House of the Children's "Project Huacaria": Five-Year Evaluation (2002-2007) of Social and Health Impacts of an Integrated Water Purification/Health Education Project

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October 2008

Introduction:

Aims

This report aims to summarize quantitative and qualitative data gathered over the course of an ongoing project seeking to improve the health of children in Huacaria, an indigenous community of Manu Biosphere Reserve in southeastern Peru. The project, carried out by the non-profit organization House of the Children (HOTC) in collaboration with Huacaria community and local health and education personnel, has made a number of different interventions including renovation of an existing tap water system, health and hygiene education, construction of flush toilets for the school house, dental care, secondary and (in one case) university education scholarships for Huacaria youths, capacity building and organization of community and youth groups to maintain the water system and other sanitary installations. This report focuses on the tap water system and its social and health consequences. Research and data presented in this report have been designed and collected by Maria Luisa Morales, a Peruvian nurse who worked for many years in the regional health ministry and who has served as HOTC's health director since 2003, Carolina Izquierdo, a Ph.D. in medical anthropology who has implemented health monitoring protocols in other indigenous Peruvian communities, and Glenn H. Shepard Jr., a Ph.D. in medical anthropology and ethnobotany Ph.D. specialized in ethnomedical practices of indigenous peoples of Manu Biosphere Reserve.

Project Background

HOTC was founded in 2000 by director Nancy Santullo after a trip to the Peruvian Amazon during which she visited Huacaria, met with community leaders, and heeded their call for assistance in improving their lives and the lives of their children without losing touch with their indigenous cultural heritage. Beginning in 2002, as a result of ongoing consultation with the community, HOTC focused its efforts on improving child welfare through health and hygiene education and especially through renovating an existing gravity-flow water system installed in 1993 by the Peruvian government agency FONCODES.

This FONCODES gravity flow tap water system simply gathered stream water and channeled it via a series of tanks to a number of rustic outdoor taps around the schoolhouse, servicing only eight of Huacaria's sixteen widely scattered households. The final and crucial stage of the

construction—the loading of the tanks with rocks and sand to achieve water purification through a natural biological process "slow sand" filtration—was never completed, meaning that contaminated stream water was delivered directly to households without any purification or treatment.
Many of the tap stands were broken, and moreover, the greywater generated flowed directly onto the ground without any drainage system, generating foul mud puddles throughout the central village area year-round.

Thus a major goal of HOTC's "Project Huacaria" was to renovate the existing gravity flow tap water system by properly installing the slow-sand filter for purification, including proper greywater drainage, and extending the reach of the tap water system to include all households.

Research Activities

HOTC carried out a number of baseline and ongoing research activities in Huacaria to document the health and social impacts of their programming. These activities included:

(1) A social-sanitary questionnaire carried out in 2003 by Shepard (GHS) to characterize the prevailing social, hygienic and sanitary conditions and practices.

(2) Ethnographic observations in 2003 by GHS of water use, sanitary practices, general observation of health and dietary practices, and in-depth interviews concerning local health concepts relevant to water and water-borne diseases.

(3) Baseline microbiological analysis of samples taken from water sources (including the existing tap water system) used in 2003 by different families of Huacaria.

(4) Ongoing microbiological analysis of water samples from the renovated water filtration system and other local water sources.

(4) Ongoing health monitoring by the project's health director, nurse Maria Luisa Morales, in collaboration with the regional health ministry including: biometric monitoring of children's nutritional status, regular analysis intestinal parasitism, anemia monitoring, and systematization of health post data concerning incidence of reported diarrheal diseases in children.

Overview of Huacaria Native Community

The community of Santa Rosa de Huacaria (hereafter, Huacaria) is located in the Kosñipata valley at the headwaters of the Alto Madre de Dios River in southeastern Peru (Map 1). The community center is located on a small tributary river, Río Huacaria, of the lower Piñi-Piñi River within the Cultural Zone of Manu Biosphere Reserve, a UNESCO world heritage site. A rocky road about 8 km long links the community to the growing Peruvian township of Pilcopata, about 180 km along the one-lane highway going from the city of Cuzco to the mission town of Shintuya on the banks of Alto Madre de Dios. Huacaria currently has a population of about 160 people belonging to three distinctive indigenous groups: Huachipaeri, Matsigenka and Quechua.

The founding members of Huacaria are descendents of the Huachipaeri, an indigenous people belonging to the Harakmbet cultural group that once dominated the Kosñipata valley and the Alto Madre de Dios River. Harakmbet peoples including the Huachipaeri were decimated by disease and violence as the Kosñipata Valley was colonized by outsiders especially beginning in the early 20th century. Especially devastating to the Huachipaeri was a smallpox epidemic brought to the Kosñipata valley in 1948 by a mestizo trader, estimated to have killed about two thirds of the total remaining Huachipaeri population and leaving only about 70 full-blooded Huachipaeri alive. Since that time, the Huachipaeri began intermarrying with other local indigenous groups (and former enemies), especially the Matsigenka who had resided in more isolated settlements along the upper Piñi-Piñi River, and hence were not as affected by the epidemic. Some Huachipaeri families joined fellow Harakmbet speakers at the predominately Amarakaeri mission community at Shintuya, and others assimilated into other indigenous groups (for example the Piro) or into the Peruvian colonist population. The only predominately Huachipaeri communities left are Huacaria and Qeros, with a combined population of about 200. But even in Huacaria, the largest extant Huachipaeri population, most of the current Huachipaeri speakers are in fact of mixed Huachipaeri-Matsigenka heritage. Nonetheless, despite their current smaller numbers, the Huachipaeri have been historically considered the politically dominant group, thus most of the mixed Huachipaeri-Matsigenka households identify more strongly with their Huachipaeri heritage.

The Matsigenka represent a much larger and more geographically extensive Amazonian indigenous group, numbering approximately 10,000. They are dispersed in small settlements ranging in size from a few dozen to a few hundred people, about 85% of whom are found along the upper Urubamba River but with smaller numbers found throughout the Alto Madre de Dios and Manu River headwaters (see Map 1). The Matsigenka belong to the Arawakan language family, entirely unrelated to Huachiapaeri. Like their divergent languages, Matsigenka and Huachipaeri cultures are also quite distinctive. Nonetheless, despite numerous cultural differences, both the Matisgenka and Huachipaeri share a general pattern of lowland Amazoniain subsistence economy based on small-scale agriculture of manioc, bananas, maize and other crops as well as hunting, fishing and gathering forest resources. Traditionally, the Matsigenka have been a politically subservient minority ethnic group in Huacaria, living mostly on the opposite bank of the Huacaria River from the main concentration of the politically dominant, mixed Huachipaeri-Matisgenka households concentrated around the schoolhouse. In recent years—and especially since 2002 when a Polish adventure film crew made an unauthorized visit to the Upper Piñi-Piñi River and spread respiratory diseases among the isolated Matsigenka living there—increasing numbers of Matsigenka families have emerged from the Piñi-Piñi and taken up permanent residence in Huacaria, seeking Western medical care, schooling and economic opportunities.

The Quechua-speaking indigenous people in Huacaria community represent a very distinctive population from both the Matsigenka and the Huachipaeri. They are relatively recent migrants from the high Andes, and live mostly by selling coca leaves and other farm products in the nearby town of Pilcopata. The Quechua mostly live along the rocky highway connecting Huacaria with Pilcopata, a reflection of their greater integration into the regional cash economy. The Quechua families are also predominantly Evangelical Protestant, in contrast to the rest of the community which is predominantly Catholic. A much smaller number (only two) mixed

Quechua-Huachipaeri households are found in Huacaria, reflecting this greater sociocultural distance. Generally, social and political relationships are more tense and conflictive between the Quechua-speakers and the rest of the community, especially the politically dominant Huachipaeri families, a further reflection of the profound culture differences.

Pre-Intervention Baseline Study (2003):

Social-Sanitary Census

The social-sanitary questionnaire administered in 2003 to eighteen of Huacaria's then 22 households (three of the Quechua households and one Huachipaeri family) were absent from the community at the time) provided a general panorama of the community and specific health-related and sanitary conditions and practices. Despite some intermarriage and a high degree of contact and exchange among the three ethnic groups, the three groups still appear to maintain distinctive sociocultural and economic features within the relatively small community (see Table 1).

Table 1: Socioeconomic characterization of the three main ethnic groups, based on interviews with 18 of 22 households. Ethnicity and language codes: H-Huachiapaeri, M-Matsigenka, Q-Quechua, Sp-Spanish. Mixed ethnicity indicated by +. Percent values indicates proportion of households per ethnic group characterized by a given socioeconomic indicator. Note that multiple economic activities are possible per household so totals for income sources may exceed 100%.

Ethnicity	No. House-holds	No. resi-dents	Location	Main Language	Religion	Income sources
M	6	28	across river 67% central community 33%	M 100%	Catholic 67% None 33%	agriculture 0% logging 0% crafts 100%
H+M	6	35	central community 100%	Sp 67% H 33%	Catholic 67% None 33%	agriculture 17% logging 33% crafts 83%
H+Q	2	12	central community 50% up river 50%	Sp 100%	Catholic 50% None 50%	agriculture 50% logging 50% crafts 50%
Q	3	21	along road 100%	Q 100%	Evangelical 100%	agriculture 100% logging 33% crafts 0%

The Matsigenka households maintain a more traditional indigenous lifestyle, living mostly separate from the main community across the Huacaria river, speaking the native Matsigenka tongue as their main household language, though many also speak Huachipaeri and/or Spanish as a second language. The Matisgenka engage mostly in traditional subsistence economy (swidden garden farming, hunting, fishing, gathering) with some cash income derived from the sale of indigenous crafts to tourists. The Quechua-speaking faction of the community engage in a lifestyle typical of migrant peasant farmers in the region, gaining cash income by selling various agricultural products (including coca leaves) in the nearby town of Pilcopata; this dependence on cash income from agricultural production is part of the reason why the Quechua families have maintained themselves along the road to Pilcopata. A few Quechua families also engage in commercial logging for income. The Quechua families interviewed were all

Evangelical Protestants, unlike the predominant Catholic religious affiliation of the rest of the community. Though Quechua is the predominant household language, most also speak some Spanish. As noted above, the politically dominant Huachipaeri ethnic group in the community is represented by ethnically mixed households, mostly Huachipaeri-Matsigenka but also including a few marriages between Huachipaeri and Quechua people. Spanish is the predominant language spoken in these ethnically mixed households, though Huachipaeri, Matsigenka and Quechua may also be spoken in these households as well. The Huachipaeri faction is concentrated in the central community region of the community, mostly organized closely around the village school house. Their economic activities represent a blending of traditional indigenous subsistence activities with some cash-earning activities such as logging and selling agricultural products in Pilcopata. Like the Matsigenka, however, many Huachiapaeri also receive supplemental cash income by selling traditional indigenous crafts to tourists.

