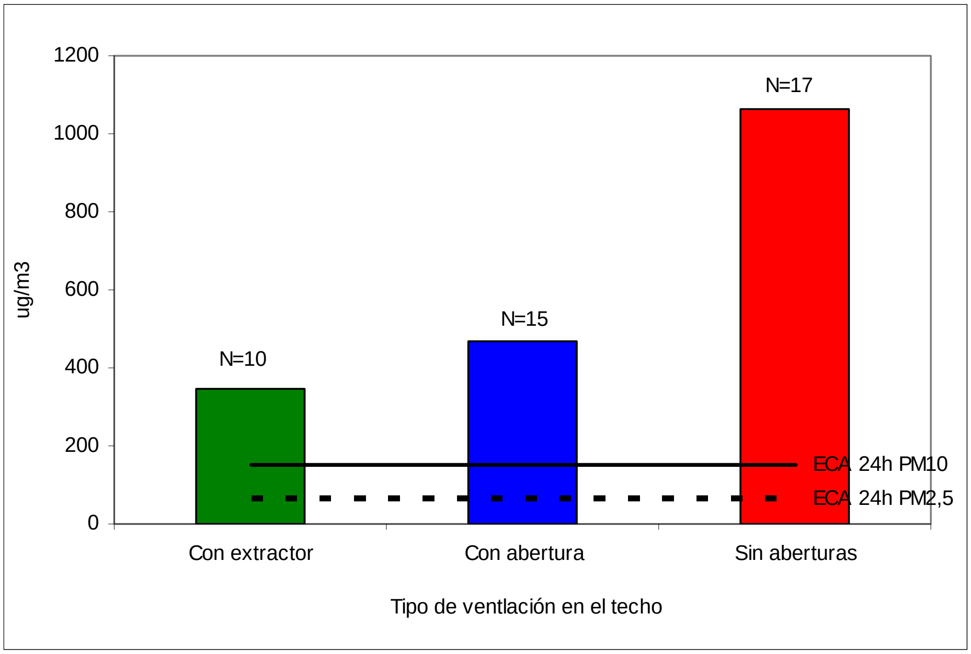
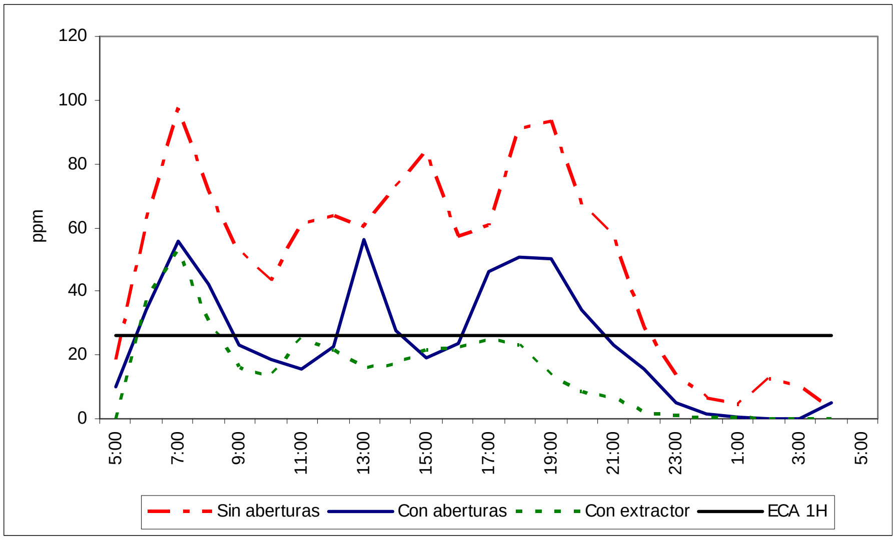


*Figure 7. Average CO hourly concentration by type of venting on kitchen roofs*



## 2.3 Results: Post-Intervention

Post-intervention monitoring took place in 44 households (of the original 48 monitored). Further, the baseline $PM_4$ data for 2 of the households were discarded from the analysis due to sampling issues. Thus, the $PM_4$ database with complete same-kitchen pre- and post-intervention information includes 42 households (**see Table 4**).

Analysis of the changes in indoor pollutant concentrations reveals a significant reduction in $PM_4$ and CO levels following the installation of the Inkawasina stoves (and the associated awareness raising and training of promoters and cooks), coming close to the project goal of 80% reduction on average.

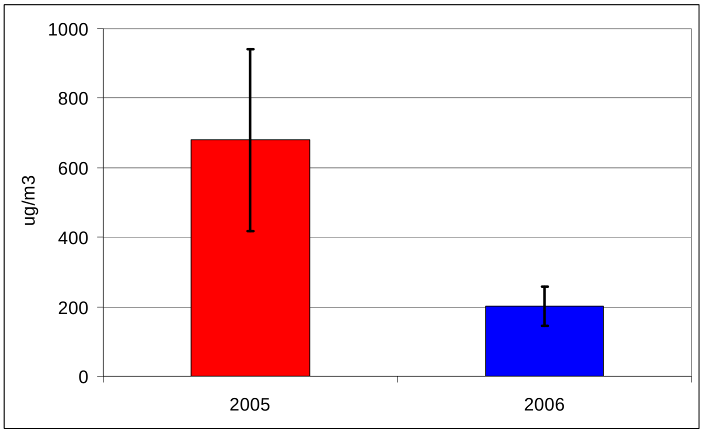
In 71% of the monitored households (30 kitchens), a reduction in $PM_4$ concentration was recorded. Curiously, no change or a slight increase in particulates was detected in 12 households. For all 42 kitchens, the average $PM_4$ concentration fell by 70% (**see Figure 8)**, while an analysis of just the 30 houses with reduced $PM_4$ levels showed a much greater average reduction of 84%, indicating the potential for the intervention to surpass the project goals.

***Table 4. $PM_4$ monitoring results***

| **Community** | **# of homes sampled*** | | **Average 24h ± SD[3] (μg/m³)** | | **% kitchens above 65 μg/m³** | |
|---|---|---|---|---|---|---|
| ***Monitoring*** | ***2005*** | ***2006*** | ***2005*** | ***2006*** | ***2005*** | ***2006*** |
| Uyurpampa | 18 | 18 | 568<br>± 656 | 219<br>± 231 | 94% | 56% |
| Amusuy[4] | 6 | 6 | 139<br>± 83 | 313<br>± 177 | 67% | 83% |
| Tungula | 10 | 10 | 944<br>± 989 | 119<br>± 129 | 100% | 60% |
| Wasicaq | 8 | 8 | 1006<br>± 1206 | 180<br>± 123 | 100% | 88% |
| **Total** | **42** | **42** | **680± 868** | **201± 189** | **93%** | **69%** |

* The number of homes considered for analysis represents those for which there was complete information for the two samplings (2005 and 2006).

***Figure 8. Average 24-hour $PM_4$ concentration and confidence intervals before (2005) and after (2006) installing improved stoves (n=42)***



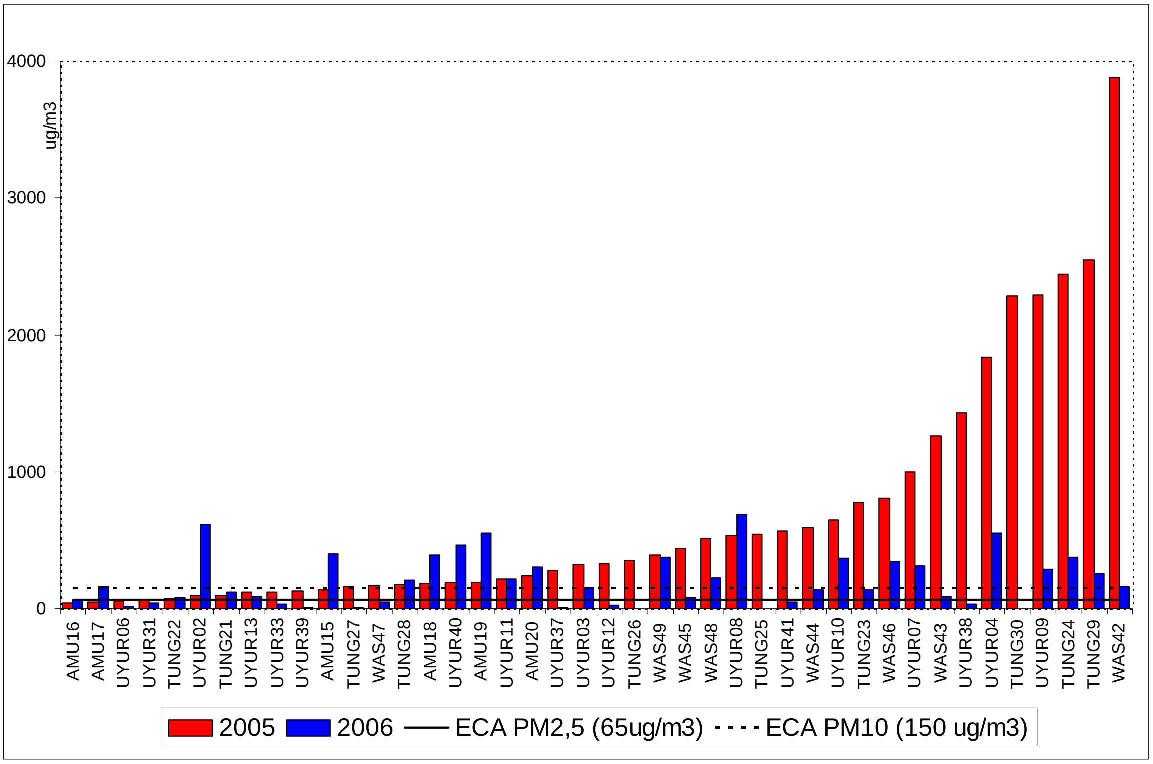
---

[3] SD = Standard deviation

[4] All values reported at Amusuy during post-intervention are greater than pre-intervention values. The reason is still unexplained.

The difference between the maximum $PM_4$ concentrations recorded before and after the intervention is significant. While the maximum recorded value in the baseline sampling was 3,880 $\mu g/m^3$, the maximum recorded value post-intervention was 688 $\mu g/m^3$ (**see Figure 9)**. This last value was for a stove (in UYUR02) where the pot is smaller than the stove's hole, leaving some room for smoke to escape into the kitchen. Even so, the maximum post-intervention value is up to five times lower than that recorded in the baseline.

***Figure 9. 24h $PM_4$ concentration at $\mu g/m^3$ before (2005) and after (2006) installing improved stoves***

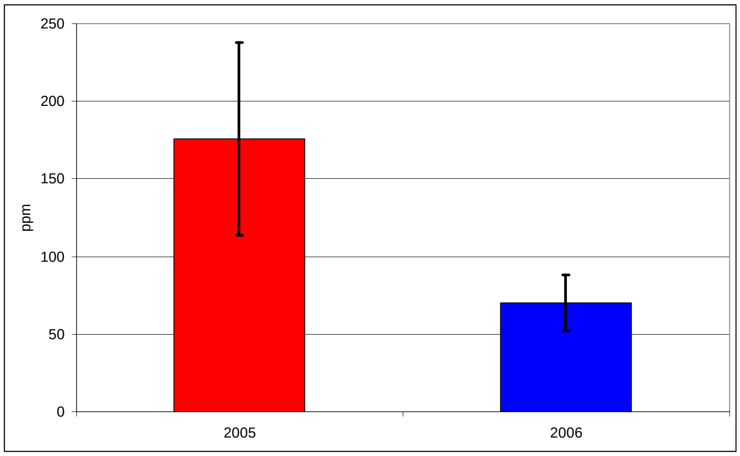


Reductions achieved in the carbon monoxide monitoring tests were similar to $PM_4$, with CO levels dropping by 71% on average. Including all 42 houses, the average maximum 1-hour value was reduced by 60% after installing the improved stoves (**see Figure 10**). Including only those homes where the CO concentration is reduced (n=30), the reduction was 76%. CO monitoring results are further detailed in **Table 5**.

*Table 5. CO monitoring results (average of maximum hourly values)*

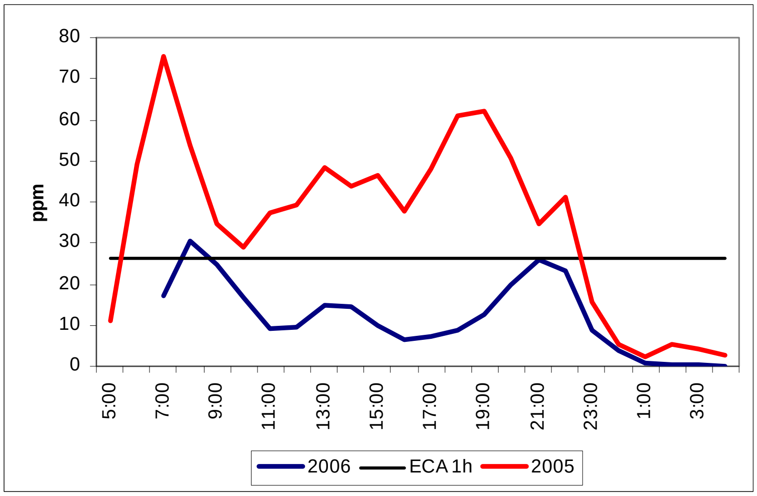
| **Community** | **# of homes sampled** | | **Maximum 1h average (ppm)** | | **Maximum 8h average (ppm)** | | **Kitchens above 1h EAQ (26.2 ppm)** | | **Kitchens above 8h EAQ (8.7 ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2005** | **2006** | **2005** | **2006** | **2005** | **2006** | **2005** | **2006** | **2005** | **2006** |
| Uyurpampa | 18 | 18 | 195 ± 260 | 80 ± 73 | 72 ± 88 | 25 ± 16 | 16 | 16 | 17 | 16 |
| Amusuy | 6 | 6 | 67 ± 41 | 82 ± 63 | 28 ± 16 | 30 ± 25 | 5 | 4 | 5 | 5 |
| Tungula | 10 | 10 | 203 ± 200 | 55 ± 51 | 96 ± 117 | 17 ± 12 | 10 | 7 | 10 | 7 |
| Wasicaq | 8 | 8 | 179 ± 135 | 58 ± 32 | 86 ± 65 | 22 ± 12 | 8 | 7 | 8 | 7 |
| **Total** | **42** | **42** | **176 ± 70** | **70 ± 60** | **74 ± 86** | **23 ± 16** | **39 (93%)** | **34 (80%)** | **40 (95%)** | **35 (83%)** |

*Figure 10. Average one-hour CO values and confidence intervals before (2005) and after (2006) installing improved stoves (n=42)*



By averaging the hourly results of all the kitchens, it can be seen that the CO concentration shows a pattern that can be associated to the meal cooking practices, and the highest peak of the day corresponds to the cooking time of the first meal of the day. Before implementing improved stoves, during the daytime (from 6:00 until 22:00 hours), the hourly CO concentration was found to be over the 1-hour EAQ value of 26.2 ppm (**see Figure 11**). Stove implementation made it possible to lower the day-long hourly averages below the EAQ standard, except for the morning peak.

*Figure 11. Average hourly CO concentration in sampled kitchens*



***August 2007 sampling***

The August 2007 follow-up sampling was conducted in 32 homes where the improved stove implemented in the project is still being used. In the 10 homes where it was reported that the stove installed in 2006 was no longer being used, no sampling was performed (**see Table 6**). With the exception of two homes, the rooms in which the stoves were installed and that were sampled in the last campaign are the same rooms sampled in 2006.

*Table 6. Homes excluded from the 2007 sampling and reasons reported*

| Community | Code | Reason |
|---|---|---|
| Uyurpampa | UYUR06 | The improved stove has been dismantled. |
| | UYUR09 | |
| | UYUR13 | |
| | UYUR38 | The improved stove is in poor condition and the homemaker didn't allow access to the staff to do the sampling. |
| Amusuy | AMU15 | The improved stove has been dismantled. |
| | AMU16 | |
| | AMU19 | |
| Wasicaq | WAS45 | The improved stove is in poor condition and no longer being used. |
| | WAS46 | |
| | WAS49 | The homemaker indicated she is no longer a beneficiary and therefore denied access to the staff to do the sampling. |

In general, the results of the 2007 sampling, which took place a year after the improved stove implementation, showed that on average the indoor air pollution in the cooking environments has increased when compared to the 2006 sampling conducted a few weeks after the stoves were installed.

Based on the comments included in the survey by the interviewer, some factors have been identified as possible causes of the increase in tested pollutant concentrations. For instance, it was reported that six stoves had elbows that were in poor condition, in another six stoves the pots used did not fully cover the boilerplates, while in another six homes the users said that the fire burned all day long. In three other homes the users indicated that the stove gave off too much smoke. These factors have been taken into account to conduct the $PM_4$ and CO analyses (see the ***Analysis*** section).

