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Application of existing appropriate technology to small communities in Honduras's Opalaca Mountains

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APPLICATION OF EXISTING APPROPRIATE TECHNOLOGY TO SMALL COMMUNITIES IN HONDURAS'S OPALACA MOUNTAINS

APPLICATION OF EXISTING APPROPRIATE TECHNOLOGY TO SMALL COMMUNITIES IN HONDURAS'S OPALACA MOUNTAINS

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of the requirements for the degree of Mechanical Engineering with Honors

By

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Abstract:

In a 2009 trip to the Opalaca Mountain region of Honduras, a need was identified for appropriate technology solutions to three key issues: housing improvements related to Chaga's Disease, indoor smoke reduction, and pure water. Through research regarding the problems, the local area, and candidate solutions, a set of three solutions was found. This includes corrugated steel roofing, vented or simple adobe rocket stoves, and solar disinfection.

DEDICATION

This Honors Thesis is dedicated to the needy living in the Opalaca region of Honduras and all of the people who have inspired and supported me towards this work, particularly Henry and Cindy Lowman, Linda Mohlman, Derek Lee, and Brian Pope.

ACKNOWLEDGEMENTS

Special thanks are due to the staff of the University of Arkansas College of Engineering faculty for all of their help, particularly Dr. Nutter for his involvement with this thesis. Also, special thanks go out to Dr. Young-gurl Kim and Dr. Fernando Vega from John Brown University's renewable energy and community development programs for their support.

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I. INTRODUCTION

In an effort to help the world's poorest, many have brought overly complicated technological solutions to fix simple problems, only to have them fail for lack of understanding and maintenance. What is needed is appropriate technology, or technology that meets the local needs at a level accessible to and reproducible by the end user. In a 7 week trip to the Opalaca Mountains of Honduras, a vision of what even the most simple technology could do to help was kindled through conversations with local residents and missionaries, as well as first hand experience in poor, isolated mountain villages.

The average Lenca Indian family in these villages lives in a poorly built, very small stick, mud, and thatch home. Beds are frequently nonexistent or little more than a stick mat. Thatch roofs frequently harbor insect vectors for Chaga's Disease, a debilitating parasite that damages the victim's heart and digestive tract. The houses are usually filled with smoke from the cooking fire within, which can cause a slew of problems for the home's inhabitants. Safe drinking water is inaccessible or not sought after, and the main commercial crops are often times insufficient to feed the farmer's people for the entire year, especially in light of recent apparent climate change [1]. Low tech, low cost technological solutions such as housing improvements, better cookstoves, and water treatment systems could have tremendous impact. A post-graduation trip by this author to attempt implementation of some or all solutions found is pending.

II. HONORS THESIS

A. Aim:

To research existing appropriate technologies and evaluate them based on the climate, people, and resources of the rural villages in the Opalaca Mountains and find the best package for implementation.

B. Background:

Through the author's trip to the villages of San Pedrito and Santa Maria in the Intibucá district of Honduras in the summer of 2009, the three problems of Chaga's Disease, drinking water, and indoor air pollution were identified. Although some villages in the area being considered have had clean water and Chaga's disease education projects before (see fig. 1), there still remain extremely remote villages with very little or no contact with such resources according to local missionaries. Furthermore, the locations that have been reached have by no means finished dealing with the addressed issues. Santa Maria, for instance, has recently been part of a Chaga's prevention program (see fig. 1) [2], but still has many unimproved dwellings. Whether the lack of effectiveness should be primarily attributed to no resources or poor education has yet to be seen. As mentioned, the end goal is to use this research as a foundation for implementation which will include not only general education about the advantages of the improvements, but also educating a few able-bodied residents about the concepts and construction involved. Ideally, these residents could use this education to create income installing the technology throughout the region.