Table 2: Dietary habits of the three main ethnic groups, based on interviews with 18 of 22 households. Ethnicity and language codes: H-Huachiapaeri, M-Matsigenka, Q-Quechua, Sp-Spanish. Mixed ethnicity indicated by +. Percent values indicates proportion of households per ethnic group mentioning a given recent food source.

Ethnicity	No. House-holds	Recent starch source	Most recent game animal consumption	How acquired	Most recent fish consumption	How acquired
M	6	manioc 100% other tubers 83% banana 17% rice 0% beans 0% potato 0%	<2 days 50% 2-7 days 17% 7-30 days 33% >30 days 0%	family member 83% non-relative 17% purchased 0%	<2 days 83% 2-7 days 17% 7-30 days 0% >30 days 0%	family member 66% non-relative 33% purchased 0%
H+M	6	manioc 100% other tubers 50% banana 17% rice 33% beans 17% potato 0%	<2 days 50% 2-7 days 50% 7-30 days 0% >30 days 0%	family member 67% non-relative 33% purchased 0%	<2 days 100% 2-7 days 0% 7-30 days 0% >30 days 0%	family member 50% non-relative 33% purchased 17%
H+Q	2	manioc 100% other tubers 0% banana 50% rice 100% beans 50% potato 50%	<2 days 100% 2-7 days 0% 7-30 days 0% >30 days 0%	family member 100% non-relative 0% purchased 0%	<2 days 100% 2-7 days 0% 7-30 days 0% >30 days 0%	family member 50% non-relative 0% purchased 50%
Q	3	manioc 100% other tubers 0% banana 33% rice 100% beans 100% potato 100%	<2 days 0% 2-7 days 0% 7-30 days 0% >30 days 100%	family member 67% non-relative 33% purchased 0%	<2 days 33% 2-7 days 0% 7-30 days 0% >30 days 67%	family member 33% non-relative 0% purchased 67%

Ethnic affiliation within the community also shows a noticeable impact on diet, as reflected in simple interviews concerning most recent dietary items (Table 2). Again, the Matsigenka show a pattern more typical of the lowland indigenous diet, with a preponderance of manioc and other native tubers, and to a lesser extent, bananas, in the diet with a complete absence (at least at the time of the interview) of introduced dietary items such as rice, beans and potatoes. The Quechua families show a noticeably different dietary pattern: typical highland

Peruvian staples such as potatoes, beans and rice were just as frequent as manioc. The mixed Huachiaperi-Matsigenka and especially Huachipaeri-Quechua families were somewhat intermediate, mentioning introduced items such as rice, beans and potatoes in some cases.

Despite significant game animal depletion in the region, game animals (especially the paca, a large rodent) hunted with shotguns as well as bow-and-arrow remain a frequent element in the diet of both the Matsigenka and the Huachiaperi families: all but one of the families interviewed for these groups had consumed some game animal within seven days prior to the interview, and all had consumed game animal meat within the past month. Fish is an even more frequent dietary item: all but one of the Matsigenka and Huachipaeri families interviewed had consumed fish within the past two days, and all had consumed fish within the past week. The Quechua families, by contrast, hunt occasionally, but none of those interviewed had consumed any game animal meat in more than a month. Likewise, only one of the Quechua families interviewed had consumed fish within the past two days, while the remaining two had not consumed fish in over a month. Whereas the Matsigenka and Huachipaeri-Matsigenka families interviewed mostly fished for their own subsistence, the majority of Quechua and Huachipaeri-Quechua families interviewed had recently purchased fish, either from other community members or in the fish market in Pilcopata.

General features of water use and sanitary practices noted in the interview also varied markedly by ethnic affiliation, though in some cases this represented mere geography (presence of tap stands only in the central community area) while in other cases it represented a true cultural difference (for example, frequency of bathing). All families—mostly ethnically mixed Huachipaeris and one Matsigenka family living in the central community area—who had convenient access to the rustic tap stands installed by the 1993 FONCODES project around the central community area used these as their main water source. Water drawn from the tap stands was used for cooking, drinking and washing (food, dishes, clothes, hands/face). Some families even used the tap stands for bathing, rather than going to the river to bathe. Where tap stands were not installed—both across the Huacaria river in the Matsigenka section and along the road in the Quechua section—most families used water carried from a nearby stream and stored in pots or buckets as their main water source. Two Huachipaeri-Quechua families living close together at some distance up river from the central village area used water channeled through the ground from a distant spring on a hill as their main source of water; additionally, one Quechua family not present at the time of the interview was observed later to use spring water channeled through the ground and along a rustic bamboo tube as their water source.

When asked about whether they performed any kind of treatment for drinking water, all families interviewed mentioned either boiling or the addition of chlorine drops. Chlorine treatment, which requires the purchase of chlorine purification drops, was only practiced by families with access to cash income, especially the Quechua as well as some of the mixed Huachipaeri households. The universal mention of water purification methods is clearly the result of health education programs that emphasize the importance of water treatment. However several families (especially among the Matsigenka) admitted during the interview that they were not consistent in performing purification of drinking water. Moreover, ethnographic observation (see below) throughout the community made it clear that untreated water, and especially the untreated water emerging from the tap stands in the central community, was frequently consumed without any treatment. As noted in more detail below, a few families interviewed mentioned that their children sometimes refused to drink treated water because of its inferior taste.

The majority of Matsigenka and Huachipaeri families had simple open-pit latrines covered with planks or logs located some 50 m or so from their residence. Those who do not have latrines, or those who are away from their households defecate on the ground in scrubby secondary growth surrounding the village, in the forest or in agricultural gardens. The Quechua families interviewed, who live on more steeply sloping, rocky ground along the road, did not have latrines but rather defecated on the ground. Young children prior to full toilet training often defecate on the ground in and around houses. Most people mentioned using the leaves or herbs to wipe themselves after defecation, while a few people mentioned using purchased toilet paper. Soiled leaves or toilet paper are universally thrown on the ground near the place of defecation. All families interviewed stated they wash their hands after defecation, some only with water (especially the Matsigenka and Huachipaeri) and the rest with soap and water, again a reflection of ongoing health education programs. Several Matsigenka families interviewed stated that they did not formerly practice hand washing after defecation, and only began doing so after receiving instructions from health personnel. A few people mentioned using certain succulent forest herbs that produce soap-like foam to wash their hands when they defecate in the forest or gardens where there are no nearby water sources for hand washing.

A significant cultural difference was noticed between the Quechua speakers and the remainder of the community with regards to bathing. Whereas all Matsigenka and Huachipaeri mentioned bathing once or twice a day, all of the Quechua speakers interviewed mentioned bathing only two to three times per *week*. This habit is associated with the belief, mentioned spontaneously by the Quechua people interviewed, that excessive bathing caused colds and other health problems because of the "shock" between the cold water and the hot tropical sun. This belief is related to the widespread "humoral" theory in Andean medical systems whereby imbalance between "hot" and "cold" properties causes illness.

Table 3: Water use and hygienic habits of the three main ethnic groups, based on interviews with 18 of 22 households. Ethnicity and language codes: H-Huachiapaeri, M-Matsigenka, Q-Quechua, Sp-Spanish. Mixed ethnicity indicated by + (note H+M and H+Q households have been combined). Percent values indicates proportion of households per ethnic group mentioning a given habit. Cl=chlorine drops or tablets. (* Note that one of the Quechua families absent at the time of the interview was later noticed to use rustically channeled spring water as its main water source).

Ethnicity	No. House-holds	Main water source	Water treatment	Place of defecation	Hand washing	Bathing frequency
M	6	tap stands 17% stream 83% spring 0%	boil 100%	latrine 67% ground 33%	water only 100%	1-2 times/day
H+M H+Q	8	tap stands 75% stream 0% spring 25%	boil 50% Cl 50%	latrine 88% ground 12%	water only 75% soap/water 25%	1-2 times/day
Q	3	tap stands 0% stream 100% *spring 0%	boil 33% Cl 66%	ground 100%	soap/water 100%	2-3 times/week

Ethnographic Observation

Ethnographic observations were carried out in all households of the central village area (Huachipaeri, Matsigenka families). It was not possible to observe water-related activities among the Quechua families because they tended to spend long periods away from their houses during the day tending their agricultural and coca fields or trading in the nearby town of Pilcopata. Observations concerning water use, hygienic habits, and food consumption were detailed in 106 vignettes, not included here. Based on these observations it seems clear that the presence of taps in the vicinity of the central community area greatly increase the frequency of water use for all purposes, when compared to the frequency of use in households without taps who bring their water from nearby streams. On the one hand, this seems to represent an advantage in terms of hygiene, as people find it more convenient to wash hands, plates, and clothes and take baths with the easily available water. On the other hand, the lack of any drainage system in the original Huacaria water system lead to the accumulation water in large, squalid puddles at the base of the concrete sink structure, which had no drainage system so that greywater drained directly onto the surface. Microbiological analysis (see following section) demonstrated these to be the most contaminated of the water samples collected in the 2003 study (see Table 4, sample #6). These puddles also likely served as centers of propagation of mosquitoes and other pests. Domestic animals such as chickens, dogs, and especially ducks drank, ate food residues, and wallowed in the puddles, which tended to spread over the entire house patio—the areas most frequented by barefoot young children— forming a foul-smelling, muddy mess even during the peak dry season. Due to the convenience, families with taps are more wasteful than those who carry water in pots from nearby streams, contributing further to the accumulation of contaminated greywater in the vicinity of houses and kitchens.