As detailed in **Table 7** below, the overall average $PM_4$ particulate concentration for the 32 homes is 781 µg/$m^3$, a value that slightly exceeds the average pre-intervention sampling but doesn't show a significant difference. This value is very similar to the pollution levels measured in the baseline study, since the 2006 measurements, taken a few weeks after implementing the kitchens, were significantly lower. Of 32 homes sampled, six have concentrations higher than 1,000 µg/$m^3$ and the maximum recorded value is 6,978 µg/$m^3$ (UYUR08). This was the same home that had the highest $PM_4$ value in 2006 (688 µg/$m^3$).

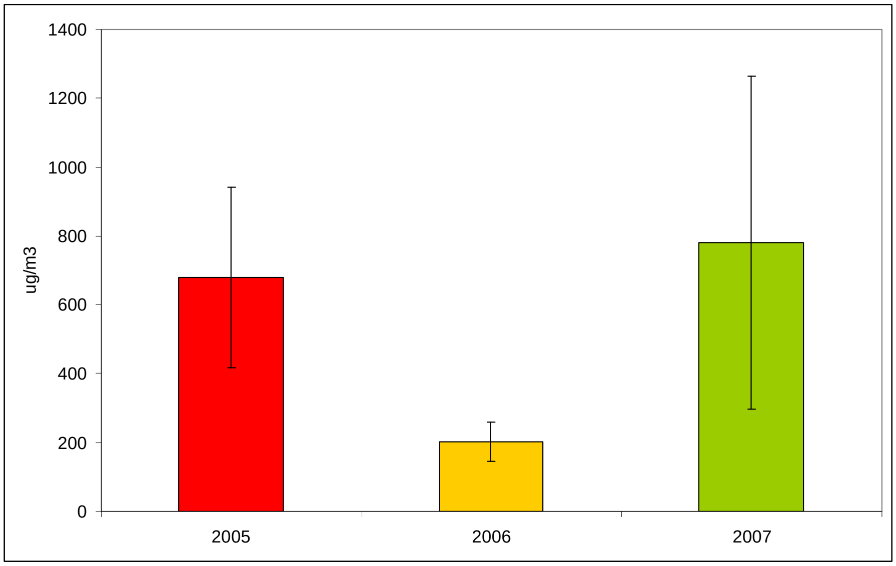
***Table 7. $PM_4$ concentration results summary***

| **Indicators** | **2005** | **2006** | **2007** |
|---|---|---|---|
| No. of houses sampled | 42 | 42 | 32 |
| 24h average ± SD | 679 ± 868 | 201 ± 189 | 781 ± 1.394 |
| Maximum recorded concentration (µg/$m^3$) | 3,880 | 688 | 6,978 |
| Minimum recorded concentration (µg/$m^3$) | 44 | < 3[5] | 11 |
| Kitchens over 65 µg/$m^3$ | 39<br>(93%) | 28<br>(67%) | 29<br>(91%) |

---

[5] < 3 µg/$m^3$ (reported concentration lower than the method's detection threshold)

*Figure 12. Average 24-hour concentrations of $PM_4$ particulate matter for the 2005 (n=42), 2006 (n=42) and 2007 (n=32) samplings and confidence intervals*



**Figures 12-14** detail the $PM_4$ concentrations for the three sampling periods. In **Table 8 below, a** comparative analysis of the three samplings considering the specific changes recorded house by house shows that between 2005 (pre-intervention) and 2006 (post-intervention – first sampling), $PM_4$ concentrations went down by 81% in the homes targeted in the intervention. In August 2007, a year after installing the stoves (post-intervention – second sampling), the percentage of homes that maintain a reduction compared to the baseline (2005) goes down to 50%. Half of the homes showing reduced $PM_4$ concentrations had an average reduction of 733 µg/m$^3$ and the maximum reduction was 2,638 µg/m$^3$ (**see Figure 15**). Likewise, 50% of the homes showing increased $PM_4$ concentrations had an average increase of 157 µg/m$^3$ and the maximum increase was 6,441 µg/m$^3$.

*Table 8. Number of homes showing increased or reduced concentrations of $PM_4$ particulate matter and average magnitude of change*

| **Period** | **Parameter** | **Number of homes** | **Magnitude in µg/m$^3$ (difference) Average ± SD** |
|---|---|---|---|
| 2005-2007 | $PM_4$ concentration reduction | 16 (50%) | 733 ± 865 |
| | $PM_4$ concentration increase | 16 (50%) | 880 ± 1602 |
| 2005-2006 | $PM_4$ concentration reduction | 23 (72%) | 775 ± 953 |
| | $PM_4$ concentration increase | 9 (18%) | 157 ± 163 |
| 2006-2007 | $PM_4$ concentration reduction | 6 (19%) | 166 ± 195 |
| | $PM_4$ concentration increase | 26 (81%) | 760 ± 1363 |

***Figure 13. 24-hour $PM_4$ concentration in the 18 homes with reduced concentrations between 2005 and 2007***

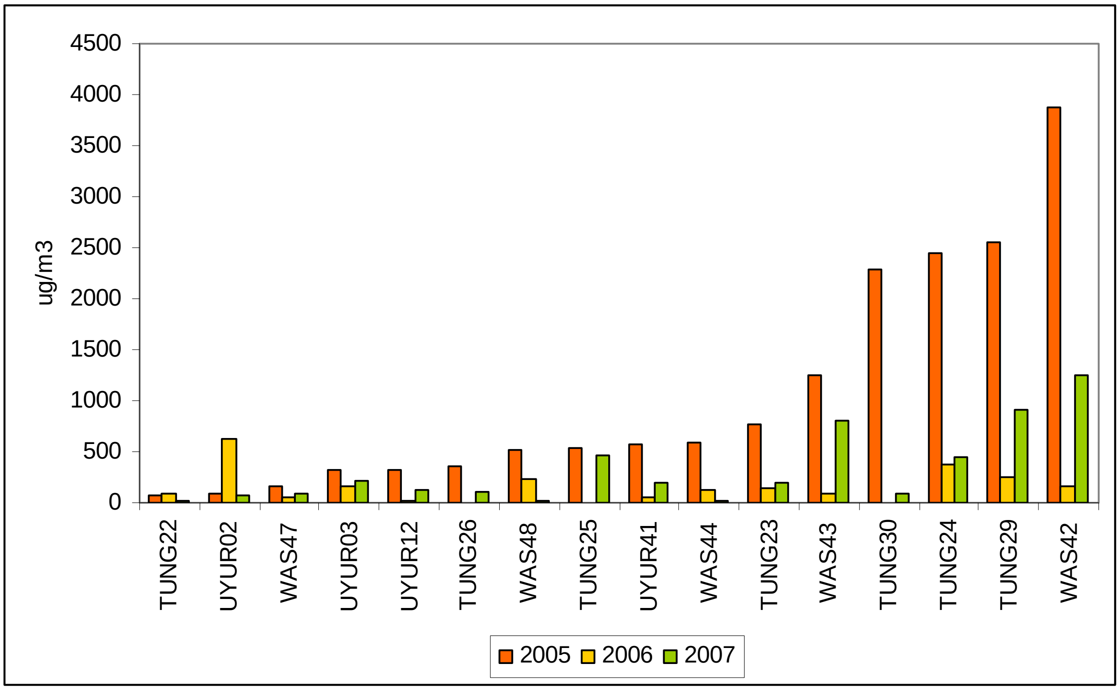


***Figure 14. 24-hour $PM_4$ concentration in the 16 homes with increased concentrations between 2005 and 2007***

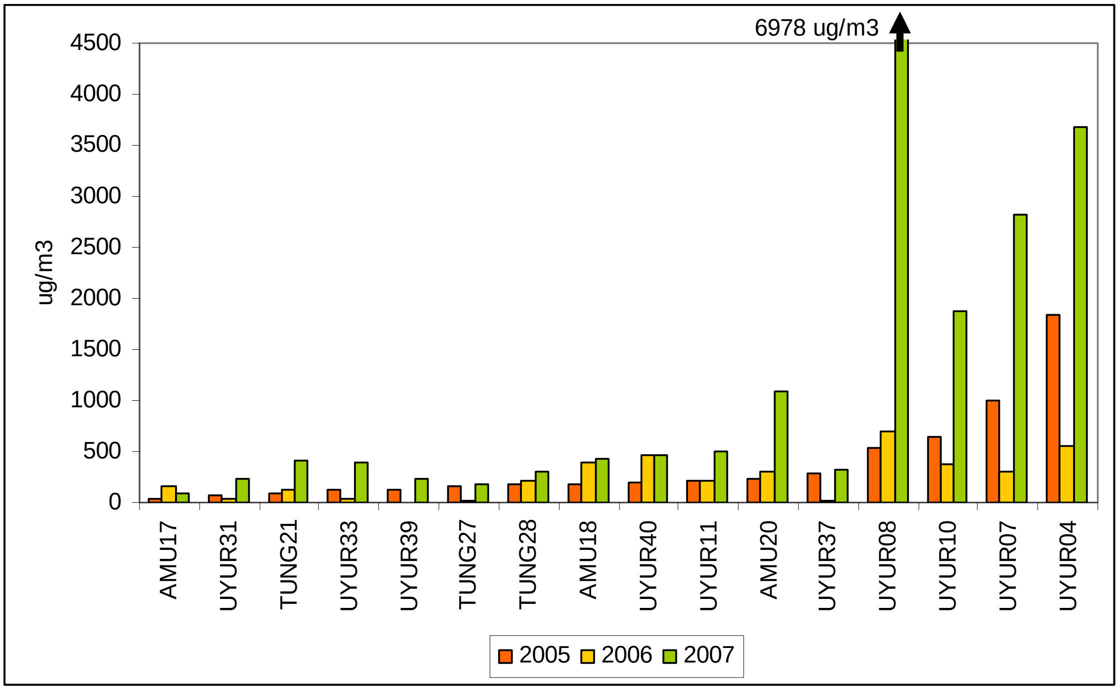
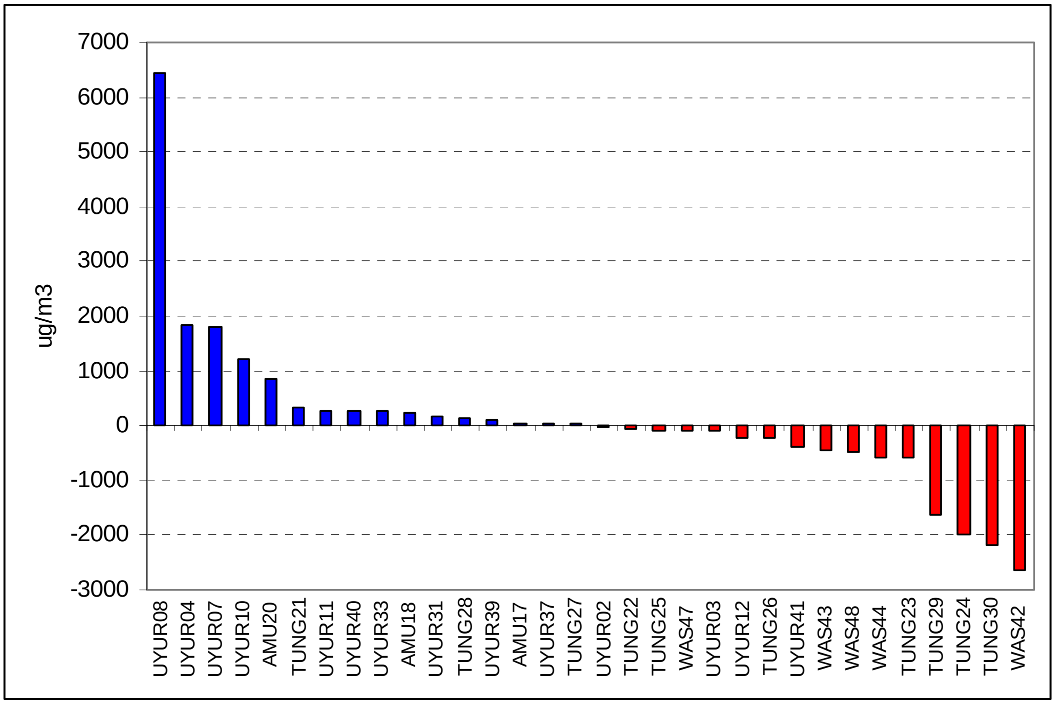


***Figure 15. 24-hour $PM_4$ concentration variation measured in each home between 2005 and 2007 (positive values: increases, negative values: reductions)***



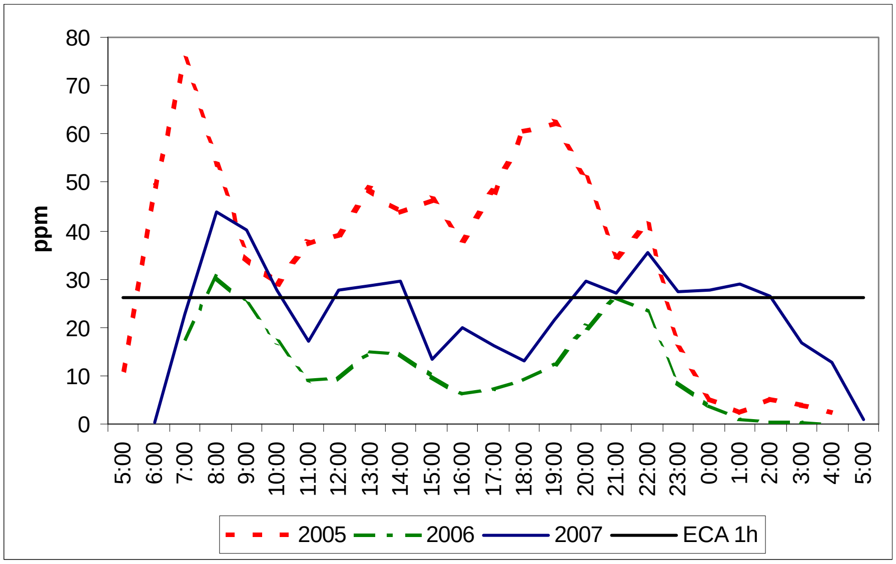
It should be noted that high variability results combined with the fact that the results in each sampled home only reflect the conditions of a day's activity in the kitchen, complicate the interpretation of home-to-home variation comparisons.

Carbon monoxide (CO) results (**see Table 9**) show daily concentrations greater than those recorded in the 2006 sampling, but lower than pre-intervention sampling levels. The three high concentration peaks, which match cooking periods, exceed the 1-hour EAQ limit.

***Table 9. CO concentration results summary***

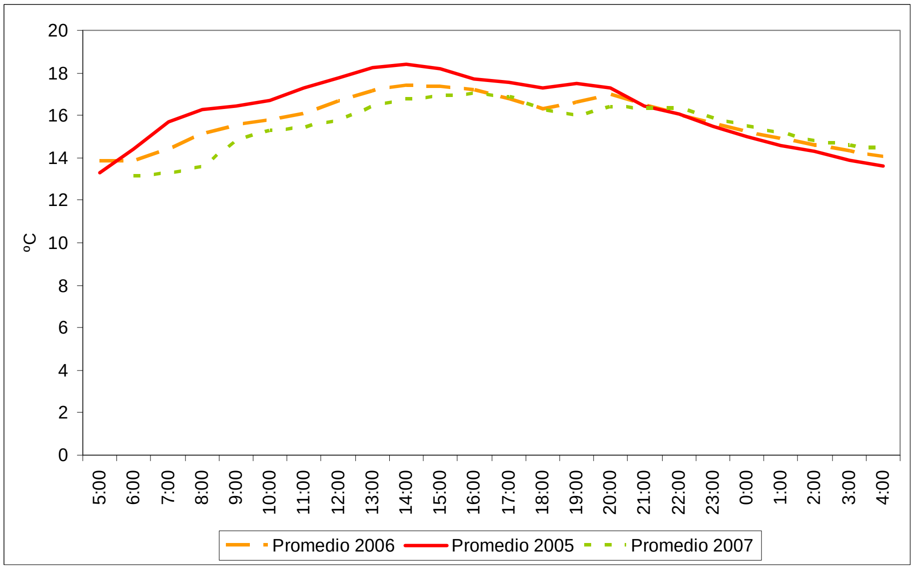
| **Indicators** | **2005** | **2006** | **2007** |
|---|---|---|---|
| # of homes sampled | 42 | 42 | 32 |
| 1-hour maximum average (ppm) | 176 ± 70 | 70 ± 60 | 147 ± 158 |
| 8-hour maximum average (ppm) | 74 ± 86 | 23 ± 16 | 57 ± 99 |
| Kitchens over 1-hour EAQ | 39<br>(93%) | 34<br>(80%) | 28<br>(88%) |
| Kitchens over 8-hour EAQ | 40<br>(95%) | 35<br>(83%) | 28<br>(88%) |

***Figure 16. Daily behavior of hourly CO concentration for 2005 (n=42), 2006 (n=42) and 2007 (n=32) samplings***



The results of temperature measurements in the kitchen show that installing improved stoves slightly reduces the average daytime temperature (**see Figure 17**). Between 5:00 A.M. and 8:00 P.M., the temperature in improved stove environments is one to two degrees Celsius lower than in cooking areas with traditional stoves. After 9:00 P.M., temperatures behave similarly. However, it should be noted that house temperatures are also influenced by external factors, such as ambient temperature. Since the samplings took place in different months in the three years, this seasonal change pattern could be causing some of these variations.