The first issue, that of Chaga's disease, is a problem plaguing much of Latin America. The disease is caused not by the insects themselves but by the blood-borne protozoan *Trypanosoma cruzi*. The insects that carry the protozoa, most commonly *Rhodnius prolixus* and *Triatoma dimidiata,* or "chinche picuda" occupy cracks in the house and come out at night to feed on animal or human blood [3]. The parasite enters the host through the chinche's faeces, and leads to cardiac, digestive, and neurological disorders that can be fatal if left untreated [4]. Multiple insecticide sprayings can be effective as a short term solution, but the insects are prone to return if the house itself remains unchanged. The most effective long term solutions involve housing improvements. The specific changes can vary by location but typically include replacing thatched roofs, plastering mud walls, making a concrete floor, and moving domestic animals outside [5]. Whereas the typical Lenca dwelling utilizes spaced wooden poles as walls which do not tend to harbor the pests [3], the primary focus of this project will be replacing the common grass thatch with a more appropriate material (see fig 2). Thatch roofs often leak and require more maintenance than many other options in addition to the Chaga's issue, so it becomes not only a health priority but also one of standard of living.

Second, many Lenca homes cook on an unvented earthen stove that burns wood. According to the World Health Organization, this causes a plethora of health issues, most notably for women and infants who spend the most time indoors. Prolonged exposure to indoor wood smoke can lead to acute respiratory infections in children, chronic obstructive pulmonary disease, or lung cancer[6]. Coupled with unsafe drinking water, minimal sanitation, and low calorie intake, excess smoke inhalation further degrades health, meaning a higher incidence of disease. To the author's knowledge, an effort has been made in parts of the region to begin to remedy the problem (see figs 3,4) but there remains a great need. A number of improved cookstoves exist with the purpose of reducing fuel usage and indoor smoke. No information could be found to quantify current fuel usage, but it appears that inefficiency does not pose as significant a problem at this time as indoor air quality.

Lastly, there is the issue of unsanitary drinking water. The U.S. Peace Corps put in a few clean water projects about 20 years ago according to a local missionary, but the water is drawn from underground springs and is delivered untreated, leaving water quality unknown. Additionally, the steep terrain makes it extremely labor intensive to carry water from this central water source (usually situated with the centralized school) to a family’s home, which can be located a significant distance away. A better solution would decentralize the sources of clean water, placing them in or near homes along major trails. The ideal solution would also be uncomplicated, one that does not rely heavily on outside materials for maintenance, and simple to operate and maintain.

Figure 1: Photo at local school in Santa Maria, one of the inaccessible towns in target area, showing efforts to control and prevent Chagas (photo by author)

Figure 2: Typical Lenca house in Santa Maria, just large enough to sleep and cook in. Note thatch and thatch with tin roofs, both likely harboring Chagas' vectors. (photo by the author)

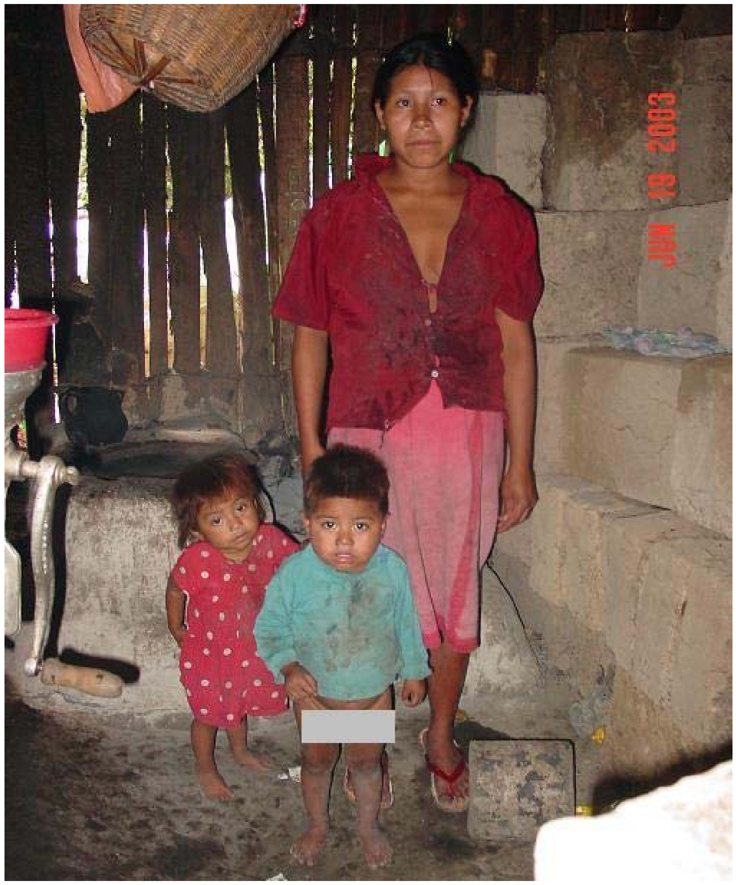

Figure 3: Typical interior of Lenca dwelling showing basic vented cookstove (photo by Henry Lowman)