Latrines made by the Matsigenka and Huachipaeri families Huacaria are mostly found at least 50 m from the house area, and are generally constructed so discreetly, often hidden by secondary vegetation, that a casual visitor would not even be aware of the structure. These rustic, open-pit latrines are fairly large and open, permitting ventilation and light. In almost all latrines, two holes or seats are found side by side, permitting couples to go to the latrine together and allowing mothers go to the latrine along with a younger child. A regional conservation organization had donated toilet-building materials to the community, from which a handful of families built rustic manual-flush toilets with "Turkish-style" (stand-up "footprint" design) concrete toilet openings housed within a brick and concrete outhouse building. However most of the donated materials lay unused in a pile behind the school house, because most families could not afford the additional costs of buying cement to build the structures. Moreover, the two existing toilets (one at the school and another at a house) were being under-used in 2003 because the internal space was cramped (building materials are cost-prohibitive on size), poorly ventilated and difficult to clean. As noted in Table 3, all families interviewed in 2003 were aware of the importance of hand-washing after defecation, mostly due to ongoing education by local health personnel of Pilcopata

All inhabitants of Huacaria in 2003 appeared aware of the risks of drinking untreated water from streams and the original tap water system. The Matsigenka families interviewed in 2003— who were still using streams as their main water source—specifically mentioned that they avoided collecting water downstream from latrines or other brush areas habitually used for defecation. In fact, one of the small streams on the opposite bank from the community center was jokingly named *Tigatsiaari*, "Feces River," by one informant, since it was known to be contaminated. As noted in Table 3, all of those interviewed stated that they routinely boiled water for drinking or treated it with chlorine drops or tablets. Several of those interviewed explicitly noted the role of health workers in promoting these water purification practices in recent years. However several of those interviewed admitted to being inconsistent in their water purification practices. Many ethnographic observations were made of people (especially children) drinking directly from the tap stands, which in 2003 still served untreated stream water. One Quechua mother mentioned the fact that her children did not like the taste of the chlorine drops or tablets in the water and would drink stream water instead; a Huachipaeri mother likewise mentioned the fact that her children sometimes ignored her warning to drink only the lukewarm water she had boiled, and preferred to drink cool water from the tap stand or the Huacaria river. Given the significant levels of water contamination observed (see following section), it was apparent that many people in the community, especially children, were frequently exposed to pathogenic water-borne fecal coliform bacteria in their drinking water

Interviews conducted in 2003 concerning recent illnesses and perceived causes of death among family members demonstrate the toll taken by gastrointestinal illnesses (diarrhea, vomiting, parasites, etc.) especially in the past. In recent decades, however, illness and especially mortality associated with gastrointestinal diseases appears somewhat to have decreased due to educational, sanitary, and medical interventions especially by the Health Post of nearby Pilcopata. The most frequent health problems noted in the community were respiratory ailments (cough, cold, bronchitis, pneumonia). Colds and other respiratory problems are typically attributed to contagion by foreign tourists who arrive regularly. Colds are especially debilitating for the Matsigenka families who have recently arrived from remote settlements in the Piñi-Piñi headwaters. They first came to Huacaria after respiratory illness spread through the region in the wake of film and adventure groups (a Polish television crew, Spanish tourists) that have explored the region in search of the mythical city of Paititi, especially since 2001. Having minimal defenses for these exotic illnesses, colds cause isolated Matsigenka to succumb quickly to severe pneumonia.

Traditional Health Concepts

Interviews concerning mythology and local medical concepts revealed important details about traditional understandings of health and hygiene. Two different Matsigenka myths concerning the origins of clean water were recorded. The first, told by Ana Vitente, was a fragmentary tale relating how in ancient times, people had no water to drink except for swamp water and slimy algae. The nocturnal, common potoo (*Nyctibius griseus*, related to the whippoorwill), known as *maronto* in Matsigenka, brought fresh water to the streams by singing its morose, hollow, descending call: *Maro-ton-ton-ton*. The second story, told by Tito Ramos, was more detailed, and related a similar fable about the lack of clean water in ancient times. In this tale, however, the origins of fresh water are attributed to *Shigentiri*, the dragonfly:

***Sanaari Nia*: "The Awakening of the Waters"**

Long ago, people had no clean water to drink. Instead, they drank from muddy swamps and stagnant puddles of algae and slime. One day, *Shigentiri*, the Dragonfly, watched a man hauling gourds of filthy water.
"Wouldn't you prefer to have clean water to drink?" asked Dragonfly.
"Yes!" answered the man. "All we have to drink is this muck."
"So be it," said Dragonfly, "I will awaken the waters. Follow me."

> The man followed Dragonfly through the forest and soon they came upon a new spring, gurgling and splashing on the rocks. "Don't fill your gourds yet," said Dragonfly. "Wait 'til tomorrow, and never again will you have to drink swamp water."
>
> The man obeyed Dragonfly's wise words, and when he awoke he saw that the spring had filled the stream basin. People have had fresh, clear water to drink ever since. And so it was.

The story reflects the traditional notion that water that is stagnant and muddy is inappropriate to drink, while water that is clear, running and free of sediment (*sanaari* in Matsigenka) is assumed to be pure and hence drinkable. The story also makes clear the importance of restraint and respect in indigenous peoples' relationship with natural resources: by obeying the dragonfly's warning and resisting greedy thirst through the night, the man allows clean water to flow eternally. Indigenous mythology is replete with such lessons in restraint and balance in the use of natural resources.

Both the Matsigenka and Huachipaeri are aware of the existence of helminthic intestinal parasites, known as *tsomiri* or *tseikintsi* ("worms") in Matsigenka; helminthic infections are attributed to the eating of unwholesome foods or dirt. The Matsigenka and Huacaria also both possess a traditional concept of water contamination and water-borne diseases, attributed to a leech-like water worm known in Matsigenka as *penta* and Huachipaeri as *mat'a*. *Penta* is said to be found in stagnant, muddy, or slow-moving waters and enters the body when such water is drunk without boiling or treatment, causing stomachache, diarrhea, chest pain, inflammation of the organs, and other serious illnesses. The existence of this traditional concept may contribute to the willingness of the Matsigenka and Huachiaperi people to adopt new practices such as boiling water for drinking. According to one Matsigenka man interviewed:

> There was no *penta* long ago. He came from deep in the water. A woman went to wash in the river and *penta* swam up her vagina. *Penta* is like the *canero* fish [a tiny gill-parasite of larger fish, which can also enter humans]. *Penta* multiplied and the woman's belly became large and she gave birth to many *penta* that entered the water and there they are today. They live in dirty, stagnant water, in mud, rotten leaves, or stuck to rocks. In fast-moving streams it gets washed away down river, but in slow water it multiplies. If you drink *penta* with the water, it goes to your organs, to your stomach, to your liver, to your heart. You get pale and skinny and yellow and then you die. It is in the tap water system too. [Sometimes we see] lots of them squirming in the water.

Although the tap water was first considered to be pure and drinkable because according to traditional notions it was clear, flowing and sediment-free (*sanaari* in Matsigenka), the observation by some people of *penta* worms and other impurities (for example, putrid flesh of animals that had drowned in an open tank) emerging from the taps provided confirmation of the unwholesome status of the water in the tap water system.

Another significant local concept relevant to health and hygiene is the notion that "the land (or soil) gets tired, annoyed, fed up" (in Matsigenka *operatanaka kipatsi*; Huachipaeri *sorok' osok'haindai*). It is said that when a family inhabits the same house and patch of land for many years, the land or environment become tired, annoyed, and fed up with the family, taking revenge (Matsigenka: *opuigatakera*) and inflicting illness and misfortune. This belief contributed in the past to a "centripetal" force minimizing village permanence and causing frequent migrations between different settlements and garden sites. Frequent migrations were part of an overall environmental strategy that helped ensure the availability of fish, game, good agricultural lands, and clean water near the village. Today, the community has become increasingly sedentary, owing largely to the availability of primary education, health services, economic opportunities, and infrastructure such as the water system and the road. The concentration around the central village area has brought certain educational, economic, and health advantages while also provoking a number of environmental problems including the paucity of fish and game near the village, and contamination of the water supply. The claustrophobic village environment also gives rise to social problems associated with envy, competition for economic resources, and political control. Several families mentioned the fact that they preferred to live at some distance from the main settlements to avoid conflict, jealousies, and *miramiento* ("envious gaze"). In recent times, however, the "centripetal" force of village dispersal to avoid environmental depletion and social conflict has been largely overcome by "centrifugal" forces created by infrastructure investments in the school, the health clinic and the tap water system. Nonetheless, some voices in the village have discussed the possibility of re-occupying the more fertile agriculture lands some 5-8 km (two hours walking) inland where past villages were located, and where fish and game are more abundant.

Microbiological water sampling

In 2003, 22 water samples were collected from different streams, springs, and drinking water sources as well as from collection and distribution tanks and several taps of the existing potable water system (see Table 1). Water samples were kept on ice and taken immediately to the Water and Food Laboratory of the Regional Health Department in Cuzco (affiliated with the Peruvian Health Ministry) for microbiological analysis. The results of the baseline water sample analysis in 2003 demonstrated that all available water sources used in 2003 by the people of Huacaria, including tap water, were contaminated by fecal coliform bacteria and thus deemed unhealthy by Peruvian Health Ministry as well as international health standards. Contamination tended to increase downriver, reaching the highest levels in larger streams and rivers such as the Huacaria (Table 4. sample #4), Bienvenida (#21, 22) and Quebrada Dumas (#16) that gather waters from multiple, contaminated sources. The highest levels of contamination are found in streams that receive runoff from the road and where large domestic animals such as goat and sheep are present, notably Quebradas Bienvenida and Dumas, showing respectively 1100 and 2400 colony forming units (CFUs) of fecal coliform bacteria per 100ml water.

The 2003 water samples can be divided into three distinct groups corresponding with the three cultural groups of the community and three distinct patterns of water use. The Matsigenka families living on the opposite bank of the river from the community center had no access to the tap water system, and thus collect water for cooking, drinking, and other purposes from small streams near the house. Though contaminated by Health Ministry standards, these streams proved to be the *least* contaminated water sources in use at the time, with an average fecal coliform level of 72 units (samples #1, 2, 3; range 48-105). The Huachipaeri section in the central community area made almost exclusive use of tap water from the existing water system. The three taps measured had average fecal coliform levels of 130 units (samples #5, 7, 15; range 60-240), nearly twice that of the stream water used by Matsigenka families on the opposite bank. The Quechua families living along the road separate from the main community area got their water from the highly contaminated Quebrada Bienvenida, with average fecal coliform levels of 603 units (samples #18, 19, 21, 22; range 93-1100).