***Figure 17. Average temperature in the kitchen before (2005 average) and after (2006 average and 2007 average) installing improved stoves ($n_{2005,\ 2006}$=42; $n_{2007}$=32)***



### *User satisfaction*

The 2007 survey included questions about user satisfaction and their perception of the benefits of using the stoves (see Annex V). In 100% of the monitored homes (N=32) the interviewees said they are happy with the improved stove. All the users have seen a reduction in smoke with the improved stoves when compared to three-stone stoves and are using less firewood (100% said firewood use has gone down by more than 33% with the improved stove and 59% of them said firewood use has gone down by more than 50%).

It should also be noted that in addition to answers in the survey to specific questions about satisfaction with the stove and smoke reduction, the person in charge of monitoring added user comments. In at least three cases (UYUR12, TUNG25, and UYUR40), the women said their stoves gave off smoke.

## 2.4 Analysis of Results

### *Air quality monitoring*

While it was expected that the results of $PM_4$ and CO concentrations would be further reduced when compared to the 2006 sampling, under the assumption that a year after the improved stoves were implemented the users would be used to them and would have optimized their use, the 2007 results show that the values have gone up. Even though the data are highly variable and show some significantly high concentrations, low concentrations have also been found. In general, $PM_4$ levels are similar to those found during the baseline sampling (2005).

While there isn't a single variable that explains these results, the user answers and the interviewer remarks show some indication of the possible reasons behind this finding:

1. Stove elbows are in poor condition: In at least six of the homes surveyed, the users said that the elbow was broken or in poor condition. Since no specific question was included about the elbow, it can't be determined whether the rest of the stove elbows were working properly.

2. The fire burns all day long: In three homes the users stated that the fire is kept burning all day long to prevent the process of firing up the stove every time lunch or dinner needs to be cooked. At night, the environment is closed off and the fire keeps burning until all the remaining firewood is consumed. This is the only indicator that could explain the extremely high values in UYUR08.

3. The pots don't completely cover the burners: In six homes, it is reported that the pots being used fail to completely cover the burner hole.

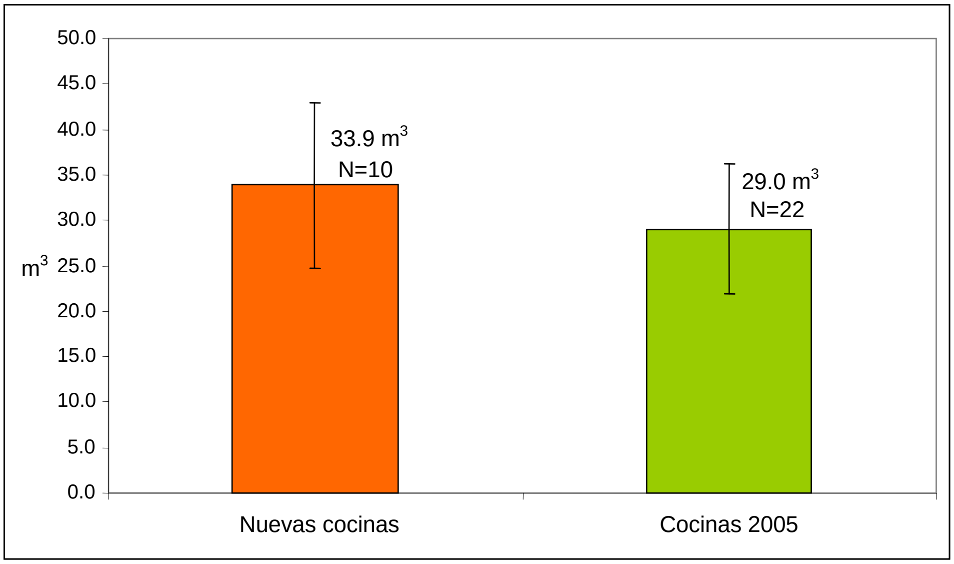
4. Use factors: There could be factors that haven't been included in the survey, such as failure to clean the inside of the stove or the chimney. After a year's use, if stove parts are not maintained, the conditions could be such that the gas exhaust is being blocked off.

It should be noted that the homes where air quality was sampled were the first ones to receive improved stoves. Thus, it's very likely that the elbows weren't in top-notch condition, since they were the first elbows to be fabricated in a place far from the intervention site. Furthermore, apparently promoters who implemented the stoves didn't have all the visuals needed to properly teach users how to use and maintain the stoves when these first stoves were installed.

Other factors that may influence pollutant concentration in homes, such as the size of the room, the number of doors and windows, the time used for cooking food, and the moisture content of the firewood used, have been considered in the survey. The results obtained do not fully explain variations in the measured concentrations. In general, the following parameters were evaluated:

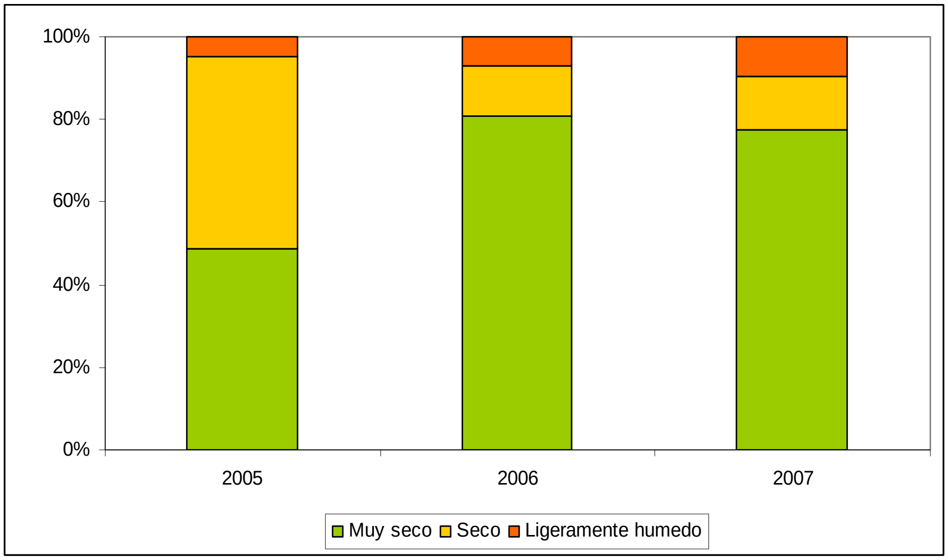
1. Room size: While the 2005 and 2006 measurements weren't accurate enough, in 2007 these measurements were taken carefully, and this gave a more accurate value of each room's size. Since some kitchens were relocated from the sites identified during the 2005 monitoring to build the improved stoves, data were separated into rooms that stayed in the same location as the originally sampled room and rooms that were relocated due to the improved stove. The average in the new rooms is slightly higher than that of the original rooms, even though the differences were not significant (**see Figure 18**). Even so, if this trend is correct, the increased volume in the room should result in a reduction of measured pollutant concentrations.

***Figure 18. Size of original kitchens and size of new kitchens used to install the improved stove***



Firewood moisture content: In the three years, surveys indicate that in more than 90% of the homes dry or very dry firewood was used for cooking (**see Figure 19**). The use of slightly moist firewood was reported in two homes in 2005 and in three homes in 2006 and 2007.

***Figure 19. Moisture content of firewood used for cooking: Percentage of homes using very dry, dry and slightly moist firewood ($N_{2005}$=42, $N_{2006}$=42, $N_{2007}$=32)***



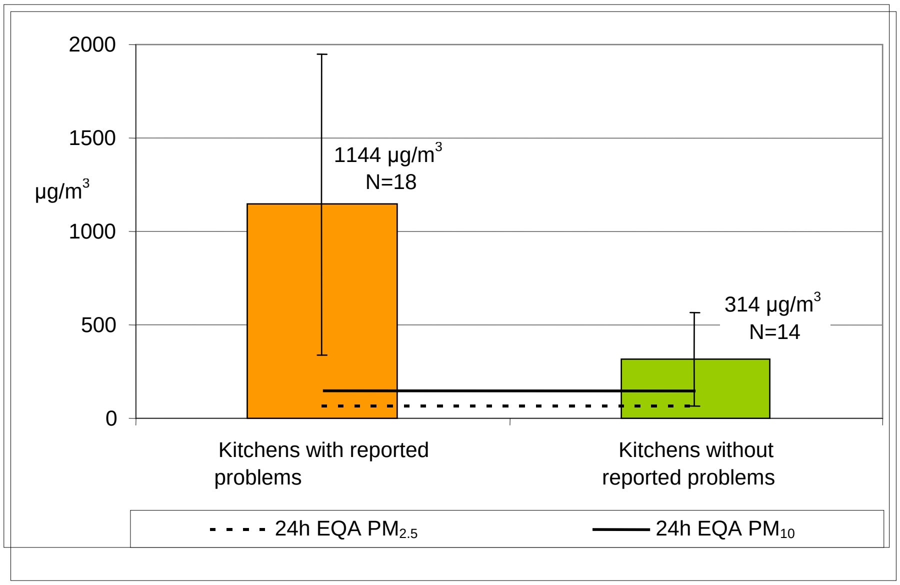
For these reasons, the data from the 2007 sampling were separated into two groups. The homes where one of the above factors had been reported (elbows in poor condition, fire burning between meals, a smoking stove or pots that don't completely cover the burner) were identified. This group was compared to the group of remaining kitchens, where the stoves apparently had not had any problems. In all, 18 homes were identified where one or more of these problems had been reported (**see Table 10**) while the remaining 14 didn't report any issues.

***Table 10. Homes reporting a problem with the stove***

| Problem observed | Number of homes | Codes |
|---|---|---|
| Elbows in poor condition or broken | 6 | UYUR03, AMU17, AMU18, AMU20, UYUR31, WAS47 |
| The fire keeps burning all day long | 6 | UYUR04, UYUR08, TUNG21, UYUR40, WAS42, WAS43 |
| The users indicate that the stove gives off smoke | 3 | UYUR12, TUNG25, UYUR40 |
| The pot doesn't completely cover the burner | 6 | TUNG23, TUNG29, UYUR33, WAS42, WAS43, WAS47 |

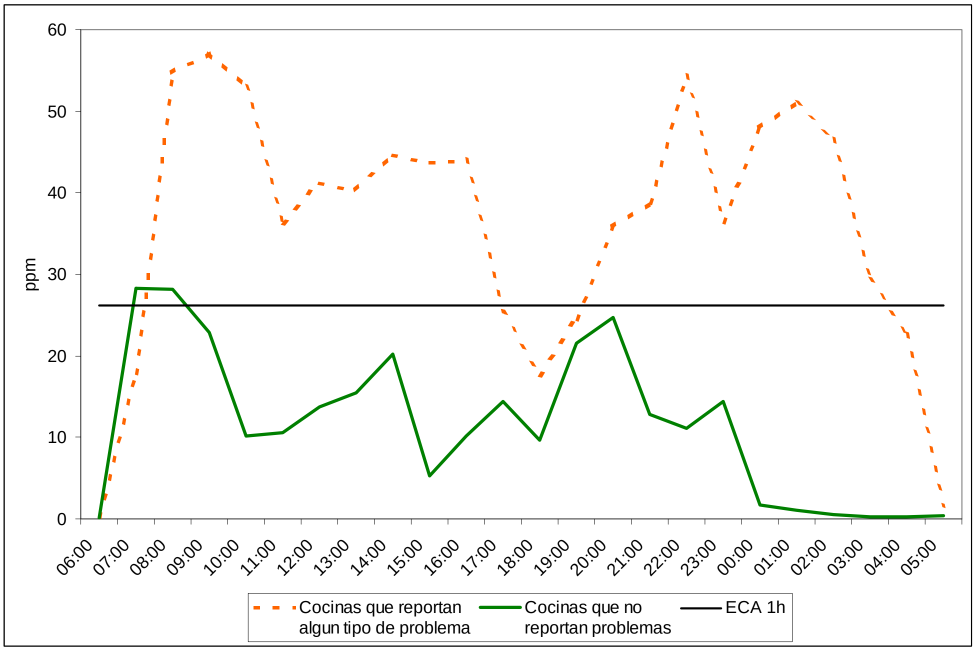
Results show that the average particulate concentration in the group that had some type of problem was more than three times the average in homes without reported problems (**see Figure 20**). Of the 14 homes where no problems were reported with the stove, only three (21%) are below the EAQ $PM_{2.5}$ standard.

*Figure 20. Average 24-hour concentration of $PM_4$ particulate matter in homes where some kind of stove problem was reported vs. those where no problems were reported (2007)*



With the same criterion, a comparative analysis was conducted of the CO hourly data, and a difference was found between homes with and without reported issues. In the second case, the average hourly behavior during the day is found to be below the 1-hour EAQ CO level, except for a morning peak, which exceeds it slightly (**see Figure 21**).

*Figure 21. Daily behavior of hourly CO concentration in homes where some kind of stove problem was reported vs. those where no problems were reported (2007)*

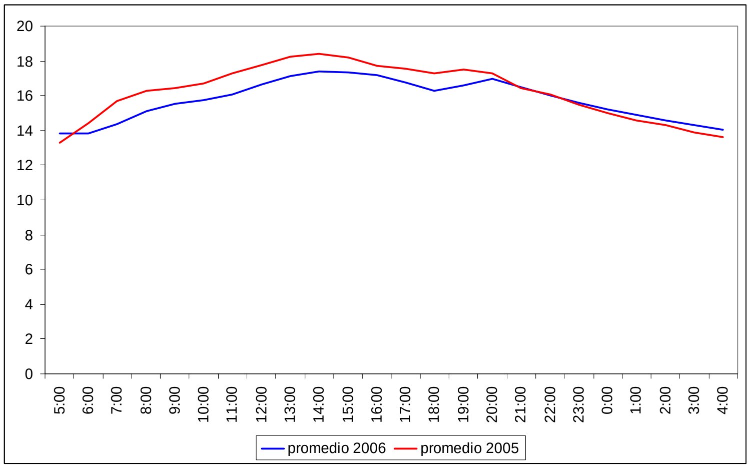


The results of temperature measurements in the kitchen show that while installing improved stoves slightly reduces the average, this reduction is not significant. This is important because of the cold climate; it is important that the stoves continue to generate some heat.

### *Observations*

The Winrock team was quite pleased with the overall reduction in indoor pollutants in the household sample. However, because no change or even an increase in smoke levels was detected in 12 households, Winrock, Centro ECO, and Swisscontact shared field notes and made visits to these households to seek any obvious explanations of this unexpected result. Several observations were made of both structural and behavioral factors that may have contributed to zero smoke reduction or an increase in smoke levels. Structural factors included a chimney that was constructed too short, such that exiting smoke was able to re-enter the kitchen. Behavioral factors included leaving one pot hole open while cooking; using damp leaves as fuel; and cooking over an open fire immediately outside the kitchen door, during a day of celebration. Centro ECO conducted follow-up visits to address both types of factors. Because of these observations and due to the fact that many families had only had their stoves for a matter of weeks, Swisscontact conducted the third round of monitoring in July 2007 to verify pollution changes after a more substantial adjustment period.

***Figure 22. Average temperature in the kitchen before (2005) and after (2006) installing improved stoves (n=42)***



### *Exposure patterns*

The exposure of women and young children to indoor air pollution was included in the survey through questions about the amount of time they spent in the kitchen while the fire was burning. This section of the survey was repeated in the three years assessed (see Peru IAP Report Annex V, section H15).

The results show that the women stay in the room used as a kitchen while the fire is burning[6] anywhere from 3 hours and 20 minutes to 4 hours on average[7] during the day. The time required to cook each meal (breakfast, lunch and supper) ranges from 1 hour to 1 ½ hours on average. The 2007 results show a slight reduction in women's exposure times, with an average of 2 hours and 51 minutes (**see Table 11**).