Figure 4: Lenca boy in front of primitive vented stove as seen in fig. 6, diagram 1 (photo by Henry Lowman)

C. Methodology:

Each identified problem was given its own decision (weighted comparison) matrix, with which candidate solutions were evaluated numerically. The score given to each solution is not a stand-alone representation of viability, but rather a comparative score relative to the other solutions and given the specific circumstances to which it will be applied (hence, “appropriate”). Because of the difficulty involved in objectively quantifying each cell, some scores were given based on the author’s best judgment.

The matrix is broken down into five main categories: Health Benefits, Standard of Living, Cost, Ease of Construction, and Simplicity. These terms apply to all three problems, and are further split into subcategories for each.

‘Health Benefits’ is the ability of the candidate solution to address the health issue in question. ‘Standard of Living’ encompasses other benefits the solution will provide for the user once installed, such as time or resource savings or improved cleanliness. ‘Cost’ is simply the initial cost of implementation. This includes materials and the cost of transportation if applicable. All costs are evaluated at U.S. prices if exact location-specific prices are unknown. Transportation is assumed to be weight-based, and reflects both city to base-town transportation and mule transportation to the final destination. For the Housing Improvements case, an Environmental Cost was also added for reasons mentioned later. ‘Ease of Construction’ includes material availability, ease of transportation, and the time required for construction. Lastly, ‘Simplicity’ includes the number of parts and the ability of locals to reproduce the technology on their own. Permanency was also set under this category.

Given that some of these metrics are more important than others to the success of the project, the author assigned weights to each subcategory. Weighting varies for each main problem, but Health Benefits was always weighted highest because it was the primary objective.

D. Chaga's Prevention: Roofing Improvements

Because of the simplicity of the problem, the solutions are fairly straightforward. Although being an unattractive nest for insect vectors is an important factor for this study, the roof's obvious purpose must be protecting the home against the elements. Although an open air roof (no roof) would deter chinche picudas, it would obviously be inappropriate. For this reason, the author weighted weather resistance (in this case mainly rain) second heaviest. Most well constructed buildings in the area have tin (really galvanized steel) roofs or fired clay roof tiles. Because biomaterials, such as wood shingles, are more likely to harbor insects and probably illegal to harvest in the surrounding forest reserve, the only materials considered were tin, clay tiles, and heavy duty tarp.

The missionary contact in the area has always used metal roofing on housing projects. Using local prices, a typical 12'x 10' Lenca home would use $192 worth of steel, a significant portion of a typical family's yearly income. This presents a problem for families making the improvement on their own, but is approximately the cost of the alternative and is inescapable. Transporting large, heavy pieces of roofing through the mountains on mules would be neither easy nor inexpensive, and could deter villagers from reproducing the improvement. Corrugated steel does have the functional advantages of being very weather proof , completely insect proof, and very easy to install with little reinforcement necessary. Also, steel does not present a burden on the local ecosystem by creating demand for plant material. Disadvantages come in the form of being noisy and difficult to transport. Longevity is acceptable, but after a number of years in the hot, humid climate local unpainted metal roofs begin to deteriorate.