One Quechua and one Huachipaeri-Quechua family were observed to have brought water downhill closer to the house from a nearby spring as far as 250 m away by means of a narrow channel cut in the earth. Short sections of plastic pipe (left over from the water system construction) or bamboo tubes were used at a few points along the trajectory. In one of these, fecal coliform levels at the spring itself were 41 units (#14), while water collected at the household had a fecal coliform count of 78 (#13), not surprisingly given the long trajectory of the water through the narrow earth channel. A pair of capybara wild animal pets were also observed to wallow and play in the water channel, likely contributing to the contamination. A second sample was taken at the house water outlet a few hours after a routine cleaning of the channel, and this sample proved to be extremely contaminated with 2400 units, due to the disturbance and high sediment levels produced by the channel cleaning.

The collecting point for the tap water system in the central community area, a small branch of Q. Dumas, had a level of fecal coliform contamination of 30 units (#9), lower than many other local sources. However community members observed that during the rainy season (this research was carried out during the dry season), the source stream receives runoff from the road, less than 150 m away, and becomes much more contaminated. However contamination levels increased steadily as water descended through the system, reaching 65 units at the distribution tank (#12) and as high as 240 at the family taps (#15). Thus it would appear that fecal material from the ground was entering the underground pipes and further contributing to water contamination. Another source of contamination was an open, narrow, never-completed filtration tank located about halfway between the collection and distribution tanks. Community members noted that wild animals such as toads, forest rodents and even deer sometimes fell into the deep tank and drowned, eventually rotting and contributing a foul odor to the tap water.

Two minimally contaminated freshwater springs were also located in 2003 with the assistance of local research assistants (samples #8, 20) was located on a slope close to the highway in the Quechua-inhabited area and also shows minimal contamination (4 units). However, these two sources could not be secured, and contamination levels varied depending on rainfall with random testing.

Table 4: Baseline Microbiological Analysis of Water Samples from Huacaria, July 2003.

No.	Date	Coordinates	Locality (Waypoint Code)	Description	Coliform bacteria CFU/100 ml Fecal	Coliform bacteria CFU/100 ml Total	Aerobic bacteria CFU/mg
1	6/28/03	S 12° 53.064' W 71° 26.932'	Quebrada Purma (H2MLC1)	Rocky stream, water source for Melchor Ankoro family	65	140	200
2	6/29/03	S 12° 53.073' W 71° 26.862	Q. Purma (H2MARI)	Water source for Mario Kaparo family; downstream from #1	48	76	240
3	6/29/03	S 12° 52.969' W 71° 26.826'	Q. Waserokmame (H2ERLIN)	Water source for Emilio and Erlinda residence group	105	106	144
4	6/29/03	S 12° 53.149' W 71° 26.745	Río Huacaria (HRIO1)	Main river, sample collected at main crossing, bathing point	312	640	216
5	6/29/03	S 12° 53.212' W 71° 26.699'	Tap #14 - School (HPIL14)	Double tap close to school house	90	90	544
6	6/29/03	S 12° 53.212' W 71° 26.699'	Tap #14 - discharge (HPIL14)	Discharge from tap #14 accumulated in puddle	600	1000	896
7	6/29/03	S 12° 53.203' W 71° 26.648'	Tap #1 - Alberto (HPIL1)	Tap used by Alberto Manqueriapa family	60	74	760
8	6/30/03	S 12° 53.797' W 71° 26.825	Spring "Cerro Alejandro"	Spring on steep hill, suggested source for renovated water	<1	10	2112

			(HCERR1)	system			
9	6/30/03	S 12° 53.472' W 71° 26.588'	Collecting tank on branch of Q. Dumas (HTANKØ)	Collecting point for current water system; receives runoff water from road (~150 m)	30	34	1832
10	6/30/03	S 12° 53.449' W 71° 26.613'	Sedimentation tank (HTANK1)	Open sedimentation tank for current water system	28	30	3016
11	6/30/03	S 12° 53.380' W 71° 26.634'	Filter tank (HTANK2)	Tank to receive slow sand filter (but filter never installed)	62	70	1648
12	6/30/03	S 12° 53.365' W 71° 26.647'	Distribution tank (HTANK3)	Distribution tank for current water system	65	104	1600
13	6/30/03	S 12° 52.945' W 71° 26.427'	Santiago household (HSANTI)	Spring water (#14) brought in earth channel ~250m	78	128	816
14	6/30/03	S 12° 52.933' W 71° 26.342'	Santiago's spring (H2SANT)	Spring on hillside; Santiago household water source (#13)	41	66	1112
15	6/30/03	S 12° 53.259' W 71° 26.691'	Tap #16 - Dumas (HPIL16)	Dumas family water source; pipe broken, water runs constantly	240	1100	2256
16	6/30/03	S 12° 53.259' W 71° 26.691'	Q. Dumas (HPIL16)	Stream by Dumas household; water source when tap dries	2400	2400	1408
17	6/30/03	S 12° 52.945' W 71° 26.427'	Santiago household (HSANTI)	Same as # 13, taken after periodic cleaning of channel	2400	2400	1044
18	6/30/03	S 12 53.709' W 71° 26.181'	Q. Bienvenida (HSERR1)	Condori family water source; near Huacaria-Pilcopata road	93	150	320
19	6/30/03	S 12 53.787' W 71° 25.984'	Q. Bienvenida (H2ALV1)	Juan Alvarez family water source; downstream from #18	120	2400	216
20	6/30/03	S 12° 53.725' W 71° 25.935'	Juan Alvarez spring (H2ALV2)	Spring on hillside near highway; suggested source for Quechua family water system	4	43	184
21	6/30/03	S 12° 53.816' W 71° 25.699'	Q. Bienvenida (HBRUNO)	Bruno Alvarez family water source; downstream from #19	1100	1100	240
22	6/30/03	S 12° 53.839' W 71° 25.635'	Q. Bienvenida (H2WILB)	Wilber Alvaro family water source; downstream from #21	1100	1100	408

Baseline study summary

Amazon rain forest such as the Matsigenka and Huachipaeri lived traditionally in widely dispersed, semi-nomadic settlements composed of a few related families. Only in recent decades—mostly due to the insistence of Christian missionaries—have they begun to live in more permanent and densely populated communities, sometimes mixing with outsiders. The community of Huacaria is currently composed of three distinctive ethnic groups—Huachipaeri, Matsigenka, and Quechua—who demonstrate certain marked cultural differences reflected in different economic adaptations, dietary habits, complex interethnic political and marriage relations, and in some cases contrasting hygienic habits. The increase in population density and more sedentary lifestyle has generated a number of problems including decreased amounts of fish and game near the community, higher levels of social conflict between families, and fecal contamination of the water supply. The people of Huacaria have recently been instructed by government health workers to treat water through boiling or chlorine drops before drinking. However ethnographic observations and comments made by community members themselves noted that community members, especially children, were not consistent in maintaining these practices. A government-funded potable water system installed in Huacaria in 1993 supplied tap water to a limited number of households, but the project engineers did not install the filtration system called for by the project design. Thus, prior to HOTC's intervention, tap water flowed directly from a contaminated stream. Thus all of Huacaria's residents were exposed to frequent and high levels of fecal coliform bacteria in all of the available water sources, including the taps.

Huacaria demonstrated numerous positive conditions for the renovation of the water system and the installation of a hygienic center for school children: the presence of nearby surface sources of relatively uncontaminated spring water; a strong village leadership; and the willingness of House of the Children to spend the time and resources necessary for achieving an appropriate, functioning system. However for the water system and hygienic center to work in the long run, the baseline study's results emphasized the extreme importance of adapting the system to local cultural conditions and environmental realities while ensuring full community participation.

Summary of intervention (2004-2006):

From 2004-2006, HOTC carried out a complete renovation of Huacaria's gravity flow tap water system. Existing structures (collecting and distribution tanks) from the FONCODES project were re-engineered to provide adequate water collection, natural pre-filtration (using local rocks) and slow-sand filtration to supply the central community area. All underground pipes were removed and replaced by new pipes. Existing tap stands (many of which no longer functioned) were destroyed and replaced with utility sinks incorporating sturdy imported materials (stainless steel sink basin, sturdy standard fittings, stone counter top) as well as local materials (river stones) in a rugged yet aesthetically pleasing design. A prototype model was first installed in one household, and then modifications were made according to the lessons learned during its construction and use. Observing local peoples needs and habits, additional auxiliary tap stands were later installed lower to the ground for use in washing pots, pans, and feet. Unlike the previous system, which dumped greywater directly onto the household patio surface, greywater are now serviced through an underground drainage system. To attend to the Matsigenka families living across the Río Huacaria, a galvanized tube supported by a small suspension bridge was constructed. The Quechua families living along the road lie at a higher elevation than the central distribution tank, hence a separate water collection, filtration and distribution was installed, taking advantage of the spring identified during the baseline study (which one of the Quechua families had been using to draw water via a rustic ditch and bamboo tube). Because of the smaller size of the Quechua section of the community, the Quechua water system is of even simpler and less expensive technology, composed mostly of plastic drums loaded with the necessary filtration materials (stones of different sizes, sand).

Carrying out this project in a fairly remote community, and especially one with three such distinctive ethnic groups, was a tremendous challenge. Respecting cultural particularities and the demands of the local economy and social customs, the project was carried out at a fairly gradual pace, such that the local people could assimilate and incorporate new habits and technologies into their lifestyle, without becoming overwhelmed. It should also be noted that there are tensions between the Quechua section and the rest of the community, owing to the cultural, economic and even religious differences observed in the baseline study. These tensions were observed throughout the planning and construction phases of the project. However their required collaboration on this project has served, at least in some measure, to bring these disparate sections of the community together to resolve the challenges and benefits they now jointly share.

