

Project Title: Field Testing of the Biosand Water Filter Technology in Nicaragua

University of Calgary Environmental Science Students:

Cameron Baughen
Delphine Bouvry
Ines Kwan
Kiran Lerner

Partners:

- Central American Water Resource Management Network (CARA) at the University of Calgary – David Bethune and Cathryn Ryan
- DAVNOR Water Treatment Technologies Ltd. – David Manz
- Samaritan's Purse – Rusty Ritenour and Dexter Cuthbert
- Center for Aquatic Resource Research/National Autonomous University of Nicaragua (CIRA/UNAN) – Katherine Vammen and Maria Elena Vargas

Project Dates: 04 July to 29 August, 1999

The Biosand Water Filter

The Biosand Water Filter is an effective way of treating contaminated waters in disadvantaged countries. Developed by Dr. David Manz of DAVNOR Water Treatment Technologies Ltd., the filter is cheaply and easily constructed and maintained and as such is a viable technology for any community. The effectiveness of the BioSand water filter has been documented by Palmateer et. Al (1997) to remove up to 97% fecal coliforms, 100% parasites, and 50-99% toxicants (i.e. pesticides). Although field testing of fecal coliform and parasite removal has been performed previously, no similar study has been undertaken for pesticides.

Samaritan's Purse constructs and distributes the filter in Nicaragua. Based out of Managua, they have facilities involved in constructing the steel molds, the concrete casings, collecting and separating the filter media, acquiring other necessary materials (i.e. PVC piping and diffuser basin).

Project Purpose

1. To measure the field efficiency of the Biosand water filter in the removal of fecal coliforms and organochloride pesticides
2. To implement Biosand water filters into several rural communities with contaminated water supplies
3. To collect data points on well contamination by fecal coliforms and organochloride pesticides in the Chinandega and Leon regions of Nicaragua (after Hurricane Mitch).
4. To acquire survey data related to rural water supply, before and after filter installation and use.

These objectives were complemented by an in-lab study on the efficiency of the Biosand Water Filter to remove fecal coliforms from the highly polluted Lake Xolotán (Lake Managua).

Preliminary Activities

Accommodation and lab facilities were provided in Managua by CIRA/UNAN. Initially Maria-Elena Vargas, a microbiologist at CIRA, assisted us to form a partnership with the director of Samaritan's Purse Nicaragua (SPN), Dexter Cuthbert. At our request SPN provided us with one filter that was installed at the CIRA compound. The filter was sampled using highly contaminated water from Lake Xolotan. This procedure had the dual purpose of perfecting our lab techniques and demonstrating the efficiency of the filter. The water that was used for this study was in no way representative of what is normally used as a potable water source, and as such results should be interpreted with this in mind. Initial bacteriological testing of the filter revealed an efficiency of 98%

removal of fecal coliforms, decreasing over time to 88%. This may be accounted for by the overgrowth of the microbiological surface layer (due to highly contaminated water) which slowed the flow rate of the filter, thereby decreasing fecal coliform removal. Although the growth of this layer is the key in the effective removal of pathogens and viruses, in normal use, this microbiological layer is removed at regular intervals to prevent the decrease of flow rate. For interest purposes, the macro-invertebrate laboratory at CIRA assisted us with qualitative observations of the top 20 cm of sand in the filter. Consistent with invertebrates present in Lake Xolotàn, we found an abundance of Copepods (*Copepodas nauplii*) and Cladocerans (*Moina* sp. and *Diaphanosoma* sp.) within the biologically active layer of the filter.

Site Selection

Prior to undertaking our fieldwork, both CIRA and SPN were consulted regarding site selection. To meet our project objective, we optimally desired villages where filters had been previously installed (so that the microbiological layer would already be developed and optimally effective) and also where the groundwater was known to be contaminated with pesticides. This proved to be impossible because CIRA's only pesticide data was collected prior Hurricane Mitch (October 1998). This created uncertainty in the data due to the changes in the groundwater and other features of the area caused by the hurricane. Upon recommendation by CIRA and SPN, and due to budgetary limitations, we tested two villages initially to confirm the presence of pesticides. The townsite Las Mojarras, located in the region of León, was chosen because of previous SPN work there building houses and installing filters for families displaced by Hurricane Mitch. During the hurricane the original village was destroyed by flooding from the Río Grande (El Viejo). El Trianón, was chosen for its location and because of CIRA interest in the area. The nine year old community had thirty-five families who have been slowly moving to El Nuevo Trianón, located 500 metres upriver, since the hurricane. Sugar cane and corn were the major crops cultivated in this area. This village borders between two municipal regions and both regions will not claim responsibility for the town, therefore they have received very little aid to rebuild after the hurricane.

In addition to these two villages 3 other villages were chosen for the study in the Leon-Chinandega region. These villages were situated approximately 3 hours drive northwest of Managua. After sampling these sites, three other villages were chosen without previous sampling; (1) El 'Nuevo' Trianón – people who have relocated from El Trianón after flooding. The people there rely on 2 to 3 meter deep wells as their source of drinking water; (2) Filadelfia (35 families present) and (3) San José de Cuasompa were chosen because pre-hurricane CIRA data showed high levels of pesticide contamination within the aquifers.

Filter Installation

Filters had previously been installed in Las Mojarras, but not in any other the other chosen study sites. With the help of an SPN technician and concrete filter and filter material donation from SPN, filters were installed in these four other villages. Community agreement and participation was ensured prior to filter installation. For example, for a one week trial period in El Trianón, one filter was initially installed into the community leader's house so as to allow exposure time to the other members of the community and to obtain their agreement to participate in the project. This community was where the majority of the installations took place in addition to one filter at Filadelfia and one in San José de Cuasompa. For the initial installations a driver and jeep were rented from CIRA. In the following week, for the larger installations, a truck was rented from CIRA. Twenty filters and their components were taken to El Trianón, where six filters were installed, and the other fourteen were taken and installed in El 'Nuevo' Trianón. Filters were numbered, as per SPN procedure, and written instructions for filter use were posted near the filter. Households were surveyed for items such as observations on well characteristics (depth and proximity to latrines), number of adults/children living in the household, and how the family was affected by the hurricane (See Appendix A).