Clay roof tiles were the second option considered. Tiles are cheap, about $0.37 each, but the total tile cost for a small Lenca home would be around $195. Tiles are made in some regions locally. Tile roofs last many, many years but not without occasional maintenance. According to the missionary, clay roof tiles do harbor triatomine insects, but further research proved this is not necessarily true. In a study published by the Revista do Instituto de Medicina Tropical de São Paulo, houses in three communities were categorized by construction materials and tested for the presence of both R. prolixus and T. dimidiata, the same species present in Intibucá. Data revealed zero or negligible increase in the presence of the insects from metal to tile roofs. The study also revealed the previous population of R. prolixus had completely disappeared. Furthermore, the authors concluded this was most likely because of the drastic decrease in thatch roofs, which were replaced in the majority of cases with tile roofs [7]. However, there seems to be no debate as the effectiveness of metal. For this reason, the metal roof was ranked slightly higher in the evaluation than was clay for reducing insects. From a practical standpoint, clay tiles involve many difficulties. They are difficult to make waterproof, involve an immense number of correctly placed parts, require an extremely robust frame (which means more lumber and therefore total cost), and present a huge transportation challenge, both because of their fragility and weight. They also carry a significant local environmental cost in that they require large amounts of hardwood to properly cure in the kiln, whereas steel is processed using less fragile sources of energy far removed from the local environment.

As a third option, inexpensive, heavy duty tarps could be used. At $30 each for a 12x20' tarp, the cost is certainly more affordable than either tin or clay. The tarp would resist water very well at first, but would be extremely noisy in heavy rain or high wind. Longevity is a major issue with tarps. Holes from birds and animals, falling debris, and UV degradation over time would eventually put the tarp out of commission. Cooking indoors with an unvented stove could also harm the tarp. At such a low cost, the tarp could be replaced easily, but this also becomes an issue of maintenance and standard of living. Given the poor education level within most Lenca communities, a family would likely not understand trading a traditional, aesthetically pleasing, functional roof for a tarp.

According to the local missionary, the Honduran government encourages the use of metal roofing for its environmental friendliness and practicality. The evaluation matrix gave the same result, suggesting the use of corrugated metal over clay tiles.

Table 1: Roofing Decision Matrix

Category	Description	Weight	Corrugated Steel		Clay Shingles		Heavy Tarp	
			Raw	Weighted	Raw	Weighted	Raw	Weighted
Health	Triatomine Reduction	30	10	30	9	27	10	30
Subtotal		30		30		27		30
Standard of Living	Maintenance Reduction	5	9	4.5	6	3	3	1.35
	Weather Resistance	15	10	15	8	12	5	7.5
Subtotal		20		19.5		15		8.85
Cost	Material	7	6	4.2	5	3.5	10	4.2
	Transportation	7	7	4.9	1	0.7	10	4.9
	Environmental	6	10	6	5	3	8	4.8
Subtotal		20		15.1		7.2		13.9
Ease of Construction	Material Availability	7	8	5.6	8	5.6	8	4.48
	Material Transportability	4	5	2	2	0.8	10	2
	Construction Time	4	9	3.6	2	0.8	10	3.6
Subtotal		15		11.2		7.2		10.08
Simplicity	Number of Parts	5	9	4.5	2	1	9	4.05
	Ability of Locals to Reproduce	5	5	2.5	4	2	6	1.5
	Permanency	5	6	3	9	4.5	2	0.6
Subtotal		15		10		7.5		6.15
TOTAL SCORE/100				85.8		63.9		68.98

E. Indoor Smoke Reduction: Improved Cookstoves

Improved cookstoves are an increasingly popular item in the development world. In many areas, fuel is scarce and so efficiency is a serious advantage. For other applications such as this, the main improvement they offer is containment and ventilation of exhaust gas. All four final design choices operate on the same basic concept because of its simplicity and efficiency: the rocket stove. Other concepts that were found required more intricate metal or ceramic work, such as wood gasification, and so did not compete well with the four rocket designs. The rocket stove consists of a tall, insulated vertical combustion chamber with one horizontal combination fuel and air feed. This makes for a very strong chimney effect, drafting air up from underneath the fuel and allowing hot exhaust gases to mix and burn completely before leaving the stove (see fig. 5). Properly built rocket stoves have high temperatures, complete combustion, and greatly reduced smoke and carbon monoxide output, along with reduced fuel consumption. Specifically, the four options considered were the Justa stove, a prefabricated metal stove, a modified round clay rocket stove, and a very simple, unvented brick rocket stove. Diagrams of each can be seen in figure 6. Also included in figure 6 is the design of basic vented stoves found in some Lenca dwellings which takes smoke out of the house but is likely not particularly efficient.