HOTC employed a Peruvian sanitary engineer and a Peruvian builder with many years prior experience installing water systems with the governmental agency FONCODES elsewhere in Peru. U.S. water and environmental engineers were also consulted during planning and construction. Throughout all construction phases, community members were actively involved in gathering and carrying construction materials, laying pipes, installing the filtration system and building the utility sinks and drainage systems. A bathroom including four stand-up flush latrines—housed in an aesthetically pleasing, well ventilated, traditionally thatched structure and the waste is serviced by a closed, ecologically sound septic tank system—was installed adjacent to the school for use especially by school children. Both adult and youth water committees were established, and these, as well as individual households, were trained in all aspects of the system, such that by the end of the project the maintenance and cleaning of the water system, household sinks and school bathroom are carried out entirely by the community itself. Both adult and youth water committee members were trained in all aspects of construction, water quality testing and sanitary measures. A nominal monthly fee is charged by the water committee to each family living in households in order to maintain resources for inevitable maintenance and repair costs.

Slow sand filtration is a simple water purification technology based on biological processes that has been in use over 200 years. A biological layer composed of algae, fungi, bacteria, aquatic arthropods and other organisms forms naturally in the upper two inches of the sand layer, consuming virtually all pathogenic bacteria and other parasites as they pass through the sand. The water that emerges from Huacaria's central community slow-sand filtration system comes close to meeting international sanitary standards for drinking water even before chlorination (see Table 5); the separate Quechua system showed problems of residual contamination (Table 5) that were resolved in 2007 by adjusting the water flow rate. Nonetheless, in accordance with Peruvian health ministry standards, chlorine is added using a low-tech drip system installed between the slow sand filter and the main distribution tank. Chlorine levels are monitored and regulated daily by members of the water committee, one each for the main community system and the independent Quechua system. Thus tap water from both the Huacaria central community and the Quechua section has consistently met international standards for drinking water purity, i.e. <1 FCU fecal coliform per 100ml (see Figure 1; Table 5). By contrast, testing carried out by the Huacaria water committee and the HOTC health director in the nearby Peruvian town of Pilcopata (where the Peruvian Health Ministry's regional base is located) demonstrates consistently unacceptable levels of fecal coliform contamination in Pilcopata's tap water supply (Table 5, bottom), levels equivalent to those found in many *untreated* stream water sources in Huacaria (compare with Table 4).

HOTC's work in Huacaria was carried out with active participation of the children and their families in every aspect of the project from the beginning. Anthropological specialists Shepard and Izquierdo were consulted frequently, as were international environmental and sanitary engineers. At the same time, HOTC took advantage of experienced Peruvian engineers and builders, providing them with valuable experience for their own further work in other parts of Peru. Interviews carried out with the Peruvian engineer and builder present in 2005 demonstrated their high level of satisfaction with the project. Both mentioned the fact that they had worked on many water projects elsewhere in Peru, often with inadequate time and resources but more importantly, without adequate integration of the local community in the project. They estimated, based on their past experiences that some half or more of water projects typically installed in Peru had failed within the first few years of operation, sometimes due to technical problems but especially due to lack of adequate training of and participation by local community members. Both mentioned that a key factor was the frequent return visits to check for and correct any problems with the system. Moreover, every effort was made to provide aesthetically pleasing, culturally and environmentally appropriate installations, a great contrast with typical development project installations which are often, quite frankly, ugly. For example, local palm trunks were used to cover exposed plastic tubing where it has to cross ravines or streams. Not only does the hard palm wood protect the plastic tubing, it also provides a more “clean,” aesthetically pleasing look to the installations. Noting community members’ avoidance of small, dark, squalid, closed cement latrines previously built by other government or aid organizations, HOTC’s bathroom installations were ample, well-ventilated, lit by natural light sources and constructed with robust and beautiful local materials such as river stones and palm thatching. Technical implementation was complemented by four years of ongoing, multilingual, culturally appropriate education and capacity building, implemented at gradual pace in order to respected local lifestyle and customs.

One especially important investment was the purchase of a portable microbiological laboratory that allows on-site water testing, with results delivered within 24 hours. Community members can see (and smell) the growth of bacterial colonies from samples taken from contaminated water supplies that were previously (and erroneously) assumed to be clear, sediment-free and thus “pure” and safe to drink. The water committee worked together with the community and local health officials in conducting water purity tests at multiple water sources in Huacaria and even in neighboring towns. Water community members were both shocked and yet also proud to learn that government-supplied tap water in nearby Peruvian towns often showed unacceptable levels of contamination, while their own current self-built, self-maintained community tap water system provides 100% pure (after chlorination) and safe drinking water.

The HOTC program also included a full-time health director – Maria Luisa Morales, a Peruvian nurse with over three years prior experience at a nearby regional health post of Pilcopata– who spent 20 days per month (2004-2007) on-site in the community working with indigenous children and families schoolteachers, water committee members and governmental medical personnel. She was responsible for weekly hygiene classes for the children, and bi-monthly classes for mothers. Monthly house-to-house visits also helped mothers to seek solutions to various health and personal needs. She was responsible for gathering and compiling, in collaboration with the Pilcopata health services, the bulk of the health-monitoring data presented in the following sections, documenting the impacts of the HOTC intervention on health in the community of Huacaria.

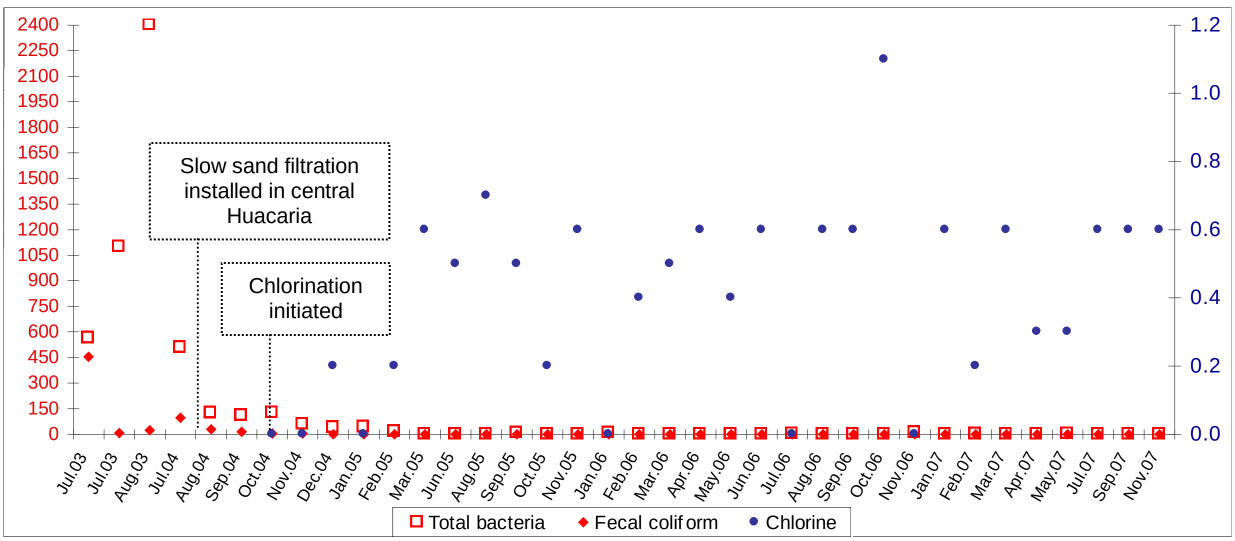
Post-Intervention Study Results (2004-2008):

HOTC’s Scientific and Medical Documentation Study was carried out by Maria Luisa Morales, in consultation with medical anthropologist Dr. Carolina Izquierdo and in collaboration with the regional health post. A battery of health tests including parasitology, anemia tests and height/weight measurements were conducted throughout the project—pre-and post-intervention—to provide an accurate biomedical health yardstick for measuring the objective health impacts on the community.

Microbiological Sampling

Ongoing microbiological testing of tap water in Huacaria from 2003 through 2007 (Figure 1) clearly shows the impact of water system renovations on water quality. Prior to the renovation of the water system in 2004, tap water samples demonstrated the high levels of coliform contamination noted in the baseline study, above. After the filtration system was completed in 2004, fecal coliform levels dropped to essentially potable levels. When chlorination was installed in December 2004, coliform levels dropped to essentially zero (see Table 5), and remain at this level through the present. Chlorine levels have been maintained within acceptable limits by the community water committee, mostly around .6 mg/L. On a few instances when chlorine levels momentarily dropped too low, coliform counts nonetheless have remained virtually at zero.

Figure 1: Microbiological Testing of Tap Water in Huacaria, 2003-2007. Red data points and numbers (left side) refer to coliform bacteria counts (CFUs/100ml); blue data points and numbers (right side) refer to chlorine concentration (mg/L).



Comparative microbiological testing of various water sources (Table 5) during the post-intervention phase demonstrates the effectiveness of the "low-tech" water purification system installed by HOTC, which consists of gravity-fed water flowing from a natural stream source, through a sediment-removing "pre-filter" made of rocks, into the slow sand filter. The water is then treated with chlorine , then flows to a reservoir tank, with round-the-clock distribution to all households and the schoolhouse. Natural stream sources throughout Huacaria remain contaminated at levels similar to those observed in the pre-intervention baseline study (compare with Table 4), namely, unacceptably high fecal and total coliform counts (average fecal coliform: 46; average total coliform: 1108). The water sources for both the central community and Quechua section water systems maintain similar levels of contamination to those found in other untreated, natural stream water sources (average fecal: 69; average total: 900; Table 5). After passing through pre-filtration, contamination is reduced slightly (average fecal 49; average total 782; Table 5).

After emerging from the slow sand filter, contamination is greatly reduced (average fecal: 6; average total: 123). In the case of the central community system, slow sand filtration alone reduces contamination to essentially safe drinking water levels (average fecal: 1; see Table 5); the Quechua system showed residual levels of contamination, mostly resolved later in 2007 by adjusting the flow rate. After chlorination, all of Huacaria's drinking water consistently meets international water purity standards, which is to say less than 1 fecal coliform unit per 100 ml (see Table 5), equivalent to less than one part fecal matter per billion. By contrast, tap water in the nearby Peruvian town of Pilcopata was found to be consistently contaminated at unsafe levels on multiple dates (average fecal: 52; average total: 509; see Table 5).

Table 5: Results of Microbiological Analysis of Water Samples from Huacaria, 2005-2007.