It is worth noting that when these results are compared to the answers to the question about cooking times in the monitoring survey (see Peru IAP Report Annex V, Section G), the averages for the three years are very similar. According to these figures, and assuming that the women are in the kitchen the entire time it takes to cook the food, exposure times would be approximately 4 hours.

***Table 11. Average exposure time for women and children in kitchens and time it takes to prepare meals (Values represent total time in one day)***

| **Periods evaluated (hours and minutes)** | **2005** | **2006** | **2007** |
|---|---|---|---|
| Exposure of woman to fire burning | 3:18 | 3:23 | 2:51 |
| Exposure of child to fire burning | 2:11 | 1:58 | 1:48 |
| Total food preparation time | 4:00 | 3:38 | 3:49 |

In the case of young children, in 2005 the average time spent in the kitchen while the fire was burning was 2 hours and 11 minutes; the shortest time recorded was 15 minutes and the longest time was 6 ½ hours. This value was slightly reduced in the next two samplings, after the installation of improved stoves.

**Figures 23-28 on the next page** show exposure patterns during the day both for women and children.

---

[6] The survey only assesses the number of hours spent by women or young children in the kitchen while the fire was burning. It does not include the number of hours the fire was not burning or the exposure of other people (for example, people eating during meal times).

[7] The survey included a question about exposure and a question about the time it took to cook the meal. Both are taken as exposure indicators. In both cases, actual exposure is not reflected, since no information is included about the additional time women may have spent in the kitchen (eating, cleaning up, etc.).

***Figures 23 – 28. Women (left) and children (right) exposure patterns vs. average hourly CO concentration in 2005 (n=42), 2006 (n=42), and 2007 (n=32)***

***Figure 23 – Women 2005***

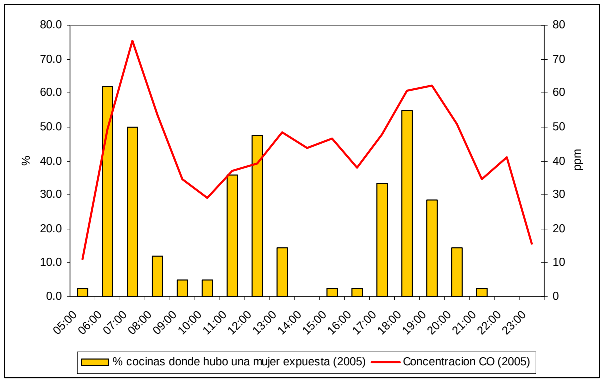


***Figure 24 – Children 2005***

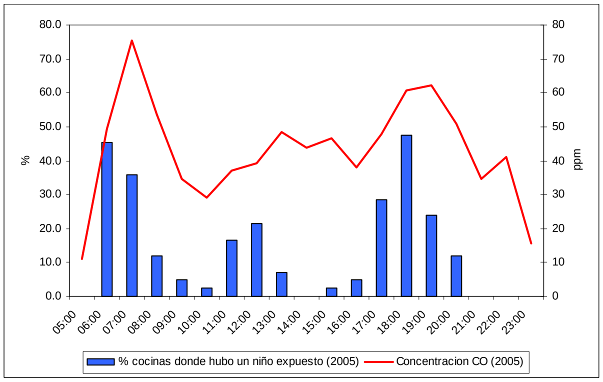


***Figure 25 – Women 2006***

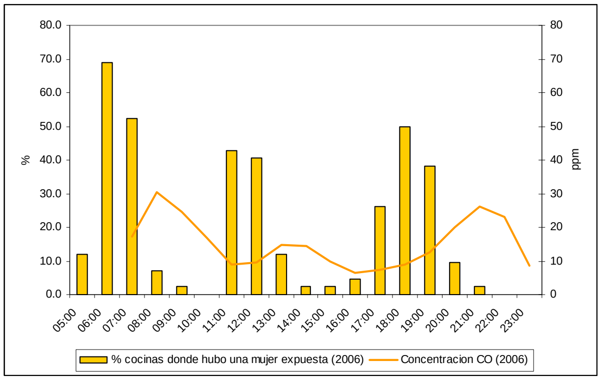


***Figure 26 –Children 2006***

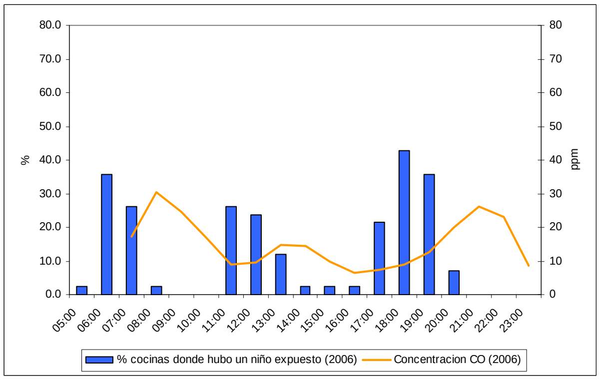


***Figure  27 – Women 2007***

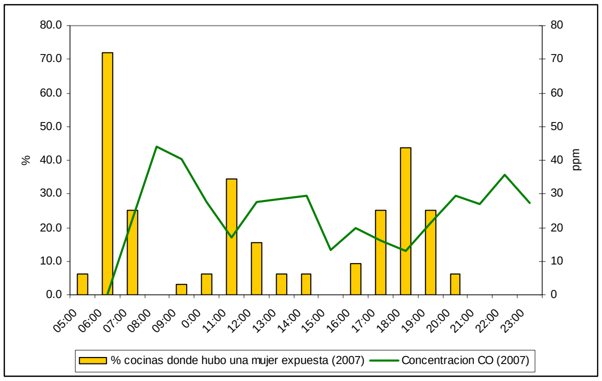
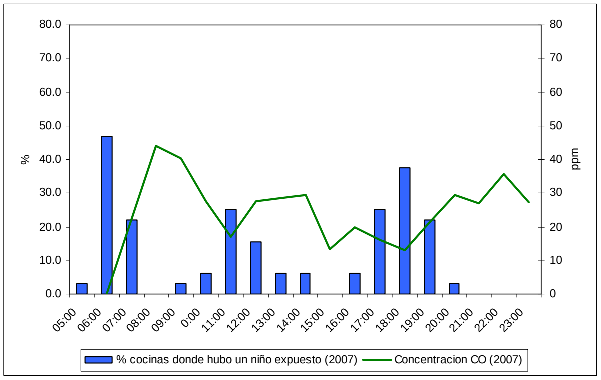


***Figure 28 – Children 2007***



Interestingly, the installation of the improved stoves appears to not have significantly reduced the time used to cook, or altered exposure patterns. It is important to note, however, that the actual CO concentrations that the women and children are exposed to are significantly lower.

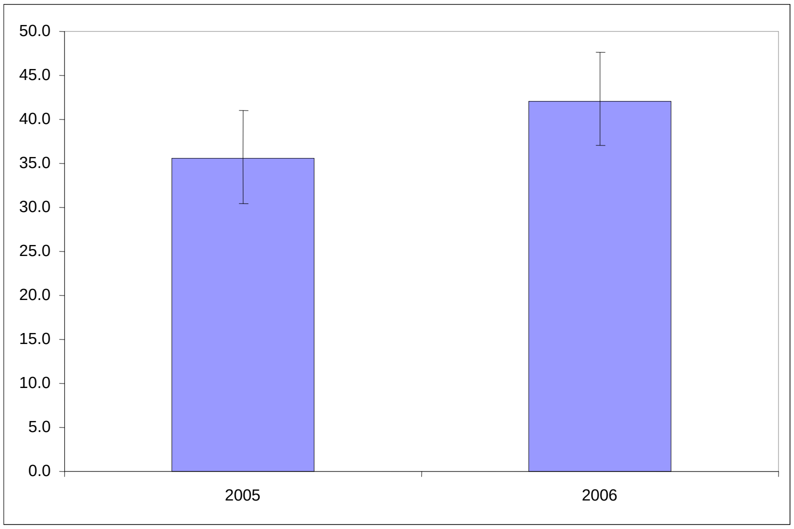
### *Additional relevant information*

To supplement the air quality monitoring, surveys were conducted in the homes monitored, in order to learn about the activities performed by the families while pollutants were being measured in their homes. Information was also collected about the houses' infrastructure.

The average area of the monitored kitchens is 12 $m^2$ (129 $ft^2$). The kitchens sampled are mostly adobe constructions (47 of 48), except for one that has wooden stick walls. They have dirt floors and the roofs are a conglomerate of reed, clay, and plastic, as well as steel and wood sheets. The number of members per household ranges from 4 to 8 people, typically consuming coffee and a high-carbohydrate diet (potato soup, thin noodles and stews, roasted corn, parboiled tubercles, and wheat tortillas), which requires a cooking time of 1 to 2 hours.

In 26 of the 42 houses surveyed, the location of the room used as the kitchen was modified to install the improved stove, responding to an interest by the users to change both the stove and the cooking area. In 2005, the average volume of the monitored kitchens was 35.5 $m^3$ (1,236 $ft^3$). By 2006, there was a slight increase to 42.1 $m^3$ (1,486.7 $ft^3$), as can be seen in **Figure 29**. As shown, this increase is not very quantitatively significant, but the modification included, in some cases, an increase in the number of windows per kitchen and the width of the windows. It is worth noting that this point was not further explored as it wasn't considered a factor to be changed in the intervention population, and therefore the relationship between this parameter and the reduced concentrations of $PM_4$ and CO has not been looked into.

*Figure 29. Average volume variation in monitored houses, in $m^3$*



### *III. Component 3: Evaluating health symptoms and lung function*
***Person responsible: Dr. Jay C. Smith, M.D., M.P.H.***

In August 2005, data were collected about adult respiratory health in a sample of houses for the project's baseline. With the help of a nurse who translated from Spanish into Quechua, Dr. Smith conducted breathing tests in 78 individuals of 44 separate households in 3 villages and applied questionnaires about lung symptoms and diseases among those who cooked at home (64 people). These tests were carried out in the same homes where indoor air quality was monitored. Spirometric breathing tests were completed in 74 individuals, for interpretation purposes. Findings were anticipated as to the degree of symptoms and breathing obstruction comparable to what would happen if those evaluated had been smoking for years, even though none of the subjects smokes tobacco on a regular basis (none of the 40 women smokes and only a few of the 34 men smoke occasionally). With these data, the goal was to be able to show significant changes after a year of reduced smoke exposure after installing the improved stoves. Results of the health assessments are included in Peru IAP Report Annex VI.

Airway obstruction while breathing out (spirometric evaluation) is the standard measurement of destruction and inflammation caused by smoking. Expiratory capacity during the first second of strong exhalation in young, healthy lungs is typically greater than 85% of the total forced capacity. This number decreases with age and decreases faster in smokers than in non-smokers. Previous research has shown that the decrease is more significant in women exposed only to indoor air pollution as a result of cooking with biomass. However, this research shows that for the first year after quitting smoking, the reduction not only stops, but is slightly reversed. The comparable effects as a cause of obstructive pulmonary disease suggest that this effect must also be seen in a non-smoker population with biomass smoke exposure as a result of cooking.

Spirometric tests found a wide range of results, as is to be expected in a population with varying ages (and a different number of years of exposure to indoor smoke). The youngest person had a FEV1% (forced expiratory volume in 1 second as a % of the total volume exhaled in 1 breath) of 93.5%. Among the other subjects, 8 had an FEV1% lower than 70%. This is part of a clinical definition of a chronic obstructive pulmonary disease (COPD). Another 27 had a lesser degree of obstruction, indicated by a FEV1% greater than 70% but lower than 80%. The average result for half of the elderly people evaluated was less than 75%. If the hypothesis that installing the improved cookstoves can reduce and partially revert COPD is true, then an improvement in the average FEV1% should be observed one year after initial replacement of the open-fire stove. Furthermore, this may correlate to the degree of indoor air quality improvement reached, even if the numbers are too low to reach statistical significance for each subgroup analysis.

The findings in the breathing symptoms and diseases questionnaire could be a little more difficult to interpret with regards to the anticipated improvements. The baseline data don't show a trend of the worst symptoms in those with the worst breathing evaluation results (17 people fit the definition, in the case of chronic bronchitis; and their average FEV1% results were virtually identical to those of the total sample). There are several potential explanations for this, including a conscious or unconscious competition among participants in spirometry testing. In any case, the elevated prevalence of chronic productive cough

(86% of the cooks) was obtained as expected. Improvements in this area can result in a helpful rate of quality of life changes.

## *IV. Conclusions*

Implementing improved stoves in Inkahuasi kitchens significantly reduced indoor air pollution levels both for $PM_4$ and CO during the first weeks post-intervention (2005 vs. 2006). Pollution levels have been reduced by approximately 70% in sampled kitchens for both pollutants.

The results obtained a year after implementing the stoves don't show the same gains seen in the first weeks. The average $PM_4$ and CO values increased when compared to the values obtained a few weeks after installing the stoves, reaching levels similar to those recorded prior to installing the improved stoves. Even so, pollution levels were reduced in 50% of the sampled homes.

Factors that could be causing a greater amount of indoor emissions could include damaged stove elbows, pots that don't completely cover the burner hole, and the local custom of letting the fire burn all day long. Other factors, such as poor stove maintenance or upkeep, cannot be ruled out as they could be causing blockages in the chimney. Faulty stove construction could also be a factor. All of these factors, both about the quality of the elbows and the ability of the users to properly maintain the stoves, could be due to the fact that these were the first homes in the intervention, which causes them to show "learning-curve" issues inherent to the beginning of a new project.

The chimney draw in the homes should also be evaluated, considering the elevated concentration values reported in the last sampling. The height of the chimneys needs to be checked, as well as the materials used to build them and the covering around the roof exhaust, so that pollutants are carried outside of the building, rather than the opposite.

The citizens who decided to enter the new stove construction program have not only implemented the improved stoves in their homes, but many have also adapted new areas to install the improved stoves. This behavior could be due to the work of various organizations that have been developing various programs to improve living conditions for the inhabitants in areas such as basic sanitation and healthy housing.

Users have said they are happy with the stoves and have reported less smoke, less time needed to cook food, and significant savings in firewood use. Although slight, indoor air pollution exposure patterns have shown some reduction in the time women spend in the kitchen exposed to pollution.

### *V. Lessons Learned*

While it has been shown that the installation of improved stoves to replace traditional three-stone stoves would significantly reduce air pollution levels in cooking environments, there are factors that, if not controlled, in the long term would cause an increase in pollution. While these factors have not been fully identified, the following can be mentioned: stove elbows that get damaged quickly; or pots that don't completely cover the burner holes. Furthermore, traditional household practices, such as keeping the fire burning all day long, could be contributing additional emissions.

Because of these factors, in order to efficiently reduce indoor air pollution, improved stove programs should pay special attention to technical matters, such as quality control for the elbows produced and supplies used to build longer-lasting stoves; and reinforcing behavioral messages on stove maintenance and upkeep, including chimneys. Thus, the implementation of improved stoves should go hand in hand with a "best practices" program regarding their use, installation, and maintenance that will allow users to feel comfortable with the stoves and use them efficiently.

Support for local coordinators is critical for the project to achieve the desired objectives. Indoor air monitoring is more feasible for technical staff with the support of local promoters, so that the sampling can be completed within the scheduled time.

## ACKNOWLEDGMENTS

Our recognition and thanks to:

A. USAID for the initiative to develop and fund the project.

B. Winrock International for trusting Swisscontact to work on the indoor monitoring component for this project.

C. Centro ECO for the coordination activities completed throughout the project and to the promoters for their support and availability for local coordination.