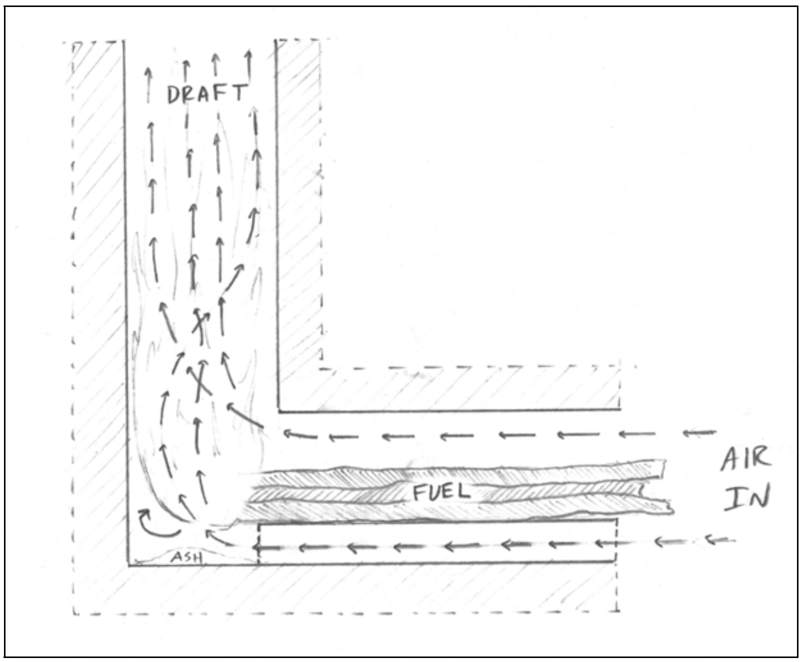

Figure 5: Rocket Stove Concept

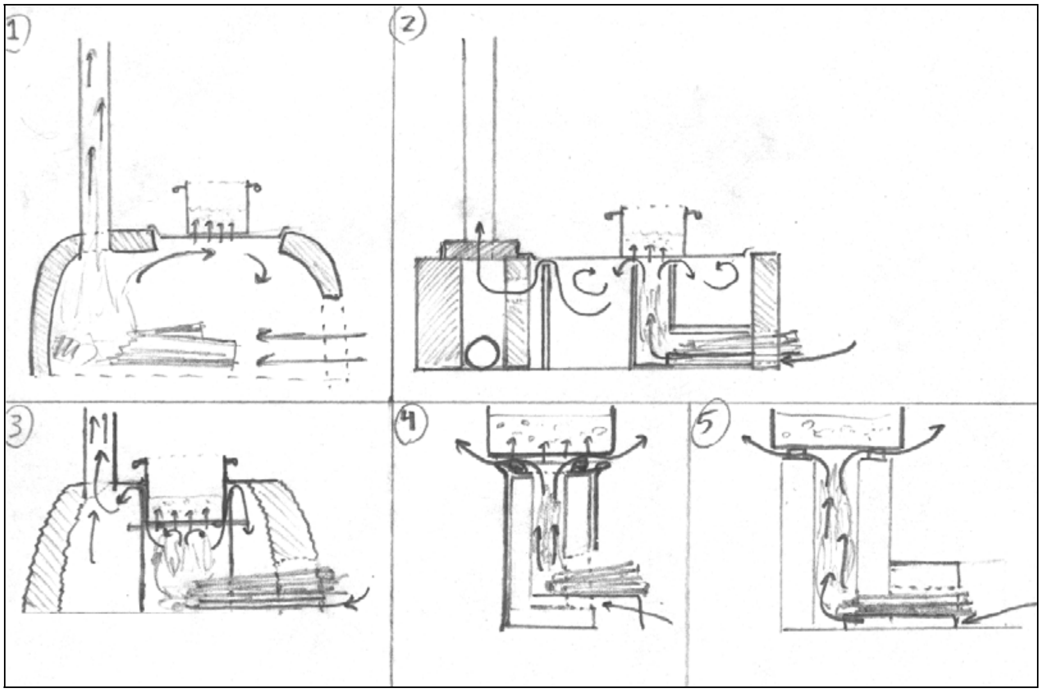

Figure 6: Improved Cookstove Designs: 1) Existing vented stove, 2) Justa Stove, 3) Vented Adobe Rocket, 4) Metal Prefab Stove, 5) Simple Adobe Rocket