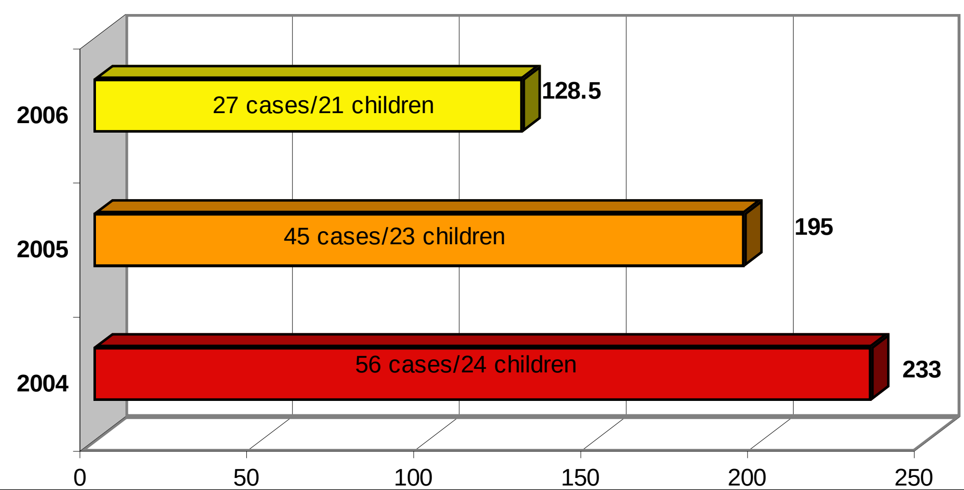
Date	Locality	Coliform CFU/100 ml	
		Fecal	Total
	Natural stream sources		
9/29/05	Río Huacaria	64	956
2/7/07	Río Huacaria	73	2100
11/7/05	Quebrada Bienvenida	0	270
	AVERAGE	**46**	**1108**
	Water system sources		
1/8/05	Community water system source	132	784
8/4/05	Community water system source	100	620
2/3/06	Community water system source	25	325
6/6/06	Community water system source	32	2380
1/5/07	Community water system source	26	764
5/6/07	Community water system source	20	800
1/8/05	Quechua water system source	16	700
2/3/06	Quechua water system source	116	1380
6/8/06	Quechua water system source	63	744
2/12/07	Quechua water system source	50	800
5/5/07	Quechua water system source	184	608
	AVERAGE	**69**	**900**
	Pre-filter output		
1/8/05	Community pre-filter	38	756
8/4/05	Community pre-filter	92	484

2/3/06	Community pre-filter	27	155
6/6/06	Community pre-filter	18	1108
1/5/07	Community pre-filter	15	1352
5/6/07	Community pre-filter	35	820
2/3/06	Quechua pre-filter	92	800
6/8/06	Quechua pre-filter	50	1000
2/12/07	Quechua pre-filter	55	760
5/5/07	Quechua pre-filter	68	588
	AVERAGE	**49**	**782**
	Slow sand filter output (pre-chlorination)		
1/8/05	Community slow sand filter	1	48
8/4/05	Community slow sand filter	2	12
2/3/06	Community slow sand filter	0	30
6/6/06	Community slow sand filter	0	18
1/5/07	Community slow sand filter	0	58
5/6/07	Community slow sand filter	3	24
	Central Community Average	*1*	*32*
1/8/05	Quechua slow sand filter	12	712
2/3/06	Quechua slow sand filter	14	240
6/8/06	Quechua slow sand filter	0	144
2/12/07	Quechua slow sand filter	37	60
5/5/07	Quechua slow sand filter	2	11
	Quechua Average	*13*	*233*
	OVERALL AVERAGE	**6**	**123**
	Huacaria tap water (post-chlorination)		
2/8/05	Community tap water	0	20
8/11/05	Community tap water	0	20
2/10/06	Community tap water	0	2
6/6/06	Community tap water	0	0
1/5/07	Community tap water	0	0
5/6/07	Community tap water	0	4
1/8/05	Quechua tap water	1	88
2/3/06	Quechua tap water	0	0
6/8/06	Quechua tap water	0	0
2/12/07	Quechua tap water	0	0
5/5/07	Quechua tap water	0	0
	AVERAGE	**0.090**	**12**
	Pilcopata tap water		
11/6/05	Pilcopata tap water	27	508
2/9/06	Pilcopata tap water	49	510
	AVERAGE	**52**	**509**

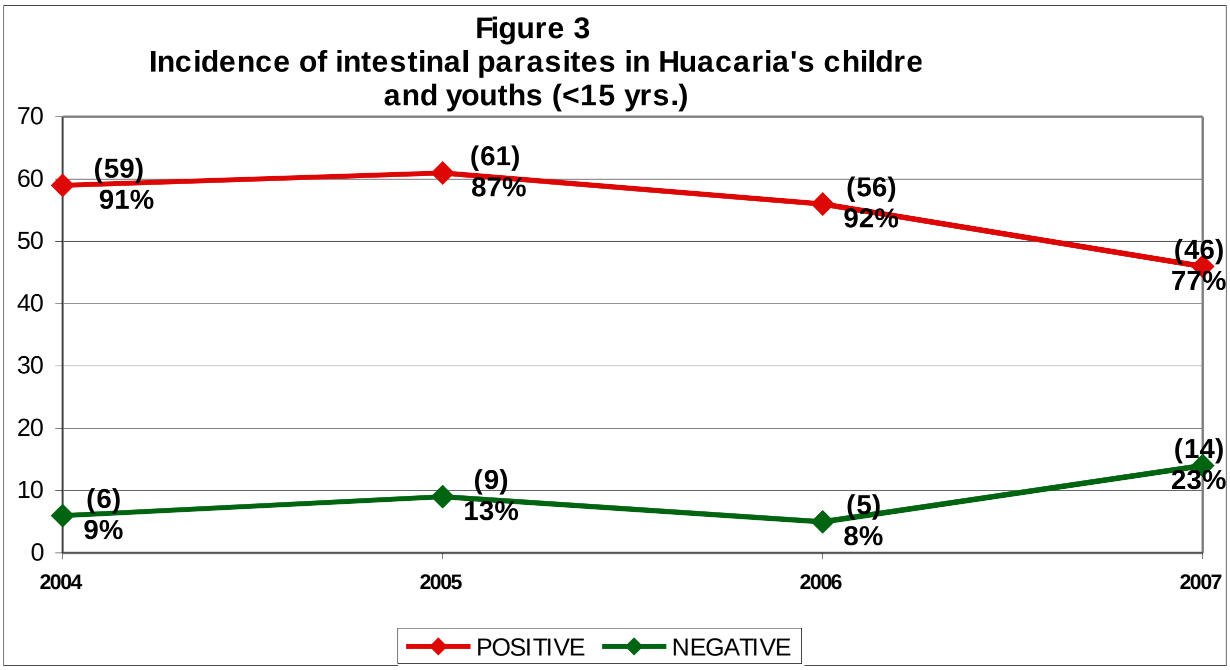
Longitudinal Health Studies

Ongoing biomedical monitoring by HOTC health director Maria Luisa Morales in collaboration with the Peruvian health ministry suggests a significant impact of the water purification system on child and overall community health in as little as two years after the beginning of the water system renovation in 2004. Longitudinal health data (Figure 2) derived from monthly, house-to-house visits demonstrate a sustained reduction in the proportion of children who suffered from at least one case of acute diarrhea: 83% (24 individuals) of children under 5 age suffered from diarrhea in 2004, compared with only 57% (21 individuals) in 2006. More dramatic and important, however, is the progressive yearly reduction in overall *prevalence* of diarrhea (counting multiple diarrhea episodes suffered by a single child), resulting in a 45% reduction in childhood diarrhea prevalence (from 233 to 129 cases/100 individuals) in the first three years (see Figure 2). Health monitoring was scaled back in 2007 and thus the data are not fully comparable, however the reductions in childhood diarrhea appear to be sustained: 16 cases for 22 children resulting in an incidence of 40% and a prevalence of 73 per 100. Diarrhea is a leading cause of infant and child mortality and morbidity in Huacaria and other indigenous communities of the region and is mainly caused by water-borne pathogens. Thus HOTC's water system renovation—virtually eliminating water-borne pathogens in drinking water—and accompanying health education projects have had a drastic and immediate positive effect in improving childhood health in Huacaria.

Figure 2
Prevalence of acute diarrhea in Huacaria's children (< yrs.)



Intestinal parasites are endemic in rural populations of the Peruvian Amazon. The fecal-oral contamination route of most intestinal parasites is not necessarily associated with dirty water, because some parasite eggs are also found in the soil. Nonetheless, access to clean water facilitates hand washing, a practice which has been reinforced by HOTC's ongoing health education project. Figure 3 demonstrates a marginally significant decline in the numbers of children and youths who tested positive for intestinal parasites, and a complementary upward trend—indeed more than doubling (from 6 to 14)—in the number of children who tested *negative* for any intestinal parasites between 2004 and 2007 (Figure 3, Fisher's Exact Test = 4.62, $p = 0.049$).



When multiple parasite infestations are considered, the results are more striking (Figure 4). Prior to the water system renovation in 2004, over half (54%) of Huacaria's children and youths suffered from multiple parasite infections (two or more parasite species simultaneously); by 2007, only 20% suffer from multiple infestations. By the same token, 23% of children in 2007 are parasite-free, up from only 9% parasite-free in 2004, a nearly threefold improvement that is statistically significant (comparison of 2004 and 2007, Pearson chi-square = 23.6, df = 3, $p < 0.001$). By 2007, *no* children showed three or more parasites, down from 17% in 2004. (Note that single parasite infestations appear to "increase" from 2004 to 2007, but this is an artifact of the reduction in the prevalence of multiple infestations). Still, the overall numbers indicate continuing parasite loads, an endemic problem that will have to be addressed with multiple health and education measures.