## APPENDIX A: $PM_4$ and CO values per home

| **House code** | **24h $PM_4$ average (µg/m3)** | | **1h maximum CO (ppm)** | |
|---|---|---|---|---|
| | **2005** | **2006** | **2005** | **2006** |
| AMU15 | 136 | 401 | 73 | 130 |
| AMU16 | 38 | 64 | 139 | 10 |
| AMU17 | 44 | 161 | 25 | 13 |
| AMU18 | 183 | 390 | 71 | 58 |
| AMU19 | 192 | 554 | 66 | 135 |
| AMU20 | 240 | 307 | 28 | 148 |
| TUNG21 | 94 | 122 | 31 | 38 |
| TUNG22 | 70 | 83 | 41 | 26 |
| TUNG23 | 774 | 135 | 153 | 80 |
| TUNG24 | 2439 | 375 | 625 | 189 |
| TUNG25 | 543 | n.d.[8] | 131 | 38 |
| TUNG26 | 351 | n.d. | 127 | 7 |
| TUNG27 | 163 | 10 | 118 | 25 |
| TUNG28 | 177 | 211 | 69 | 56 |
| TUNG29 | 2546 | 256 | 238 | 57 |
| TUNG30 | 2281 | n.d. | 495 | 37 |
| UYUR02 | 94 | 617 | 74 | 138 |
| UYUR03 | 316 | 153 | 111 | 142 |
| UYUR04 | 1835 | 548 | 1067 | 46 |
| UYUR06 | 56 | 16 | 31 | 83 |
| UYUR07 | 1001 | 310 | 266 | 104 |
| UYUR08 | 537 | 688 | 68 | 101 |
| UYUR09 | 2290 | 288 | 518 | 91 |
| UYUR10 | 650 | 370 | 261 | 325 |
| UYUR11 | 215 | 213 | 119 | 62 |
| UYUR12 | 328 | 22 | 75 | 47 |
| UYUR13 | 116 | 90 | 40 | 94 |
| UYUR31 | 66 | 43 | 13 | 37 |
| UYUR33 | 121 | 30 | 54 | 26 |
| UYUR37 | 280 | 10 | 393 | 45 |
| UYUR38 | 1430 | 32 | 280 | 22 |
| UYUR39 | 128 | 6 | 58 | 29 |
| UYUR40 | 191 | 463 | 19 | 31 |
| UYUR41 | 565 | 46 | 71 | 10 |
| WAS42 | 3880 | 158 | 453 | 107 |
| WAS43 | 1258 | 85 | 85 | 40 |
| WAS44 | 592 | 134 | 141 | 37 |
| WAS45 | 443 | 77 | 120 | 33 |
| WAS46 | 806 | 341 | 123 | 85 |
| WAS47 | 169 | 45 | 81 | 11 |
| WAS48 | 510 | 225 | 108 | 75 |
| WAS49 | 387 | 375 | 324 | 78 |

---

[8] n.d.= non detectable. The detection limit was estimated at 3µg/$m^3$

## APPENDIX B: Kitchens with increased pollution and associated remarks

| Code | 24h $PM_4$ (µg/m3) | | 1h Max CO (ppm) | | 2006 kitchen location | Stove installation date | Remarks |
|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | | | |
| AMU15 | 136 | 401 | 73 | 130 | Separate room | | The firewood used was slightly wet |
| AMU16 | 38 | 64 | | | Separate room | | |
| AMU17 | 44 | 161 | | | Separate room | | |
| AMU18 | 183 | 390 | | | Separate room | | |
| AMU19 | 192 | 554 | 66 | 135 | Separate room | | |
| AMU20 | 240 | 307 | 28 | 148 | Separate room | | |
| TUNG21 | 94 | 122 | 31 | 38 | Separate room | | |
| TUNG22 | 70 | 83 | | | Same room | | |
| TUNG28 | 177 | 211 | | | Separate room | | |
| UYUR02 | 94 | 617 | 74 | 138 | Separate room | | The pot is smaller than the hole in the stove |
| UYUR03 | | | 111 | 142 | Same room | | |
| UYUR06 | | | 31 | 83 | Same room | | |
| UYUR08 | 537 | 688 | 68 | 101 | Separate room | | |
| UYUR10 | | | 261 | 325 | Separate room | | The son prepared breakfast and the mother cooked at night. The mother isn’t yet comfortable with the improved stove. |
| UYUR13 | | | 40 | 94 | Separate room | | The lady cooked in a small pot that didn’t cover the entire stove hole. |
| UYUR31 | | | 13 | 37 | Same room | | |
| UYUR40 | 191 | 463 | 19 | 31 | Separate room | | The stove gives off too much smoke and the mother wasn’t there |

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX V – Household Cooking Practices and Perceptions Survey

# ANNEX V. Household Cooking Practices and Perceptions Survey

***Survey questionnaire used in the pollutant sampling campaigns in households in the Inkahuasi district of Peru.***

***Source: Survey on household energy practices indoor air pollution & health in the Philippines. 1st version. August 2004***

| | |
|---|---|
| F | **INTERVIEWER'S REMARKS: HOUSE AND KITCHEN CHARACTERISTICS**<br>**The information will be obtained from the interviewer first or after the interviews in the homes.** |

| |
|---|
| **INTERVIEWER:** |
| **FAMILY INTERVIEWED:** |
| **ID:** |
| **DATE:** |

| | | | |
|---|---|---|---|
| F.1 | Type of house. ***Please enter the codes in the spaces provided for the roof, walls and floor. Where appropriate, specify "Other" categories in the box.*** | | |
| | | STRAW | 1 |
| | | WOOD | 2 |
| | ROOF | GROOVED STEEL SHEETS | 3 |
| | | BRICKS | 4 |
| | | ROCKS | 5 |
| | | ADOBE | 6 |
| | WALLS | SOIL | 7 |
| | | LLUVISOL | 8 |
| | | MUD | 9 |
| | | STICKS | 10 |
| | FLOOR | CEMENT | 11 |
| | | CALAMINE | 12 |
| | | OTHER<br>(SPECIFY) | 99 |

| | | | |
|---|---|---|---|
| F.2 | Location of the house. ***Mark only ONE answer*** | | |
| | ON LAND | 1 | |
| | ON STILTS | 2 | |

| | | |
|---|---|---|
| F.3 | Location of the kitchen/cooking area. ***Mark only ONE answer*** | |
| | IN A ROOM USED FOR LIVING OR SLEEPING (WITH A PARTITION) | 1 |
| | IN A ROOM USED FOR LIVING OR SLEEPING (WITH NO PARTITION) | 2 |
| | IN A SEPARATE ROOM USED AS THE KITCHEN | 3 |
| | IN A SEPARATE BUILDING USED AS THE KITCHEN | 4 |
| | OUTDOORS (WITH ONE OR TWO PROVISIONAL WALLS AND A ROOF) | 5 |
| | OUTDOORS (OPEN-AIR, NO STRUCTURAL SUPPORT) | 6 |
| | SECOND STORY | 7 |
| | OTHER<br>(SPECIFY) | 99 |

| | | | |
|---|---|---|---|
| F.4 | Dimensions of the kitchen/cooking area. ***Mark only ONE answer. Refer to the instructions manual to measure the dimensions with the measurement instrument provided.*** | | |
| | ☐ LENGTH (A)<br>☐ WIDTH (B)<br>☐ HEIGHT (C)<br>☐ HEIGHT (D) | < 1 M | 1 |
| | | > 1 M – 2 M | 2 |
| | | > 2 M – 3 M | 3 |
| | | > 3 M | 4 |
| | | (Specify the appropriate dimensions) | |

| | | |
|---|---|---|
| F.5 | Type of ventilation in the cooking area/kitchen roof. ***Mark only ONE answer*** | |
| | OPENINGS | 1 |
| | CHIMNEY | 2 |
| | EXHAUST | 3 |
| | SLIT | 4 |
| | OTHER<br>(SPECIFY) | 99 |

| | | | |
|---|---|---|---|
| F.6 | Permanent ventilation diameter. ***Record the proper codes in the appropriate spaces; to measure the dimensions with the provided measurement instrument, refer to the directions.*** | | |
| | ☐ OPENING 1<br>☐ OPENING 2<br>☐ OPENING 3<br>☐ OTHER (SPECIFY) | NONE | 1 |
| | | < 10 CM | 2 |
| | | > 10 CM | 3 |
| | | OTHER<br>(SPECIFY IN THE BOX) | 99 |

| | | |
|---|---|---|
| F 7 | Depth of the eaves in the cooking area/kitchen. ***Mark only ONE answer. Refer to the instructions manual to measure the dimensions with the measurement instrument provided.*** | |
| | NONE | 1 |
| | < 10 CM | 2 |
| | > 10 CM | 3 |
| | OTHER<br>(SPECIFY) | 99 |

| | | |
|---|---|---|
| F.8 | Location of the eaves. ***Mark only one answer. See the manual for further instructions.*** | |
| | AROUND THE ROOM | 1 |
| | OUTSIDE THE WALLS | 2 |
| | ALONG THE WALLS INSIDE THE HOUSE | 3 |
| | ROOF | 4 |
| | OVER THE KITCHEN | 5 |
| | OVER THE DOOR OR WINDOW | 6 |
| | OTHER<br>(SPECIFY) | 99 |

| | | |
|---|---|---|
| F.9 | How many windows are there in the kitchen/cooking area? ***Mark only ONE answer*** | |
| | NONE | 0 |
| | ONE | 1 |
| | TWO | 2 |
| | THREE | 3 |
| | FOUR | 4 |

| | | | |
|---|---|---|---|
| | FIVE | 5 | |
| | > FIVE<br>(SPECIFY) | 6 | |

| | |
|---|---|
| F.10 | Window dimensions (width). ***Properly record the codes in the appropriate spaces. Refer to the instructions manual to measure the dimensions with the measurement instrument provided.*** |

☐ WINDOW 1 ☐ WINDOW 4

☐ WINDOW 2 ☐ WINDOW 5

☐ WINDOW 3 ☐ WINDOW 6

| | |
|---|---|
| < 10 CM | 1 |
| 10 – 20 CM | 2 |
| 21 – 30 CM | 3 |
| 31 – 59 CM | 4 |
| > 60 CM<br>(SPECIFY) | 5 |

| | | | |
|---|---|---|---|
| F.11 | How is the window kept? ***Mark only ONE answer*** | | |
| | PERMANENTLY CLOSED | 1 | |
| | CLOSED DURING COOKING | 2 | |
| | OPEN DURING COOKING | 3 | |
| | PERMANENTLY OPEN | 4 | |

| | | | |
|---|---|---|---|
| F.12 | How many doors does the kitchen/cooking area have? ***Mark only ONE answer*** | | |
| | ONE | 1 | |
| | TWO | 2 | |
| | THREE | 3 | |
| | FOUR | 4 | |
| | FIVE | 5 | |

| | | | |
|---|---|---|---|
| F.13 | How is the door kept? ***Mark only ONE answer*** | | |
| | PERMANENTLY CLOSED | 1 | |
| | CLOSED DURING COOKING | 2 | |
| | OPEN DURING COOKING | 3 | |
| | PERMANENTLY OPEN | 4 | |

| | | | |
|---|---|---|---|
| F.14 | What kind of stove do you have? ***Mark only ONE answer*** | | |
| | IMPROVED STOVE | 1 | |
| | THREE-STONE | 2 | |
| | OTHER<br>(SPECIFY) | 99 | |

| | |
|---|---|
| F.15 | Layout of the cooking area/kitchen |

***In the following space, please draw a sketch of the cooking area. The sketch should be simple and indicate the following:***

- ***Rooms, identifying the kitchen (if it's part of the main house)***
- ***Position of the fire/stove (with chimney if appropriate)***
- ***Position of the doors***
- ***Position of the windows***
- ***Position of the eaves***
- ***Position of other openings***

| | |
|---|---|
| | Sketch: |

| | | | |
|---|---|---|---|
| F.16 | Do you have an additional stove? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.17 | If YES, what kind of stove? | | |
| | THREE-STONE | 1 | |
| | SOLAR | 2 | |
| | OTHER<br>(SPECIFY) | 99 | |

| | | | |
|---|---|---|---|
| F.18 | Do you use it? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.19 | If YES, what for? | | |
| | COOKING | 1 | |
| | LIGHTING | 2 | |
| | HEATING | 3 | |
| | OTHER<br>(SPECIFY) | 99 | |

| | | | |
|---|---|---|---|
| F.20 | How often? | | |
| | ONCE PER DAY | 1 | |
| | ONCE PER WEEK | 2 | |
| | ONCE PER MONTH | 3 | |
| | ONCE PER YEAR | 4 | |
| | OTHER<br>(SPECIFY) | 99 | |

| | | | |
|---|---|---|---|
| F.21 | Do you cook now in the same room you cooked in 2006? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.22 | Do you cook now in the same room you cooked in 2005? | | |
| | YES | 1 | |
| | NO | 2 | |

| | |
|---|---|
| F.23 | If you answered NO to either of these two questions, why did you move to a different area? |
| | |

| | | | |
|---|---|---|---|
| F.24 | Does the pot you use completely cover the stove burner? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.25 | Are you happy with your improved stove? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.26 | Why? | | |
| | | | |
| F.27 | Do you feel that the improved stove reduces the amount of smoke in your kitchen? | | |
| | SI | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.28 | Do you spend additional time in the kitchen doing things other than cooking? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | | |
|---|---|---|---|---|
| F.29 | If YES, how long? | | | |
| | < 1 HOUR | 1 | >5 - 7 HOURS | 4 |
| | 1 - 3 HOURS | 2 | >7 - 10 HOURS | 5 |
| | >3 - 5 HOURS | 3 | > 10 HOURS | 6 |

| | |
|---|---|
| F.30 | If YES, what do you do during those times? |
| | |

| | | | |
|---|---|---|---|
| F.31 | Are you using less firewood when compared to your previous stove? | | |
| | YES | 1 | |
| | NO | 2 | |

| | | | |
|---|---|---|---|
| F.32 | If YES, how much less? | | |
| | 100% OF THE TOTAL FUEL | 1 | |
| | 50% OF THE TOTAL FUEL | 2 | |
| | 33% OF THE TOTAL FUEL | 3 | |
| | 25% OF THE TOTAL FUEL | 4 | |
| | OTHER<br>(SPECIFY) | 99 | |

| | |
|---|---|
| G | **AIR POLLUTION DUE TO PARTICULATE MATTER AND CARBON MONOXIDE**<br>***This section of the survey should be completed by the field team handling the monitoring equipment. Data will be collected when the equipment is turned on, at filter change 12 hours later and at the end of the monitoring period.*** |
| **Interviewer's name**<br>**Interviewee's ID** | |

| | | |
|---|---|---|
| G1 | TURNING ON THE EQUIPMENT | |
| | Stage | Data |
| | Homemaker ID | |
| | Date | / / 200___ |
| | *Equipment turned on* | |
| | Pump number | |
| | Cyclone number | |
| | Serial number of first cassette | |
| | Serial number of CO monitor used in the room | |
| | *Pump and cyclone location* | |
| | Enter the height of the cyclone/CO monitor | _______________ meters |
| | Enter the distance of the cyclone/CO monitor from the edge of the stove | meters |
| | *Monitoring starts* | |
| | Have 30 minutes gone by since the last meal was cooked? If YES, proceed; if NO, wait until 30 minutes have gone by. | |
| | Time when pump was turned on (24-hour format) | hours minutes |
| | Temperature | °C |
| | Press **ENTER** to turn on the pump<br>Is the flow between 2090 – 2310 mL/min? (**YES/NO)** | |
| | **YES**, enter the flow | mL/min |
| | Note: If the answer is **NO**, the pump must be recalibrated | |
| | Time when the CO monitor was turned on (24-hour format)<br>Can a reading be seen on the monitor? (YES / NO) – if **NO**, the monitor is malfunctioning and monitoring should be stopped. | ____ hours ______minutes |
| | Indicate rain levels over the past 3 days (ask about primary stove)<br>Heavy, constant rain = 1<br>Some rain = 2<br>Little rain = 3<br>Very dry = 4 | |
| | | |
| G2 | AT THE END OF THE FIRST SESSION | |
| | Stage | Data |
| | Date | / / 200___ |
| | Serial number of second cassette | |
| | Time when the pump was put on HOLD | minutes |
| | Flow (indicated in the pump) | mL/min |
| | Temperature | °C |
| | Elapsed time (recorded in the pump) | ____ hours ______minutes |
| | Total volume sampled (recorded in the pump) | liters |
| | If the pump stops, the reason should be indicated | |
| | Reason: | |
| | Time when the pump is turned on again (by pressing ENTER) | ____ hours ______minutes |
| | Is the flow between 2090 – 2310 mL/min? (YES/NO) | |
| | If the answer is YES, enter the flow | mL/min |
| | Note: If the answer is NO, the pump must be recalibrated | |
| | Was the first filter cassette sealed with the plugs? (YES/NO) | |

| | | |
|---|---|---|
| | | |
| | | |
| G3 | AT THE END OF THE SECOND SESSION (24 HOURS) | |
| | Stage | Data |
| | Date | / / 200___ |
| | Time when the pump is turned off | ____ hours ______minutes |
| | Flow (indicated in the pump) | mL/min |
| | Temperature | °C |
| | Elapsed time (indicated in the pump) | ____ hours ______minutes |
| | Total volume sampled (recorded in the pump) | liters |
| | If the pump stops, the reason should be indicated | |
| | Reason: | |
| | Time when the CO monitor is turned off (5 beeps) | ____ hours ______minutes |
| | Is a reading shown? (YES/NO) | |
| | Was the second filter cassette sealed with the plugs? (YES/NO) | |