The Justa stove [10] is used by La Asociación Hondureña Para el Desarollo (AHDESA) and uses a plancha (flat griddle) rather than a pot. It can be made using a variety of materials, including adobe, brick, and cinder blocks. The advantages of this design are material flexibility and large, flat cooking area. Traditional Honduran food almost always includes homemade corn tortillas because of the extremely low cost and high availability, and this stove caters to that expressly. This design was given a 10 for smoke reduction and cleanliness because of its completely sealed and vented design. However, disadvantages come in the cost of making and transportation of the metal plancha and the loss of efficiency when using a pot, resulting in low scores in the Simplicity category. It also scored lowest on fuel efficiency because heat is rejected to the air across the entire plancha so that only some of the heat goes to any pots or skillets resting on it.

Second, the vented adobe rocket stove was considered [11]. According to Manibog, rural mud stoves such as this account for the majority of world improved cookstove work [8]. Like the Justa, it is built in place using some local materials and a few metal pieces. The design is more or less cylindrical, with the combustion chamber underneath the pot, and the rest of the stove being built around these. A chimney comes out from one side.

Prefabricated metal stoves, such as the ones sold by stovetec [12], are another viable option. These could be made somewhat locally, but quality ones, though cheap, require ceramic and metal skilled labor. Once the stoves were obtained, they would need no installation. They do require a pot to cook with, although a makeshift plancha could also be used on the stove. These stoves do not have a chimney, and thus do not reduce the indoor smoke as much as a vented unit. However, a well designed metal rocket stove significantly reduces smoke and CO output through the efficient and complete combustion of fuel. Durability, if well taken care of, would be very long but possibly not as long as a well constructed, built-in stove.

The last and simplest solution is the simple adobe rocket [13,14,18]. This design's advantage is that it would be completely independent of outside materials or money and be easily reproducible. Teaching the locals the basics of the rocket stove principle, they could build their own un-vented, but improved stoves out of adobe bricks or wet adobe that would cost nothing but their own labor and improve their standard of living and environmental impact considerably. The disadvantage, like the stovetec, is that it would not be as effective at reducing indoor smoke as vented designs.

Ultimately, no one solution will be perfect across the board. Some families are starting from nothing, and so would greatly benefit from any of the above. However, both of the unvented stoves, although an improvement in terms of smoke and fuel use, may be a step down for some families in terms of cooking capacity. Those families who already have a smoky but otherwise functional stove may benefit from the simple addition of only a metal chimney pipe that could be obtained inexpensively. For the purposes of this study, however, a family using an open ground fire is assumed. Looking at the weighted scores, all stoves came within 3 point of each other with the exception of the metal prefab stove. The vented and unvented adobe rocket stoves ranked highest with 80.6 points each. Depending on the circumstances, either could be used appropriately to positively impact a home.

Table 2: Improved Cookstove Decision Matrix

Category	Description	Weight	Justa Stove		Vented Adobe		Metal Prefab*		Simple Adobe	
			Raw	Weighted	Raw	Weighted	Raw	Weighted	Raw	Weighted
Health	Indoor Smoke/Soot Reduction	30	10	30	9	27	7	21	6	18
Subtotal		30		30		27		21		18
Standard of Living	Maintenance Reduction	5	5	2.5	5	2.5	5	2.5	5	2.5
	Cleanliness	5	10	5	10	5	8	4	8	4
	Fuel Reduction	10	7	7	8	8	9	9	8	8
Subtotal		20		14.5		15.5		15.5		14.5
Cost	Material	10	7	7	8	8	6	6	10	10
	Transportation	10	6	6	7	7	7	7	10	10
Subtotal		20		13		15		13		20
Ease of Construction	Material Availability	7	8	5.6	8	5.6	5	3.5	10	7
	Material Transportability	4	7	2.8	8	3.2	8	3.2	10	4
	Construction Time	4	7	2.8	7	2.8	10	4	9	3.6
Subtotal		15		11.2		11.6		10.7		14.6
Simplicity	Number of Parts	5	5	2.5	7	3.5	8	4	9	4.5
	Ability of Locals to Reproduce	5	5	2.5	8	4	2	1	10	5
	Permanency	5	8	4	8	4	9	4.5	8	4
Subtotal		15		9		11.5		9.5		13.5
TOTAL SCORE/100				77.7		80.6		69.7		80.6