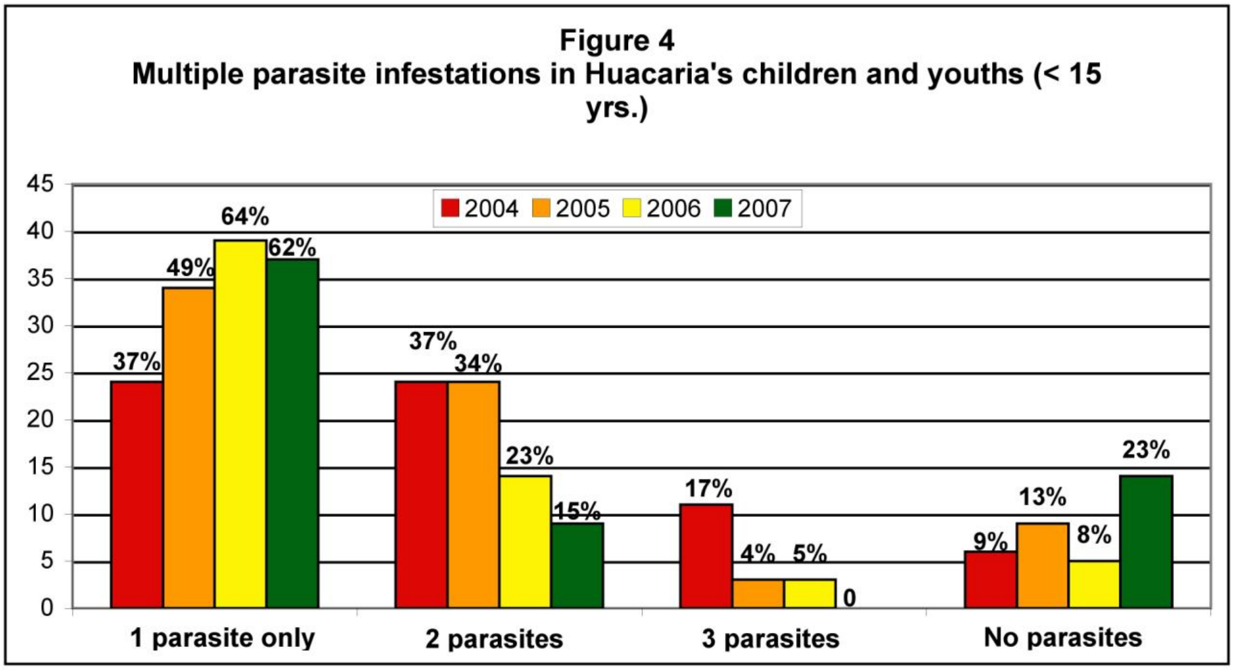


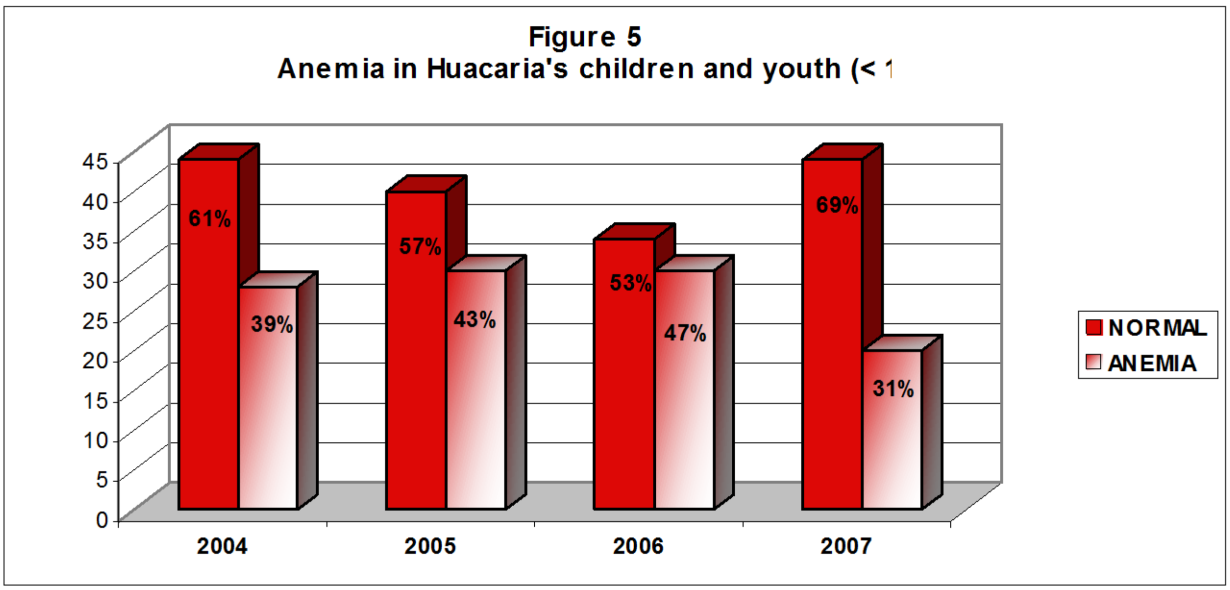
Table 6
Parasite testing within the general population of Huacaria, 2004-2007
(+ low egg/cyst concentration; ++ medium concentration; +++ high concentration)

Parasite type	2004	2005	2006	2007
Ascaris +++	79	32	2	4
Ascaris ++	0	52	13	14
Ascaris +	15	19	59	53
Giardia +++	0	0	2	2
Giardia ++	0	0	3	3
Giardia +	16	8	7	5
Himenolepis nana ++	0	0	1	1
Himenolepis nana +	2	3	7	5
Uncinaria +	30	20	1	0
Trichuris +	24	15	1	1
Strongyloides +	10	8	2	1
Negative	15	20	20	24
TOTAL	**191**	**177**	**118**	**113**

Yearly parasite testing throughout the community, covering 72% (2004) to 85% (2006) of the overall population demonstrates comparable results (Table 6). Overall parasite infestation is down by 40% (from 191 to 113), with especially notable reductions of 95% in high-concentration *Ascaris* (+++) infestations, and 90-100% reductions of *Uncinaria*, *Trichuris* and

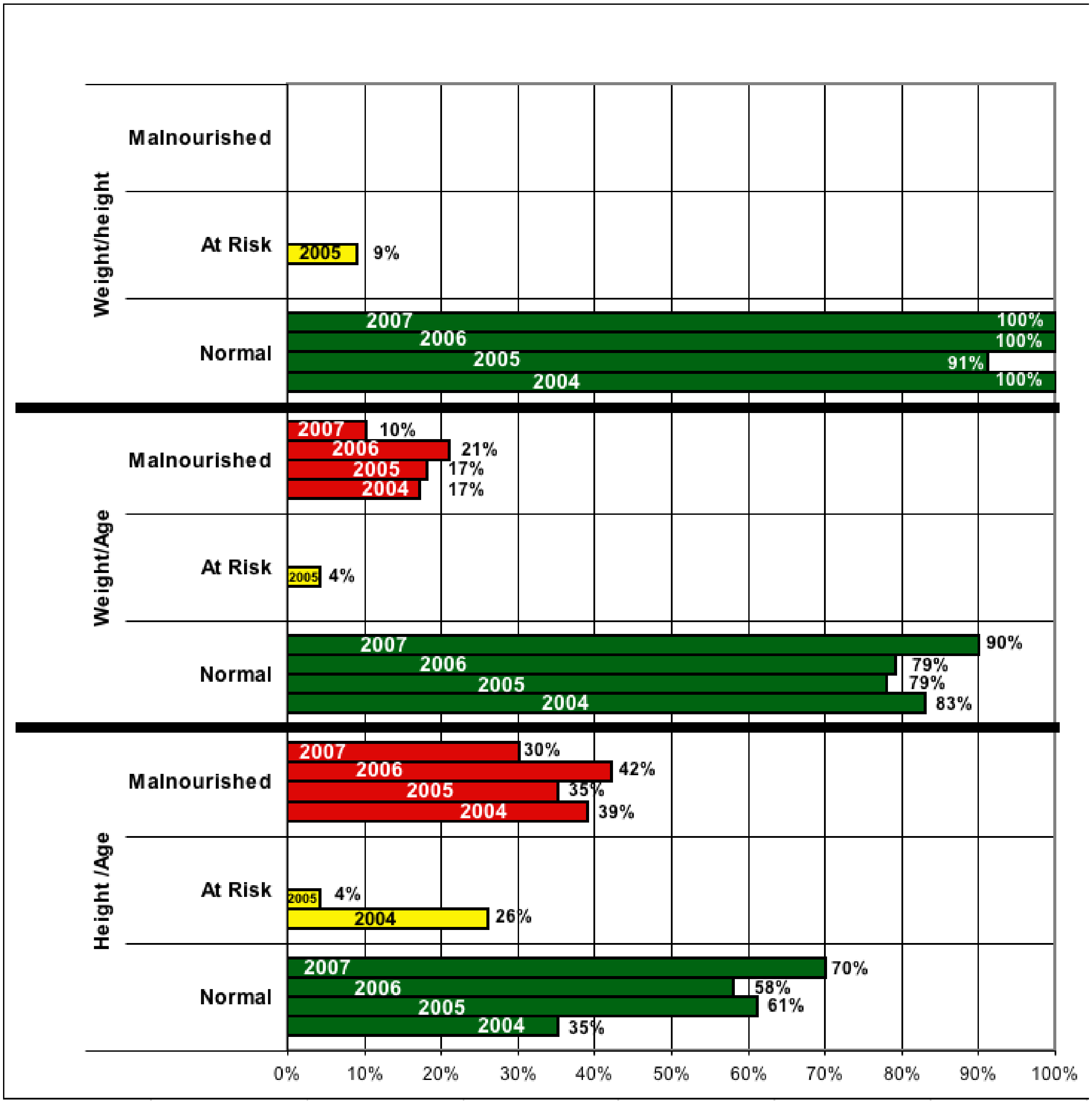
Strongyloides. Nonetheless, overall infestations of *Giardia* (a water-borne pathogen) were only reduced by about 31%, less than might be expected with a project focusing on water treatment. However because the community size is so small, a single outbreak of *Giardia* in one family (and not necessarily contracted in Huacaria: many families travel frequently to Pilcopata and drink the contaminated tap water there) would be enough to skew these results. Clearly, health monitoring and other health-related interventions must continue.

Blood studies (Figure 5) reveal a reduction in anemia and an increase in "normal" hemoglobin counts in 2007, compared with previous years, but this difference is not statistically significant (Fisher's Exact Test, $p = 0.374$). Moreover, the 2004-2006 trend showed an increase in anemia, suggesting that the 2007 decline could be anomalous. Thus, future measurements will be required to confirm the apparent improvements seen in 2007.