| | |
|---|---|
| Supervisor who checked the boxes | |
| Is the form complete (YES/NO)? | |
| If NO, what action was taken? | |

| | |
|---|---|
| H | **POST-MONITORING QUESTIONS**<br>***The following questions will be asked after air monitoring. All the questions refer to what happened during the time that the monitors measured smoke, so that the amount of smoke produced can be matched to its cause.*** |
| **Interviewer’s name:**<br>**Interviewee's ID:** | |

| | | | | | |
|---|---|---|---|---|---|
| H1 | FIRST MEAL AFTER TURNING ON THE MONITOR | | | | |
| H1.1 | What kind of fuel was used to cook the first meal after the monitor was turned on and started working? ***(Record the appropriate codes and number from most to least important)*** | | | | |
| | | | | FIREWOOD | 1 |
| | FUEL 1 | | | COAL | 2 |
| | | | | DRY LEAVES | 3 |
| | | | | CROP RESIDUE | 4 |
| | FUEL 2 | | | SAWDUST | 5 |
| | | | | KEROSENE | 6 |
| | | | | LPG | 7 |
| | FUEL 3 | | | CANE | 8 |
| | | | | LLUVISOL | 9 |
| | | | | OTHER | 99 |
| | | | | (SPECIFY) | |
| H1.2 | How dry was the fuel (if applicable) when used? ***(Mark only ONE answer)*** | | | | |
| | N/A | 1 | | | |
| | VERY DRY | 2 | | | |
| | DRY | 3 | | | |
| | SLIGHTLY WET | 4 | | | |
| | WET | 5 | | | |
| | GREEN | 6 | | | |

| | | |
|---|---|---|
| H1.3 | What time did you start cooking this meal? | hours minutes |
| H1.4 | How long did it take to cook this meal? | hours minutes |
| H1.5 | What dishes and drinks did you cook for this meal? | |
| | | |
| H1.6 | How many people (including children) did you cook for? ***Record ID numbers in the space provided. IDs should match the ID numbers recorded with the family in the Confidential Family Record.*** | |

| | | | | |
|---|---|---|---|---|
| | ID # | | ID # | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| | | |
|---|---|---|
| H1.7 | What time was it when you ate this meal? | ____ hours ______minutes |
| | | |
| H2 | SECOND MAIN MEAL AFTER TURNING ON THE MONITOR | |
| H2.1 | What kind of fuel was used to cook the second meal after the monitor was turned on and started working? ***(Record the appropriate codes and number from most to least important)*** | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | FIREWOOD | 1 |
| | FUEL 1 | | | COAL | 2 |
| | | | | DRY LEAVES | 3 |
| | | | | CROP RESIDUE | 4 |
| | FUEL 2 | | | SAWDUST | 5 |
| | | | | KEROSENE | 6 |
| | | | | LPG | 7 |
| | FUEL 3 | | | CANE | 8 |
| | | | | LLUVISOL | 9 |
| | | | | OTHER | 99 |
| | | | | (SPECIFY) | |

| | |
|---|---|
| H2.2 | How dry was the fuel (if applicable) when used? ***(Mark only ONE answer)*** |

| | | |
|---|---|---|
| | N/A | 1 |
| | VERY DRY | 2 |
| | DRY | 3 |
| | SLIGHTLY WET | 4 |
| | WET | 5 |
| | GREEN | 6 |

| | | |
|---|---|---|
| H2.3 | What time did you start cooking this meal? | ____ hours ______minutes |
| H2.4 | How long did it take to cook this meal? | ____ hours ______minutes |
| H2.5 | What dishes and drinks did you cook for this meal? | |
| | | |
| H2.6 | How many people (including children) did you cook for? ***Record ID numbers in the space provided. IDs should match the ID numbers recorded with the family in the Confidential Family Record.*** | |

| | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| | | |
|---|---|---|
| H2.7 | What time was it when you ate this meal? | ____ hours ______minutes |
| | | |
| H3 | THIRD MEAL AFTER TURNING ON THE MONITOR | |
| H3.1 | What kind of fuel was used to cook the third meal after the monitor was turned on and started working? ***(Record the appropriate codes and number from most to least important)*** | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | FIREWOOD | 1 |
| | FUEL 1 | | | COAL | 2 |
| | | | | DRY LEAVES | 3 |
| | | | | CROP RESIDUE | 4 |

| | | | | | |
|---|---|---|---|---|---|
| | FUEL 2 | | | SAWDUST | 5 |
| | | | | KEROSENE | 6 |
| | | | | LPG | 7 |
| | FUEL 3 | | | CANE | 8 |
| | | | | LLUVISOL | 9 |
| | | | | OTHER | 99 |
| | | | | (SPECIFY) | |
| H3.2 | How dry was the fuel (if applicable) when used? ***(Mark only ONE answer)*** | | | | |
| | N/A | 1 | | | |
| | VERY DRY | 2 | | | |
| | DRY | 3 | | | |
| | SLIGHTLY WET | 4 | | | |
| | WET | 5 | | | |
| | GREEN | 6 | | | |
| H3.3 | What time did you start cooking this meal? | | | hours | minutes |
| H3.4 | How long did it take to cook this meal? | | | hours | minutes |
| H3.5 | What dishes and drinks did you cook for this meal? | | | | |
| | | | | | |
| H3.6 | How many people (including children) did you cook for? ***Record ID numbers in the space provided. IDs should match the ID numbers recorded with the family in the Confidential Family Record.*** | | | | |
| | ID # | | ID # | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| H3.7 | What time was it when you ate this meal? | | | ____ hours | ______minutes |
| | | | | | |
| H4 | OTHER USES FOR OPEN FIRE/STOVE | | | | |
| H4.1 | Since monitoring started, have you used the open fire/stove for other things (for example, preparing food and drinks for sale)? ***(Mark only ONE answer)*** | | | | |
| | YES | 1 | | | |
| | NO | 2 | | | |
| H4.2 | If YES, what did you use it for? ***(Mark ALL that apply)*** | | | | |
| | COOKING FOOD/DRINKS FOR SALE | 1 | | | |
| | HEATING WATER (NOT FOR COOKING) | 2 | | | |
| | COOKING FOOD FOR ANIMALS | 3 | | | |
| | LIGHTING | 4 | | | |
| | OTHER ACTIVITIES | 99 | | | |
| | (SPECIFY) | | | | |
| | | | | | |
| H5 | Did you use the same open fire/stove at the same time as one of the following? ***(Mark only ONE answer)*** | | | | |
| | FIRST MEAL OF THE DAY | 1 | | | |
| | SECOND MEAL OF THE DAY | 2 | | | |
| | THIRD MEAL OF THE DAY | 3 | | | |
| | A DIFFERENT TIME OF DAY<br>(SPECIFY) | 4 | | | |
| | YOU USED A DIFFERENT STOVE<br>(SPECIFY) | 5 | | | |
| | | | | | |
| H6 | What kind of fuel did you use for this activity? ***(Record the appropriate codes and number from most to least important)*** | | | | |
| | | | | FIREWOOD | 1 |
| | FUEL 1 | | | COAL | 2 |
| | | | | DRY LEAVES | 3 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | CROP RESIDUE | 4 |
| | FUEL 2 | | | SAWDUST | 5 |
| | | | | KEROSENE | 6 |
| | | | | LPG | 7 |
| | FUEL 3 | | | CANE | 8 |
| | | | | LLUVISOL | 9 |
| | | | | OTHER | 99 |
| | | | | (SPECIFY) | |

| | | |
|---|---|---|
| H7 | How dry was the fuel (if applicable) when used? ***(Mark only ONE answer)*** | |
| | N/A | 1 |
| | VERY DRY | 2 |
| | DRY | 3 |
| | SLIGHTLY WET | 4 |
| | WET | 5 |
| | GREEN | 6 |

| | | |
|---|---|---|
| H8 | What time did you start cooking this meal? | ____ hours ______minutes |

| | | |
|---|---|---|
| H9 | How long did it take to cook this meal? | ____ hours ______minutes |

| | | |
|---|---|---|
| H10 | How much of the day's fuel was used for this activity? ***(Mark only ONE answer)*** | |
| | 100% OF THE TOTAL FUEL | 1 |
| | 50% OF THE TOTAL FUEL | 2 |
| | 33% OF THE TOTAL FUEL | 3 |
| | 25% OF THE TOTAL FUEL | 4 |
| | OTHER<br>(SPECIFY) | 99 |

| | | |
|---|---|---|
| H11 | Was the open fire/stove kept burning especially for heating (not for cooking)? ***(Mark only ONE answer)*** | |
| | YES | 1 |
| | NO | 2 |

| | | | | |
|---|---|---|---|---|
| H12 | If YES, how many hours was the stove fuel kept burning for heating? ***(Mark only ONE answer)*** | | | |
| | < 1 HOUR | 1 | >5 - 7 HOURS | 4 |
| | 1 - 3 HOURS | 2 | >7 - 10 HOURS | 5 |
| | >3 - 5 HOURS | 3 | > 10 HOURS | 6 |

| | | |
|---|---|---|
| H13 | Was the open fire/stove kept burning for lighting (not for cooking)? ***(Mark only ONE answer)*** | |
| | YES | 1 |
| | NO | 2 |

| | | | | |
|---|---|---|---|---|
| H14 | If YES, how many hours was the stove fuel kept burning for lighting? ***(Mark only ONE answer)*** | | | |
| | < 1 HOUR | 1 | >5 - 7 HOURS | 4 |
| | 1 - 3 HOURS | 2 | >7 - 10 HOURS | 5 |
| | >3 - 5 HOURS | 3 | > 10 HOURS | 6 |

| | |
|---|---|
| H15 | AMOUNT OF TIME THE FAMILY WAS MONITORED PER DAY |
| H15.1 | How long was the woman in the monitored room while the fire was burning? |

| | Put an X on the monitoring starting time | Time of day (*starting at midnight*) | The fire was:<br>Not on = 1<br>Slow burning = 2<br>Burning = 3 | Never | One fourth of the time | Half the time | Three quarters of the time | All the time |
|---|---|---|---|---|---|---|---|---|
| | Midnight to noon | | | | | | | |
| | AM | 12-1 o’clock | | | | | | |
| | | 1-2 o’clock | | | | | | |
| | | 2-3 o’clock | | | | | | |
| | | 3-4 o’clock | | | | | | |
| | | 4-5 o’clock | | | | | | |
| | | 5-6 o’clock | | | | | | |
| | | 6-7 o’clock | | | | | | |
| | | 7-8 o’clock | | | | | | |
| | | 8-9 o’clock | | | | | | |
| | | 9-10 o’clock | | | | | | |
| | | 10-11 o’clock | | | | | | |
| | | 11-12 o’clock | | | | | | |
| | Noon to midnight | | | | | | | |
| | PM | 12-1 o’clock | | | | | | |
| | | 1-2 o’clock | | | | | | |
| | | 2-3 o’clock | | | | | | |
| | | 3-4 o’clock | | | | | | |
| | | 4-5 o’clock | | | | | | |
| | | 5-6 o’clock | | | | | | |
| | | 6-7 o’clock | | | | | | |
| | | 7-8 o’clock | | | | | | |
| | | 8-9 o’clock | | | | | | |
| | | 9-10 o’clock | | | | | | |
| | | 10-11 o’clock | | | | | | |
| | | 11-12 o’clock | | | | | | |
| H15.2 | If a child was present, how long was the youngest child in the monitored room while the fire was burning? | | | | | | | |
| | Midnight to noon | | | | | | | |
| | AM | 12-1 o’clock | | | | | | |
| | | 1-2 o’clock | | | | | | |
| | | 2-3 o’clock | | | | | | |
| | | 3-4 o’clock | | | | | | |
| | | 4-5 o’clock | | | | | | |
| | | 5-6 o’clock | | | | | | |
| | | 6-7 o’clock | | | | | | |
| | | 7-8 o’clock | | | | | | |
| | | 8-9 o’clock | | | | | | |
| | | 9-10 o’clock | | | | | | |
| | | 10-11 o’clock | | | | | | |
| | | 11-12 o’clock | | | | | | |
| | Noon to midnight | | | | | | | |
| | PM | 12-1 o’clock | | | | | | |
| | | 1-2 o’clock | | | | | | |
| | | 2-3 o’clock | | | | | | |
| | | 3-4 o’clock | | | | | | |
| | | 4-5 o’clock | | | | | | |
| | | 5-6 o’clock | | | | | | |
| | | 6-7 o’clock | | | | | | |
| | | 7-8 o’clock | | | | | | |
| | | 8-9 o’clock | | | | | | |
| | | 9-10 o’clock | | | | | | |
| | | 10-11 o’clock | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 11-12 o'clock | | | | | | |
| If you have one or more children recorded in the previous box, please provide the age(s) of the child(ren). | | | | | | | | |
| | | | | | | | | |

| | |
|---|---|
| H16 | REMARKS AND OBSERVATIONS |
| H16.1 | Can you think of anything that was different today than it would have been without the monitoring? |
| | |
| H16.2 | Other remarks and observations from the interviewee (please feel welcome but not required to fill this box) |
| | |
| H16.3 | Other remarks and observations from the interviewer (please feel welcome but not required to fill this box) You may include information about the interviewee's attitude when asked certain questions. |
| | |

PERU HEALTHY KITCHEN/HEALTHY STOVE PILOT PROJECT

# ANNEX VI – Pulmonary Health Assessment

# **ANNEX VI.** Pulmonary Health Assessment

## Abating Indoor Air Pollution Improved Lung Function Tests:

## Improvement in Pulmonary Obstruction Measured in a Rural Andean Population after a “Rocket Stove” Program Reduced Exposure to Biomass Cooking Smoke

**December 2008**

Submitted by:
Jay C. Smith, M.D., M.P.H.
386 Pembroke Street
Pembroke, NH 03275 USA
603-485-4231
jcmd7699@pol.net

## Abstract

*Objective:* Using an analogy to studies of smoking cessation, we should find that lowering indoor air pollution (IAP) with improved cookstoves should improve lung airflow.

*Materials and methods:* Airflow rates in adult household members and kitchen particulate levels were measured before and months after installation of chimney stoves in households that had been cooking on open fires.

*Results:* Division into 2 groups by particulate reduction showed a trend of improvement in exhalation force with better reduction among subjects with tests that fully met clinical validity criteria. Removing a subject whose cooking status changed, as well as an outlier, made the difference significant ($p < 0.01$). The difference was also significant ($p < 0.05$) after adding in subjects whose tests did not quite meet validity criteria. Stratifications by gender and baseline airflow showed significance for women and those without baseline decrease. Mean differences were similar across gender. Carbon monoxide (CO) reduction and particulate reduction correlated. In multivariate analysis, just baseline exhalation force and a statistic that combined percent and absolute particulate reduction remained predictors of improvement.

*Discussion:* Biomass smoke exposure is known to correlate with death and disability where poorly ventilated burning is done for cooking, but what degree of reduction in exposure is important in prevention of airway problems is poorly defined. These results suggest that obtaining good reduction of particulate exposure will lead to less obstructive lung disease morbidity. This smoke pollution also causes a large number of deaths from pneumonia, especially in children. Thus, this intervention has potential to also reduce the high rate of under-5 mortality in impoverished countries.

Keywords: **Indoor air pollution, lung diseases, biomass fuels, poverty**

## Executive Summary

In August 2005 and 15 months later, data were collected by survey and breathing tests in adults from 44 households that initially used indoor open fires to cook. Levels of respirable particulates and carbon monoxide in the cooking areas of the households were also measured before and after installation of “rocket” stoves with chimneys.

Symptomatic lung disease was common in these subjects despite tobacco smoking not being a significant issue. At baseline, virtually all respondents reported a chronic cough. Many had sufficient symptoms to be classified as having chronic bronchitis. Repeated survey the next year showed nearly complete resolution of all symptoms. By analogy to the improvement in breathing environment that occurs with tobacco smoking cessation or reduction of high level exposure to second-hand smoke, lower amounts of kitchen pollution should also reverse rates of decline in breathing obstruction (FEV1% measured by spirometry) as it does with cessation of cigarette smoke exposures. By an extrapolation from the literature on cessation of tobacco smoke exposure, the reduction in the airway damage associated with indoor air pollution (IAP) from cooking fire smoke should have lead to a 2.78% average increase in FEV1% over the follow-up period.