F. Clean Water: Water Purification Methods

Because the villages in this study already have access to groundwater, the main focus of this part of the study is not the collection but rather the treatment of water through appropriate technology. Three vastly different apparatuses were taken into consideration: slow sand filtration (SSF), Solar Disinfection (SoDis), and rainwater catchment.

The most thorough treatment technology, in terms of cleaning the water of both disease causing agents and particulates, is slow sand filtration. Water, regardless of source, is passed through a column of increasingly large sand particles which filter out the majority of particulates and harmful parasites. The World Health Organization's report on SSF claims that the system improves the water's physical, chemical, and bacteriological properties simultaneously [20]. In the uppermost layer of sand, a beneficial layer of bacteria forms which consumes microorganisms caught in the sand. A SSF unit, as constructed by Clean Water For Haiti [15] would require a prefabricated mold, cement, sand, gravel, and a few PVC fittings. Occasional maintenance and a break in period before effectively cleaning the water present disadvantages along with the expenses of transporting cement.

SoDis is a relatively recent and brilliantly simple solution to the problem of unclean drinking water. Plastic PET (Polyethylene terephthalate**)** bottles, such as typical soda bottles (anything with a #1 recycling symbol on it), are filled with water and left in the sun for 6 hours in the sun or 12 hours when cloudy. UV-A rays directly kill harmful organisms, create highly reactive forms of oxygen that kill microorganisms, and also heat the water, resulting in synergistic effects above 50°C [16]. The effectiveness of the process is greatly increased if the bottles are placed on a reflective surface such as a corrugated metal roof. In the cases of high turbidity (but not more than 30 NTU, Nephelometric Turbidity Units) or cloudy weather, two days are needed. Some concern has been raised regarding DEHA and DEHP, toxic chemicals that can leach from plastic, levels in SODIS water, but a study by the Indian Institute of Technology Madras published a 2009 study that both of these levels are significantly below World Health Organization standards for safe drinking water [19]. The advantage of this system is that the only things needed are PET bottles, readily available in most areas, and education about how to use the technology. If not done properly, solar disinfection does not remove enough pathogens to be considered clean, so extensive training for community promoters is necessary.

The third option considered was rainwater harvesting [17]. This technology could be coupled with the improved roof during construction, and for most of the year would provide clean water. Initial calculations shown in Table 3 reveal that, based on an average sized house and climatological data from Tegucigalpa (figure 7), the system would produce less than one gallon per day for four months out of the year, which is hardly adequate for a family in the tropics. Also, adequate water storage capacity, such as food grade 55 gallon drums, must be brought in. These will most likely be fairly easy to acquire, but again present a transportation problem. Because of its ineffectiveness for a third of the year, rainwater harvesting would not be a viable solution on its own and would have to be paired with something like SoDis or SSF. Because a lack of source water is not the problem and other methods of water purification would still be necessary, rainwater harvesting received very low scores for effectiveness and reliability.