Biometric monitoring (height and weight by age) of children in Huacaria was also carried out during the study period to assess child malnutrition (Figure 6). Note that the height/weight/age standards used by the World Health Organization to assess child development are based on values derived from developed world populations, and may not be appropriate for indigenous people with a different genetic makeup and ecological context. When the test for acute malnutrition (weight/height; Figure 6, upper third) is applied, 100% of Huacaria's children under five years are considered "normal," and hence not suffering from acute malnutrition, in both 2004 and 2007 (Note: the height/weight test respects possible inherent differences in stature caused by genetic or ecological factors). When the tests for "global" (weight/age) and "chronic" (height/age) malnutrition are applied, a significant proportion of Huacaria's children are considered to be underweight (10-17%) and undersize (30-42%) for their age, and hence malnourished by WHO standards.

Figure 6: Nutritional status of Huacaria's children by biometric monitoring.
Green = normal; yellow = risk; red = malnourished. Biometric tests using WHO standards: acute malnutrition = weight/height; global malnutrition = weight/age; chronic malnutrition = height/age.



While keeping in mind the caveat regarding the application of universal child growth standards across genetically and ecologically distinctive populations, a trend in improving nutritional status can be discerned in Huacaria's children between 2004 and 2007, with an overall increase in the percentage of children considered of normal weight (increasing from 83% in 2004 to 90% of children in 2007) and especially normal stature (doubling from 35% in 2004 to 70% in 2007) for their age. A concomitant trend is noted towards decreasing numbers of children considered malnourished because of being underweight (from 17% to 10%) and undersize (from 39% to 30%) for their age. Though it is difficult to assign causality for such a small population, the drastic reduction in episodes of infant and child diarrhea (Figure 2) and the notable reduction in intestinal parasites (Figures 3-4) certainly appear to be relevant in reducing child malnutrition. Nonetheless, ongoing monitoring is required to verify the noted trends.

Discussion:

A renovated tap water system in Huacaria, using natural gravity flow, slow-sand filtration, and minimal chlorination delivers water at international water purity standards to the indigenous people of this community. The water is not only of far superior quality to that which the people of Huacaria drank until recently from contaminated tap stands or streams, but it is also superior to that found in the tap water of the nearby Peruvian town of Pilcopata. Quality sanitary installations include durable stone utility sinks with underground greywater drains throughout the community and a sanitary, environmentally safe flush latrine and septic system for the school. In association with ongoing health and hygiene education, these new installations have provided not only pure water but also permitted a great improvement in hygiene practices at home and at school and greatly reduced the contamination of surface water in the community and the local ecosystem. At a more subtle level, the community's direct involvement in this process has brought them a greater awareness of the relationship between their behavior, their physical surroundings and their health. This is especially important for example in the daily involvement of school children in using, cleaning and maintaining the school's flush latrine system: the hope is that these habits will become ingrained in the youth population and passed on to future generations.

The elimination of bacterial contamination from Huacaria's water supply appears to be directly correlated with a sharp decrease in the prevalence of acute diarrhea episodes in Huacaria's children. Other objective measures of child health—intestinal parasitism, anemia, and biometric evaluation of nutritional status—also demonstrate coherent trends suggesting long-term improvement in overall health status. However it is difficult to confirm the exact cause and long-term direction of these changes; thus, ongoing health monitoring should continue. Nonetheless, these results taken together suggest a significant positive impact of the combined HOTC programs (water, sanitation, health education, etc.) on child health and overall population health in Huacaria.

HOTC's partnership with the regional offices of the Peruvian Health and Education ministries has permitted these important governmental agencies and their employees—which have a history of often inappropriate, inefficient and ineffective intervention in the region's indigenous communities—to better understand the integral socio-environmental context in which health programming and education should be brought to native communities to ensure effectiveness and long-term sustainability. HOTC's project has created a working model that has produced results in a relatively short time period, in contrast to numerous past interventions that have failed, for example: Health Ministry water chlorination buckets that were not robust enough and soon broke and were then strewn throughout the community; water-boiling education that was understood but mostly not put into practice; latrine-building projects that merely donated materials but didn't assist in the design or construction of actual latrines. HOTC's health director, Maria Luisa Morales, was a former local Health Ministry employee, and will likely return to the Ministry at the conclusion of the project, taking her experience with her to enrich Health Ministry interventions throughout the region. These partnerships with the Health and

Education ministries are nonetheless still preliminary, and continue to face numerous challenges while also remaining mutually enriching.

Aside from the objective measures of health improvement and coordination with government agencies, community members show a high level of satisfaction and pride in their accomplishment. The training and experience provided through this project has enabled the people of Huacaria to maintain the water system on their own, using funds raised locally. In November of 2007, indigenous members of the Huacaria water committee, together with HOTC personnel, visited other indigenous communities in the region in the hopes of sharing their experience and expertise. The vocational training that has been acquired by the Huacaria water committee could become a source of income for them as they begin to consult and assist in the installation of similar water systems in other indigenous communities of the region (two such projects are currently being evaluated) as well as in the numerous ecotourism lodges that operate in and around Manu Park. In this sense, the HOTC intervention has proven not only sustainable for the community of Huacaria, but may soon grow beyond the Huacaria pilot project to bring clean water, improved health and new economic opportunities to the people of Huacaria and other communities in the region.

Building HOTC's previous support of high school education, a recent high school graduate from Huacaria, Julia Ramos, has been sent to Cusco with an HOTC university scholarship. Though the community has an interest in seeing more children attain higher education degrees, they are also concerned that their qualified children disappear into the anonymous Peruvian work force without bringing benefits back to the community. Therefore the scholarship assistance is contingent on Julia's frequent return visits to Huacaria, and a commitment to pass on her educational experiences to village youths. Young people who leave the community are subject to tremendous pressures and stress in the dominant national society, and HOTC continues to monitor this process and provide support for Julia and other native youths who aspire to higher education.

One particularly interesting, unexpected result of the project was the resurgence and reinvention of native ceremonies by a creative local shaman and community leader. Incorporating elements of both Amazonian and Andean ritual and spiritual practice, the shaman carried out blessing ceremonies at various crucial stages of the project. He himself observed that without the ceremonies, the project would not achieve its larger goal of integrating the people with their environment and ensuring long-term sustainability. School children assisted by a Canadian artist hired by HOTC decorated the main filtration tank with images derived from the Huachipaeri myth, "Wanamei: The Tree of Life," as well as words of thanks and blessing to water and nature in the three indigenous languages plus Spanish. Thus the ideas and physical structures of HOTC's project have become part of not only local practical habits, but part of their ritual and cultural life. The project has also inspired the community to take better care of the village and surrounding environment, for example by using leftover project materials to build durable trash cans at the school house to reduce litter, and develop a routine for trash disposal, with special treatment for toxic items such as batteries. Attention to such details, and the flexibility to incorporate new elements and make appropriate changes along the way, sets HOTC apart from most other development agencies and projects.

HOTC continues to monitor the preliminary health advances noted in Huacaria, and hopes to maintain and document these advances into the future. The initial results are encouraging, and HOTC is now seeking funds to replicate the project in other regional indigenous communities, using the same "low-tech," low maintenance methods, now enhanced in efficiency by the experience in Huacaria. The people of Huacaria have made a clear and conscious change in their relationship with their community organization, community infrastructure and with their health. They have overcome numerous habits and a cultural attitude of dependency and apathy that had kept them and especially their children unhealthy for a long time. Now, the community's health is firmly back in their own hands, their own hearts, and their own rich cultural life.

Appendix 1: Community Member Testimonials about HOTC's "Project Huacaria"

> "I think the water project is good because we have now safe and clean water. I like my work with the Water Committee. Now I can change the broken or damaged tubes. Step by step I am learning about construction matters.
>
> "At the beginning, before we understood, the water system maintenance was hard. But now we know about that and we do it well. When we use the sinks the water does not form puddles. Before the puddles of water attracted mosquitoes, even a bad smell, and with the new drainage system, we do not have that problem any more!"

-- *Carlos Chinchai (Matsigenka), age 25, Water Committee member.*

> "At the beginning when the water was not safe it was bad for our health. Now it is better than before, we have top quality water and we have the Water Committee to monitor the water system. Because of this I want to stay together and take care of the water that nature gave us. Let's take care of the water!"

-- *Alvino Mamani Huayta (Quechua), age 23, Water Committee member.*

> "When the river swelled, the water got dirty. We would take the water from the stream and the community got sick. When we boiled the water it stayed dirty. We would sometime boil the water, but not always. Now in Huacaria the water is clean, I can drink it from the sink. I use to get sick so often that I got too thin and I could see my bones, but it does not happen any more."

-- Belen, age 15.

> "In the Native Community Santa Rosa de Huacaria we are working with House of the Children Indigenous since the 2004 with safe water. In the previous years we got sick with diarrhea, parasites and other sickness because the water was contaminated. Now that the water system is finished, I feel good. We almost never get sick and we drink the water without boiling it."

-- *Mabel Ramos Dumas (Huachipaeri), age 20, community member.*

"The native community of Saint Rose of Huacaria works with House of the Children. We formed a five member water committee to learn all the necessary things, including all about materials. We started by putting in 20, 30, 40 centimetre stones at the beginning of the stream where we catch the water. Then we filled a pre-filter with 10, 5 and 1 centimetres stones. The slow sand filter was filled with 10 and 5 centimetre stones, above this, 1 centimetre stones, and finally we filled it with 98 centimetres of sand."

"We like that the slow sand filter purifies the water, we even like the chlorine. We have had less sickness in the 2004 to 2006. We have purified water that is chlorinated!"

-- Emilio Caparo (Matsigenka), age 27, President of Huacaria community and of the Water Committee

"Personally, I think we are working well since the beginning when water first arrived at my house. We do not want to go back to drinking contaminated water. Now our kids are healthy. Thank you to House of the Children that are children are in good health."

-- Elizabeth Dumas (Huachipaeri), age 20, Water Committee

"My name is Julia Ramos Yoshiro. I want to thank House of the Children Indigenous managed by Senorita Nancy for giving me this great support of my high school education and some other things. The first thing I want to say that HOTC supported me from my 1st year in high school until now. I like to study. I seize the opportunity they give me. I study with good feelings and enthusiasm."

"I received high honors from my 1st year in high school until I finished my high school studies. Now I am still studying to reach my goals at the university and to be a professional, to help my community, my parents, and everyone who needs it. Thank you very much for this support from of House of the Children and to their Director Senorita Nancy Santullo."

-- Julia Ramos Yoshiro (Matsigenka), age 19, community member and current HOTC university scholarship recipient in Cuzco.