Some problems occurred with our data collection, largely due to loss to follow-up and spirometric tests that did not meet clinical reproducibility criteria. In the 15 subjects with fully valid tests in both years, there was an overall decrease in FEV1% of –1.38% (95% confidence interval was clearly different from the 2.78% improvement expected). This might have meant that the project failed to achieve meaningful reductions in lower respiratory tract consequences of biomass smoke exposure. However, there were large differences in the degree of reduction of biomass smoke pollution as indicated in the monitoring data for respirable particulates and carbon monoxide. An examination of this data set showed that combined cut-points of both “>100 mcg per meter squared” and “>64%” reduction in particulates discriminated between groups with better and worse spirometry results but this did not reach significance at the traditional $p< 0.05$. However, one of these subjects wasn’t cooking initially but was at follow-up. Another subject was an outlier with an FEV1% increase of 8.82%; this is consistent with this subject having asthma. The analysis was repeated with just the other 13 individuals. The difference between groups was then significant at $p < 0.01$.

Examining all of our data, including those with too much variation to meet clinical validity criteria, increases variance and reduces the likelihood of a statistically significant difference. But this could reassure us that the above results are not just due to post-hoc analysis. Doing this gave us 36 subjects. Despite the increased random error from including those with less repeatable results, this yielded a very similar analysis after dropping 4 outliers whose large FEV1% changes indicated they probably had asthma. The difference between groups with better and worse reductions in particulate pollution was significant at $p < 0.05$. The confidence interval for the average FEV1% change in the group with better reductions in particulates was –0.88 to 2.35% improvement. While this is not quite as good as hoped for by analogy to cessation of high-level tobacco smoke exposure, it is still reassuring that this amount of reduction in cooking smoke exposure can make a difference in the rate of progression of chronic obstructive lung disease.

This analysis focused on particulates but all of these households also had analyses of CO levels in both years. Scattering either the change in CO or its percentage drop from baseline against the change in FEV1% (or adding them to a regression model along with the change in particulates) shows no correlation so it is clear that the lung function results are associated primarily with the ability of the "rocket" stove installations to markedly reduce particulate pollution when installed and used properly.

Using the larger data set, it was also possible to check whether results varied by gender or by presence or absence of baseline obstruction. For the 17 men, there was no significant difference in FEV1% change between groups with more or less particulate reduction in the kitchens of their households. For the 15 women, there was a difference that was significant at $p < 0.05$. Although the mean changes were similar for both genders, the higher variance among the men may reflect wider variation in time spent in the kitchen. Although the majority of men in this sample cooked at least once a week, the women were the primary cooks in all these households so this result is consistent with women having had more chance of benefiting from reduction in kitchen smoke.

Comparing those with evidence of obstruction at baseline showed them to have improved FEV1%; those without didn't seem to benefit ($p < 0.0005$). Linear regression that included this variable did not negate the statistical significance of the reduction in particulate exposure. Having the statistical program (STATA 8.2) pick predictors of improvement (by backwards, stepwise exclusion) showed that just these two variables are significant. These results are especially striking because baseline obstruction does not predict achieving better particulate reduction (8 did and 9 didn't). Those without baseline obstruction also showed nearly equal levels of better reduction (6 did and 9 didn't). So reducing particulates by this amount has real benefit. In this sample, the impact seems to only be measurable for those already damaged by many years of smoke inhalation.

**Discussion:**

It is widely known that biomass smoke exposure is associated with death and disability in households in the poorer parts of the world where poorly ventilated burning of various fuels is done for cooking. However, it is still unknown what degree of reduction in exposure is important in prevention of airway problems. The largest mortality burden from smoke pollution is due to lower airway infections (mostly in small children who stay near the kitchen fire with their mothers for long periods). Measuring impact on this would likely require a large number of households over several years and proof of the amount of pollution reduction in all of the test households.

While the impact of chronic obstructive lung disease on mortality is less well defined, the most important airway damage in this disease is in small airways. Damage to these same small airways is also the primary reason that indoor air particulate pollution increases deadly infections. Measuring changes in the continuous decline in force of exhalation among those exposed to damaging levels of particulates gives a valid measure of progression of their disease. The added benefit of a known, and relatively large, reversal of effect in the first month after cessation of indoor exposure to another biomass smoke source (tobacco) made this an especially appealing model for study.

In terms of airway symptoms, there was no difference in their alleviation by the success (or lack thereof) in reducing measured IAP. Chronic cough was highly prevalent in the first survey and virtually disappeared in the second. This may be due to problems in administering the survey. It is also possible that it reflects changes in production of larger particles that may induce more cough through effects on the upper airway. Since total airborne particulates were not measured, we don't know whether this stove design in this setting reduces them more than it does the respirable particulates that were measured and which are known to have major impact on the lower airways.

This study did not try to find out which patients had asthma. Because of the higher variability in their FEV1% changes after "smoking" cessation (due to other interval factors and illnesses), the handful of people whose large change in FEV1% from year to year made asthma likely was simply excluded. This weakness of our study could be avoided in larger studies with enough asthmatics for a stratified analysis.

The expanded analysis of 32 individuals gave us a data set with nearly equal numbers of men and women. Both genders were equally affected at baseline, likely because most of these men cooked regularly and because of the attractiveness of the warmth of the hearth during the coolness of morning and evening cooking times in this high altitude area. Women had a more significant FEV1% change in this sample, which may reflect the IAP reduction from a baseline of higher, longer exposures. Longer follow-up or more data from more households could help solidify this finding.

Finding some means of going back and rewarding everyone who completes the follow-up testing could be one way of accomplishing this. Most individuals in the project area depend on subsistence agriculture and it was evident that people lacked motivation to do the follow-up testing. There may also have been issues around the strangeness of the test.

The reason for testing the association between a combined reduction statistic (both percentage and absolute) for particulate pollution and improved lung function involves the stationary location of the pollution measurement equipment. It is unlikely to capture an equal proportion of the breathing zone smoke that each cook is exposed to in each kitchen. The figures for each kitchen needed to be seen as more relative than absolute. However, if a kitchen started with low levels of particulates, it is unlikely that a 65% or greater reduction in the level of fine particles is anything more than random day-to-day variation so an absolute decrease of >100 mcg per meter squared was also required to put a household in the category of better improvement in IAP.

While reductions in CO did not associate with the improvement in lung function, there are other known health benefits of these CO reductions (e.g. in reducing stillbirths and low birth weight in newborns and in exacerbations of ischemic heart disease) so it is also encouraging that almost all of the households with good particulate reductions had substantial reductions in CO.

Expanding this study could solidify our findings and address other health effects of IAP. It would be especially appealing to do a case-control or ecologic study by examining records of pneumonia diagnoses at the two health posts in the area.

# Introduction

The food of about 2.4 billion people worldwide is cooked on open fires with biomass fuels (wood, dung, and crop residues), often indoors with little or no ventilation. As reported by Ezzati et al. (2002) this leads to much ill health from indoor air pollution (IAP). Indoor air pollution is thought to contribute greatly to the incidence of pneumonia and lower respiratory infections that are the leading cause of death in small children. Smith et al. (2000) note that this is likely because children often stay near cooking fires with their mothers for long periods. Ezzati and Kammen (2001) have shown that infection rates differ by IAP exposure level but, as stated by Smith (2002), the reduction needed to reduce infection rates is not fully tested.

Smith et al. (2006) have published preliminary results from the RESPIRE Guatemala study showing a trend towards reduced pneumonia in small children. However, most other research, such as that on improved ventilation by Akunne, et al. (2008), that shows a beneficial effect on respiratory infections of measures to reduce IAP has not differentiated between upper and lower respiratory infections. Bruce, N et al (2007) have noted how difficult this distinction is to make when laboratory and X-ray testing are not available.

The same damage to the small airways that leads to the increase in respiratory infections like pneumonia also causes chronic obstructive pulmonary disease (COPD) in adults. According to Rabe and Soriano (2006), COPD is common from biomass fuel use, though the burden is not well quantified. By lowering biomass IAP, development of this breathing obstruction in exposed individuals should decrease. Scanlon et al (2000) found that a year after COPD patients quit smoking tobacco, airflow improved when measured by spirometry as FEV1% (Forced Expiratory Volume exhaled in the first second expressed as a % of total lung volume). By testing airflow before and the year after installing improved cookstoves to reduce IAP, we hoped to find a similar improvement in lung health in project participants in the Andean highlands.

The initial plan was to compare changes in airflow in women versus men because women, as primary cooks, are more highly exposed to biomass smoke IAP. However, men frequently cooked in this region even if not as much as women. Men’s exposure is also high from congregating near fires during cooking times in this high-altitude, cool temperature location. Thus, we examined airflow improvement overall as is seen in ex-smokers and those whose heavy exposure to second-hand tobacco smoke has been eliminated, like the non-smoking Scottish bar workers studied by Menzies et al. (2006). Their FEV1 (Forced Expiratory Volume exhaled in the first second) improved greatly a month after a smoking ban was instituted. Age-related decline for these workers had resumed on retesting after the second month. Factoring in the percentage increase in FEV1 in this bar study with the longer term decline from aging noted when comparing smokers with ex-smokers (Scanlon et al, 2000), we thought our subjects in Peru should also have improved lung capacity at follow-up the next year.

## Materials and Methods

In August 2005, as part of an improved stove project in several villages in the Peruvian Andes, we surveyed adults from 44 households where cooking was done over indoor open fires. We used a brief pulmonary health questionnaire and spirometry to test FEV1%. The program was multi-faceted, using micro-credit based on animal husbandry, local health promoters, and training of local people to make and install the stoves. These were chimney stoves of a design that is known as "rocket" technology. Bryden et al. (2005) have shown that these stove models improve combustion and heat transfer, thus reducing firewood use and IAP, but stove installation, maintenance, and usage issues can lead to wide variation in IAP reduction. In November 2006, data collection was repeated several months after the installation of the improved cookstoves.

Initial data were obtained from 82 individuals. Of these 82, there were 57 whose airflow tests met clinical criteria for reproducibility. Of the 82, only 55 agreed to follow-up testing. Only 37 of these had valid tests; 22 had lung capacities that varied $\leq$ 5%; only 17 had reproducible tests in both years. Two of these lived in homes that did not have IAP monitoring both years, leaving 15 individuals with IAP results for both years who met clinical validity criteria

Monitoring of IAP in these homes included 24-hour measurement of particulate IAP with a pump and filter, capturing particles smaller than 4 microns ($PM_4$). IAP monitoring was conducted by an engineer whose team simultaneously measured carbon monoxide levels with a T82 Datalogger. Equipment was placed following standards for location of monitoring devices in the cooking area published by the Indoor Air Pollution Team at the School of Public Health, University of California, Berkeley (2005). IAP data for households was collected for 24 hours on one occasion before the installation of improved cookstoves, and once several months after installation.

### Results

Participants were also questioned about their overall health and lung capacity. The short questionnaire about illness episodes, chronic cough, and shortness of breath with various tasks revealed striking levels of symptoms at baseline, especially chronic cough. Many had sufficient symptoms to indicate chronic bronchitis. At follow-up, almost all symptoms had resolved, regardless of whether IAP improved or worsened.

At baseline, many of the health assessment participants had below normal FEV1%, despite almost no tobacco smoking (no women smoked; a few men smoked occasionally, but none smoked as often as once in a week). We expected average improvement in our subjects' FEV1% from the first year to the second year (if they were comparable to former smokers and bar workers no longer exposed to smoke), but airflow dropped -1.38% (95% confidence interval, -3.77 to +1.01). These results are shown in **Table 1 on the next page**

***Table 1. Results for the 15 individuals with valid test results from both years***

| Gender | Baseline FEV1% | % change in FEV1% | PM 4 at baseline | PM 4 at follow-up |
|---|---|---|---|---|
| F | 85.04% | -6.61 | 94 | 617 |
| M | 81.51% | -6.41 | 121 | 30 |
| M | 82.30% | -1.89 | 2290 | 288 |
| M | 82.07% | -2.5 | 650 | 370 |
| M | 81.27% | -0.95 | 1430 | 32 |
| M | 80.60% | -2.09 | 44 | 161 |
| M | 80.19% | -6.65 | 240 | 307 |
| M | 85.25% | -4.29 | 94 | 122 |
| M | 61.79% | +8.82 | 70 | 83 |
| F | 82.37% | -0.19 | 2546 | 256 |
| M | 65.33% | +3.05 | 543 | ND |
| M | 72.66% | -4.81 | 2281 | ND |
| F | 85.27% | -0.93 | 565 | 46 |
| F | 81.13% | +1.08 | 169 | 45 |
| M | 69.91% | +3.73 | 592 | 134 |
| Mean | 78.45% | -1.38 | 782 | 192 |

These results might indicate no reduction in lung damage in these participants despite > 75% average reduction in $PM_4$. However, household IAP monitoring data showed large differences in IAP reduction. Thus, comparing the improvements in obstruction between those living in households with greater versus little or no IAP reduction seemed logical. Stratifications by absolute $PM_4$ reductions or $PM_4$ at follow-up did not show a distinct correlation between IAP reduction and improved lung function but splitting the subjects into two groups by percentage reduction (65% or greater) showed a more distinct division. A combined cut-point of $PM_4$ reduction of both “>100 mcg per meter cubed” and “>64%” was even more clear but the difference between groups was not quite significant at $p < 0.05$. This difference is shown in section 1 of **Table 2, on the next page**.

***Table 2. Detailed breakouts of test subjects, by group***

**GROUPS**

```
          |#subjects |   Mean    | Std. Err. | Std. Dev. | 95% Conf. Interval
--------- +-------------------------------------------------------------------
FULLY ACCEPTABLE TESTS IN BOTH YEARS
Poor IAP  |      7   | -2.81857 | 2.071386  | 5.480372  | -7.88707    2.24993
Good IAP  |      8   | -0.11375 | 0.970916  | 2.746166  | -2.40960    2.18210
difference|          | -2.70482 | 2.287645  |           | -7.91954    2.50990
                                                                    p = 0.2688
FULLY ACCEPTABLE TESTS IN BOTH YEARS MINUS 1 OUTLIER AND 1 SUBJECT NOT COOKING
Poor IAP  |      6   | -4.75167 | 0.863259  | 2.114544  | -6.97075   -2.53259
Good IAP  |      7   |  1.70e-08| 1.111976  | 2.942012  | -2.72091    2.72091
difference|          | -4.75167 | 1.407731  |           | -7.85948   -1.64385
                                                                    p = 0.0064
ADDING-IN 5 NEARLY ACCEPTABLE TESTS* MINUS 3 OUTLIERS AND 1 SUBJECT NOT COOKING
Poor IAP  |      9   | -3.76222 | 0.879365  | 2.638095  | -5.79004   -1.73440
Good IAP  |      9   |  0.31444 | 1.024636  | 3.073907  |  2.04837    2.67726
difference|          | -4.07667 | 1.350245  |           | -6.94442   -1.20891
                                                                    p = 0.0083
19 TESTS WITH HIGH INTRAINDIVIDUAL VARIANCE BUT < 20% YEAR-TO-YEAR FVC** CHANGE
Poor IAP  |     12   | -0.41583 | 0.864684  | 2.995352  | -2.31899    1.48732
Good IAP  |      7   |  1.47143 | 0.998688  | 2.642281  | -0.97227    3.91513
difference|          | -1.88726 | 1.321006  |           | -4.71944    0.94491
                                                                    p = 0.1749
THESE 19 ADDED TO THE ORIGINAL 13 FULLY VALID TESTS (4 OUTLIERS STILL EXCLUDED)
Poor IAP  |     18   | -1.86111 | 0.800832  | 3.397644  | -3.55072   -0.17150
Good IAP  |     14   |  0.73571 | 0.746421  | 2.792853  | -0.87683    2.34826
difference|          | -2.59683 | 1.09475   |           | -4.83298   -0.36067
                                                                    p = 0.0243
RESULTS FOR JUST THE MEN IN THIS SET OF 32 SUBJECTS (1 OUTLIER STILL EXCLUDED)
Poor IAP  |     10   | -1.201   | 1.184457  | 3.745582  | -3.88043    1.47843
Good IAP  |      7   |  0.87    | 1.356727  | 3.589564  | -2.44979    4.18979
difference|          | -2.071   | 1.801013  |           | -5.94922    1.80722
                                                                    p = 0.2702
RESULTS FOR WOMEN IN THIS SET OF 32 SUBJECTS (NON-COOK AND 3 OUTLIERS EXCLUDED)
Poor IAP  |      8   | -2.68625 | 1.036641  | 2.932064  | -5.13752   -0.23498
Good IAP  |      7   |  0.60143 | 0.753375  | 1.993242  | -1.24201    2.44487
difference|          | -3.28768 | 1.281483  |           | -6.07145   -0.50391
                                                                    p = 0.0243
COMPARING THOSE WITH AND WITHOUT BASELINE OBSTRUCTION (FEV1% <80)
Poor FEV1 |     15   | -2.816   | .6744273  | 2.612046  | -4.26250   -1.36950
Good FEV1 |     17   |  1.12    | .696054   | 2.869904  | -0.35557    2.59557
difference|          | -3.936   | .9691973  |           | -5.91547   -1.95653
                                                                    p = 0.0003
```

*These extra tests were from individuals who accomplished two valid tests in one of the two years and had FVC that was less than 5% changed from year to year. The best test from the year without 2 valid tests was used for comparison with the other year.