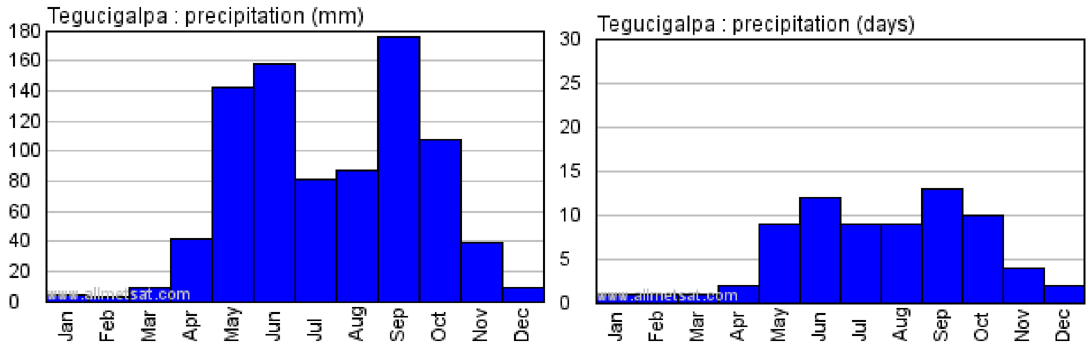

Figure 7: Monthly Precipitation Data

Table 3: Rainwater Catchment Calculations

Typical House 12'x10' roof	A=	120	ft^2			
WET SEASON	May	Jun	Jul	Aug	Sep	Oct
mm Precip/month	142	158	80	85	177	107
Days rain	9	12	9	9	13	10
First Flush losses, gallons	10.8	14.4	10.8	10.8	15.6	12
Monthly Totals, gallons	365.582	404.3913	201.2462	214.4991	453.5523	271.6118
Daily Allowance, gallons	12.1861	13.47971	6.708207	7.14997	15.11841	9.053727
DRY SEASON	Nov	Dec	Jan	Feb	Mar	Apr
mm Precip/month	40	10	5	4	10	41
Days rain	4	2	1	1	1	2
First Flush losses, gallons	9.6	4.8	2.4	2.4	2.4	4.8
Monthly Totals, gallons	96.4231	21.70578	10.85289	8.202311	24.10578	103.8737
Daily Allowance, gallons	3.2141	0.723526	0.361763	0.27341	0.803526	3.462456

Almost 11 points higher, solar disinfection was determined to be the best solution. Its simplistic genius, ability to spread virally, and almost zero cost, coupled with pathogen removal capabilities comparable with the other technologies make it an obvious winner.

Table 4: Water Purification Decision Matrix

Category	Description	Weight	Slow Sand Filtration		Solar Disinfection		Rainwater catchment	
			Raw (/10)	Weighted	Raw	Weighted	Raw	Weighted
Health	Waterborne Disease Reduction	30	8	24	8	24	5	15
Subtotal		30		24		24		15
Standard of Living	Labor Reduction	5	6	3	4	2	7	3.5
	Reliability	10	9	9	8	8	5	5
	Drinkability	5	10	5	7	3.5	10	5
Subtotal		20		17		13.5		13.5
Cost	Material	10	4	4	10	10	8	8
	Transportation	10	4	4	6	6	7	7
Subtotal		20		8		16		15
Ease of Constructior	Material Availability	7	8	5.6	10	7	8	5.6
	Material Transportability	4	5	2	8	3.2	6	2.4
	Construction Time	4	6	2.4	10	4	7	2.8
Subtotal		15		10		14.2		10.8
Simplicity	Number of Parts	5	6	3	10	5	7	3.5
	Ability of Locals to Reproduce	5	8	4	9	4.5	7	3.5
	Permanency	5	10	5	9	4.5	9	4.5
Subtotal		15		12		14		11.5
TOTAL SCORE/100				71		81.7		65.8

G. Conclusion:

Out of all solutions considered, the best technology package would include a corrugated metal roof, a simple or vented adobe rocket stove, and SoDis water purification. This grouping requires a minimum of capital and gives a maximum result and ability to be reproduced.

H. Future Works:

Having settled on the most appropriate group of technological solutions, the question of implementation methodology still remains. This is an issue all to itself, and is in all probability more experiential than anything else. However, goals outlined for this research have been met and the author feels confident in their potential in the field.

The author is currently making plans to travel to Honduras for two months following graduation. The first month will be spent leading a group of college students doing volunteer work and will include exploring in the intended application area, and the second month is committed to putting this technology into practice. Through research necessary for this paper, the author has made several contacts already working in Honduras, specifically with water and stove dissemination. As resources and local circumstances allow, he will observe the construction and implementation methodologies used by these groups and be able to apply these observations in the Opalaca Mountains.

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