**Many things contribute to unacceptable variations in FVC (the amount of air that can be exhaled from the deepest breath possible). More problems with mucus plugging in one year than the other could be one reason. The percentage exhaled in the first second would be much less affected by this. The 20% cutoff was selected due to the authors perception that most of the subjects with >20% FVC variation had not been able to be coached into doing the tests properly.

The large variance among those with less improvement indicated possible outliers. There was one outlier with a large effect on the data average. He had improved 8.82%, beyond the 99% confidence interval (C.I.) for non-asthmatics in the smoking ban study but within the 95% C.I. for asthmatics. Removing that outlier from the data analysis, since he may have asthma, along with another subject we learned hadn't been cooking the first year but was cooking at follow-up, gave significant results (**Table 2, part 2**).

Further analysis was done using tests that came close to clinical reproducibility criteria. There were 7 subjects with $\leq$5% difference in total volume exhaled between a year with two tests that agreed and the best test in the other year; removing two outliers (whose tests showed changes of 23% and 15% in FEV1%) left 18 total subjects. The difference in FEV1% change remained significant (**Table 2, part 3**). Adding more tests with variation exceeding validity criteria in both years increased the variance further, reducing the likelihood of a statistically significant difference, but should not introduce bias and may add confidence that the small data set results were not due to post-hoc analysis finding chance differences. This gave 36 subjects from 25 households (8 remained excluded for inconsistency in all tests in 1 year or because total exhaled volume varied >20% between years). With outliers excluded as probable asthmatic, the additional tests lack significance by IAP category (**Table 2, part 4**) by themselves. However, combining them and the initial 13 yields a significant result for 32 subjects (**Table 2, part 5**). One household had no detectable particles the second year, which could mean no cooking was taking place, or suggest monitoring equipment failure. Removing these subjects still yields a significant result (p = .0124).

Stratified analysis was done by gender since women, as the usual primary cooks, are more exposed. The difference did not reach significance for men but it did for women (**Table 2, parts 6 and 7**). Overall means in the exposure groups were similar so this may just be due to higher variance among the men.

Excluding 4 outliers who might be asthmatic (|%change in FEV1%| > 8), 17 had some baseline airflow obstruction (FEV1% <80). These17 had a significant improvement without stratifying by IAP compared to 15 with no obstruction (**see Table 3 on the next page**), raising the possibility that improvement in people who already have lung damage might not be dependent on achieving this level of reduction in $PM_4$. However, in multivariate analysis, $PM_4$ improvement remained an important predictor after controlling for baseline obstruction (**see Table 4, on the next page**). This was somewhat surprising since this group did not achieve better particulate reduction (8 did and 9 didn't) than those without baseline obstruction (6 did and 9 didn't). Perhaps those with more airflow problems were motivated to decrease their personal exposure to the ambient $PM_4$ that was measured (e.g., by doing less of the cooking tasks in the household). Alternatively, their sensitivity to particulates may be different.

***Table 3. Multivariate analysis of baseline obstruction and good versus poor IAP change***

```
                                TABLE III

CHANGE IN FEV1% FOR THOSE WITH AND WITHOUT BASELINE OBSTRUCTION (FEV1% <80)
FEV1% >80 |     15  | -2.816   | .6744273 | 2.612046  | -4.26250   -1.36950
FEV1% <80 |     17  |  1.12    | .696054  | 2.869904  | -0.35557    2.59557
difference|         | -3.936   | .9691973 |           | -5.91547   -1.95653
                                                            p = 0.0003
```

***Table 4. Multivariate analysis showing $PM_4$ improvement as an important predictor after controlling for baseline obstruction***

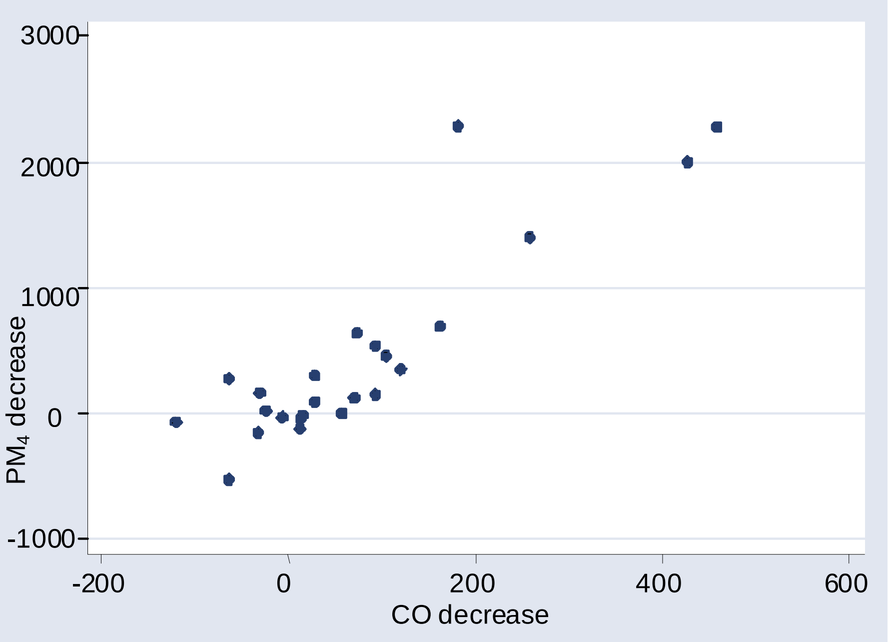
```
                                TABLE IV

MULTIVARIATE ANALYSIS OF BASELINE OBSTRUCTION AND GOOD VS. POOR IAP CHANGE
  FEV1change |   Coef.  Std. Err.     t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------
IAP reduced  | 2.327417 .9019702     2.58   0.015    0.482681    4.172154
baseFEV1% <80| 3.771712 .8966488     4.21   0.000    1.937859    5.605564
```

Further analysis using multivariate regression modeling showed that adding percent reduction in $PM_4$ did not add more predictive value, but absolute reduction added a small amount. This raises the possibility that a larger data set might show more value in just one of these reduction statistics or in different cutoffs of the absolute and percent reductions used in this combined statistic.

This analysis focused on particulates, but households also were monitored for carbon monoxide (CO) levels in both years. PM reductions correlated to CO reductions, as shown in **Figure 1**, but adding either change in CO or its percentage drop did not aid prediction.
Letting the statistical program pick airflow improvement predictors (backwards, stepwise exclusion with gender, CO, absolute and percent reductions in $PM_4$, the combined cutoff, and presence of baseline obstruction) showed that baseline obstruction and IAP reduction (by the combined cutoff) were the only significant variables.

***Figure 1. Correlation between CO and PM decreases***



## Discussion

This project aimed to show that a locally constructed "rocket" stove (with a minimal number of components that would not be difficult to obtain and maintain) would reduce some **harmful** effects of biomass smoke. Although there were problems with our testing that make it hard to be sure that the results are meaningful, there is a suggestion that before and after stove installation measurement of FEV1% could be a valuable assessment tool.

The relative simplicity of measuring a continuous decline in airflow among those exposed to damaging levels of fine particulates from cooking fires made this a logical surrogate measure for morbidity and mortality from IAP. Knowing that a month after cessation of indoor exposure to another biomass smoke source (tobacco) leads to a relatively large improvement in airflow made this an especially appealing model for study. Even if biomass smoke exposure reduction does not prove to correlate with reductions in lower airway infections in larger studies, it is important in itself, since damage from exposure leads to COPD, which can cause substantial morbidity in middle-aged people. Reduction in airway irritation is another benefit (although that probably pales in comparison to the many health needs in impoverished communities). This paper has not focused on those symptoms because of survey problems and their relatively lower health impact.

We were surprised that our survey found no difference in alleviation of symptoms by success (or lack thereof) in reducing measured IAP. Perhaps bias was introduced by the person translating questions into Quechua (a local nurse or the local project engineer). It is also possible that the lack of correlation of symptoms with $PM_4$ reduction is due to differential reduction of smaller particles (<$PM_4$) compared to larger ones that are removed from inhaled air in the upper airways. These larger particles may have more impact on cough, amount of sputum production, and number of upper respiratory infections, which may be more relevant to the symptoms on the questionnaire. Subjects reported few lower respiratory infections at baseline so significant improvement could not have occurred or been measured at the follow-up testing.

Because of the complexity of testing for this disease, this study did not try to find out which patients had asthma, which responds to many other interval factors that impact lower airway narrowing (and thus change FEV1%) through inflammation. The Scottish bar smoking ban study had sufficient numbers of asthmatics to overcome their high variability in response before and after the smoking ban. In the Peru study, the handful of people whose large change in FEV1% from year to year made asthma likely were too few for stratification within the data we collected.

The expanded analysis of 32 individuals had nearly equal numbers of men and women. While it was surprising to find that both genders were equally affected at baseline, most of these men did cook regularly and might have congregated near the fire during the cool morning and evening cooking times. The significant effect of greater $PM_4$ reduction among the women is reassuring that this type of intervention is meaningful for those who usually have the higher exposure. Longer follow-up testing in a larger portion of the women in the initial sample could help solidify this finding.

Finding the resources to go back and reward those who complete the follow-up testing could be one way of accomplishing this goal. People in this area are mostly working in subsistence agriculture and it was evident that many lacked motivation to do the follow-up testing.

The decision to use a statistic combining percent and absolute reductions of IAP came from observing that the stationary location of the measurement equipment would not capture equal proportions of smoke inhaled in each kitchen since particulates do not disperse evenly. As Cynthia, AA et al (2008) have noted, patterns of air currents and the height and habits of the cook would all contribute to differences between measured IAP and what was actually inhaled. Thus, levels need to be seen as relative but, if a kitchen started with low IAP levels, it seemed likely that > 65% reduction was just random day-to-day variation.  Therefore absolute reduction was included in the combined cut-off used for comparison. Even if this reasoning proves invalid with further testing, the results would still be explainable since people in households that started with low exposures wouldn’t have the improvement expected from “smoking cessation.”

It would also be helpful to do more analyses of this population for other effects of both the particulate pollution reduction and the reduction in CO levels. Carbon monoxide has not been associated directly with airway disease so it is not surprising that it did not correlate with improvement in lung function here. However, there are other known health benefits of these CO reductions, so it is encouraging that almost all of the households with good particulate reductions had substantial reductions in CO. Their mean decrease was 183 ppm (range 28 to 458) versus a mean increase of 18 ppm (range 120 to –57) in those with little or no reductions in particulates.

These results will likely not be easily generalized to other settings for several reasons. The location in the Andes at up to 3,200 meters above sea level may have some effects on the formation and behavior of particulates and on lung responses. The ethnic make-up of the population and their lung development and responses in this area of lower atmospheric pressure also might mean that other populations might have different results.

The use of equipment measuring particles <4 microns means that results would probably be somewhat different for studies that measure particles <2.5 or 10 microns or total particulates (but it is probably best to measure the smaller particles if possible since they have greater impact on lower airways). Nonetheless, we succeeded in showing that it is possible to obtain real improvements in lower airway function in a subset of households with significant IAP reductions after an intervention to promote the use of low-cost, efficient stoves with so-called "rocket" stove design characteristics. At follow-up, this group all had $PM_4$ $\leq$310 micrograms/meter$^3$ (average of 123.2), which represents $\geq$69% reduction (average 86.5%) in respirable particulates with the new stoves. The 14 people tested in these 10 households with better reduction in IAP had an average increase in FEV1% of 0.74% while the 18 subjects in the 12 households with little or no reduction had an average worsening of 1.86%.

The lack of prominence of IAP reduction efforts in the health and development literature is surprising. As stated by Rehfuess et al. (2006), there is an "urgent need for development agendas to recognize the fundamental role that household energy plays in improving child and maternal health and fostering economic and social development." This important area for improvement in the health of impoverished people worldwide may be relatively neglected because it is unclear how much health improvement will actually result from various programs to reduce IAP. Thus, more studies of actual health outcomes from reductions in exposure to biomass cooking smoke pollution are needed.

## Acknowledgments

All statistical testing was done with STATA 8.2
(StataCorp. 4905 Lakeway Drive, College Station, Texas 77845 USA)

This study would have not been possible without the key help of Winrock International project staffers, Lisa Buttner, Rogerio Miranda, Elisa Derby; and the staff of Centro Eco. I am especially grateful for the long hours of work from the local project engineer, Jose Humberto, and to Nelly Huaman, the nurse who functioned as both testing assistant and translator between Spanish and Quechua. Thanks also to Adrian Montalvo, Swisscontact's air pollution engineer who supplied pollution monitoring data; and to Manchester Community Health Center (Manchester, NH) for the timely donation of spirometry equipment.

## Bibliography

Akunne, A.F., Louis, V.R., Sanon, M., Sauerborn, R., 2006. Biomass solid fuel and acute respiratory infections: The ventilation factor. Int. J. Hyg. Environ. Health 209 (5), 445-450.

Bruce, N., Weber, M., Arana, B., Diaz, A., Jenny, A., Thompson, L., McCracken, J., Dherani, M., Juarez, D., Ordonez, S., Klein, R., Smith, K.R, 2007. Pneumonia case-finding in the RESPIRE Guatemala indoor air pollution trial: standardizing methods for resource-poor settings. Bull. WHO 85 (7). 535–544.

Bryden, M., Still, D., Scott, P., Hoffa, G., Ogle, D., Bailis, R., Goyer, K., 2005. Design Principles for Wood Burning Cook Stoves, Aprovecho Research Center (www.repp.org/discussiongroups/resources/stoves/Pcia/Design%20Principles%20for%20Wood%20Burning%20Cookstoves.pdf).

Cynthia, A.A., Edwards, R.D., Johnson, M., Zuk, M., Rojas, L., Jiménez, R.D., Riojas-Rodriguez, H., Masera, O., 2008. Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. Indoor Air 18 (2), 93-105.

Ezzati, M., Lopez, A.D., Rodgers, A. Vander Hoorn, S., Murray, C.J., Comparative Risk Assessment Collaborating Group, 2002. Selected major risk factors and global and regional burden of disease. Lancet 360 (9343), 1347–1360.

Ezzati, M., and Kammen, D.M., 2001. Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infections in Developing Countries. Environ. Health Perspect. 109 (5), 481-488.

Indoor Air Pollution Team, 2005. Installing Indoor Air Pollution Instruments in a Home, Version 5.1, School of Public Health, University of California, Berkeley (http://ceihd.berkeley.edu/Docs/Installing%20IAP%20Instruments%20in%20a%20Home_19Oct2005.html).

Menzies, D., Nair, A., Williamson, P.A., Schembri, S., Al-Khairalla, M.Z., Barnes, M., Fardon, T.C., McFarlane, L., Magee, G.J., Lipworth, B.J., 2006. Respiratory symptoms, pulmonary function, and markers of inflammation among bar workers before and after a legislative ban on smoking in public places. JAMA 296 (14), 1742-174.

Rabe, K.F. and Soriano, J.B., 2006. Chronic obstructive pulmonary disease: current burden and future projections. Eur. Respir. J. 27, 397–412.

Rehfuess, E., Mehta, S. and Prüss-Üstün, A., 2006. Assessing Household Solid Fuel Use: Multiple Implications for the Millennium Development Goals. Environ. Health Perspect. 114 (3), 373-378.

Scanlon, P.D., Connett, J.E., Waller, L.A., Altose, M.D., Bailey, W.C., Buist, A.S, 2000. Smoking cessation and lung function in mild-to-moderate chronic obstructive pulmonary disease. The Lung Health Study. Am. J. Respir. Crit. Care Med., 161, 381-90.

Smith, K.R., Samet, J.M., Romieu, I., Bruce, N., 2000. Indoor air pollution in developing countries and acute lower respiratory infections in children. Thorax 55, 518–532.

Smith, K.R., 2002. Indoor air pollution in developing countries: recommendations for research, Indoor Air 12 (3), 198-207.

Smith, K. R., Bruce, N., Weber, M. W., Hubbard, A., Jenny, A., Dherani, M.; Acevedo, R., Arana, B., 2006. Impact of a Chimney Wood Stove on Risk of Pneumonia in Children Aged Less Than 18 Months in Rural Guatemala: Results from a Randomized, Controlled Trial. Epidemiology 17 (6) Suppl., S45.