Bacterial and Pesticide Sampling

Although we optimally would have liked a longer period of time to ensure build-up of the bacteriological layer, time constraints required sampling two weeks after installation in the four villages. Pre-filtered and post-filtered water were sampled for fecal coliforms and pesticides. Pesticide testing was done by CIRA and lab resources were made available to us for the fecal coliform sampling. Measurements of water temperature, pH, dissolved oxygen and conductivity, as well as the height of the water head in the filter and its flow rate were taken during sampling. In total ten filters and ten wells were tested within our study villages, with the filters in El 'Nuevo' Trianón and El Trianón being randomly chosen. Further surveys were conducted for the overall satisfaction with the filter, improved taste or smell, amount filtered per day and any changes in health since the filter installation (See Appendix A).

Results

Some of the basic questions that were raised in the beginning of the study, and a few questions that came up after the experimentation period include:

- 1) Does the filter remove pesticides?
- 2) Is there a correlation between coliform removal and pesticide removal?
- 3) Is there a dependent relationship between pesticide/fecal coliform removal and the initial input concentrations?
- 4) Is there a relationship between dissolved oxygen (DO), pH, or temperature and pesticide/coliform removal?

Using a two tailed t-test or a nonparametric Wilcoxin test, it was found that there were no significant differences between the prefiltered water and the post filtered water in terms of pesticide concentration (see Table 1, Figures 1-5). These results could indicate that the filter generally has no effect in terms of organochloride pesticides, possibly related to the fact that they are not very degradable in the environment. Another possibility is that the concentration of pesticides was too low to be accurate. Many of the values found in the study were very close to detection limits which could account for some degree of error (see Appendix B). For example, in the study conducted by Palmateer et. Al (1997) concentrations 10-100 times environmental pollution levels were used to find notable results in the study. However, when naturally found concentrations were used, they could not find notable results because of limitations with their equipment. As our study water contained very low concentrations of pesticides (below limits recommended for health reasons) this may also have been a problem with our study. However, CIRA-UNAN has a standardized quality assurance protocol that is used for all sampling activities so for the values far above detection limits other factors may be responsible for the results. For example, although not significant, the increasing values for pesticides for some of the filters (Notable Sample #1 El Trianon), may indicate a contamination of the sediment being used in the filters provided by Samaritan's Purse. More study will be required to verify this.

A regression analysis was used to determine if the efficiency of removal of pesticides was related to the efficiency of the removal of fecal coliforms (see Table 2). This analysis revealed no relationship for dieldrin ($R^2 = 0.32$, $p > 0.42$), p'DDE ($R^2 = 0.27$, $p > 0.67$) and no relationship for p'DDT ($R^2 = 0.04$, $p > 0.135$). The other pesticides Endrin and p'DDD had insufficient data for this test to be performed. These results could indicate that the buildup of the biolayer (effective unit of bacteria removal) is not a factor in the removal of pesticides or once again that the data was not accurate due to low values.

To determine if any relationship existed between removal efficiency and initial pesticide concentration a regression analysis was performed (Table 3). This test revealed no relationship for p'DDT ($R^2 = 0.27$, $p > 0.37$), Dieldrin ($R^2 = 0.44$, $p > 0.33$) and p'DDE ($R^2 = 0.18$, $p > 0.25$). Once again, for endrin and p'DDD there was insufficient data to correctly perform the analysis. The results indicate that removal was not dependent on concentration.

A few discrepancies exist in the data. Namely for the El Trianón filtered water, the values increase dramatically from prefiltered to postfiltered (Figure 1). This could be the result of sampling error in terms of analysis or sample gathering. Another possibility is that it could indicate that the

sediment used in this particular filter was previously contaminated with these pesticides and was contributing concentrations to the water. Removal of the values from this filter when calculating statistics did not change the results significantly.

Bacteria concentration decreased significantly after being filtered ($t = 0.004$, $df=8$), with an average efficiency of 79.7% (64.4%-95%). (Table 4, Figure 6). This indicates that the filters were efficient at removing bacteria even within a 15 day buildup of the microbiological layer (see Appendix A). Although the time that maximal efficiency is achieved will vary from well to well depending on contamination level, it is important to know an approximate time frame for biolayer build-up. These results also reconfirm previous studies on the efficiency levels of the filter.

A regression was performed to determine if there was any effect of initial concentration of fecal coliforms to the efficiency of the filter. The results indicated no significant relationship ($R^2 = 0.0951$, $p>0.42$). Therefore, no matter how contaminated the initial water, the removal rates of the fecal coliforms should be the same.

Concentrations of Endrin were too small to determine if any significant removal had occurred. The single value obtained indicated a 25% removal efficiency. Further study will be required to verify this number.

Using regression, the data was analyzed for a relationship between DO, pH, or temperature and removal of pesticides or bacteria (Table 5). The results show no significant relationship for either pesticide or coliform removal in relation to DO, pH, or temperature. Endrin was once again too small a sample size to test for a relationship. Interesting to note is that when the anomalous values for El Trianón were removed, p'DDD was shown to have a significant relationship with pH for removal ($R^2 = 0.72$, $p>0.0038$). This could possibly indicate that pH does affect the behaviour of this particular pesticide in the filter. Further study will be required to verify this.

Conclusions and Recommendations

The results from our study indicate that the Biosand Water Filter appears to be ineffective at removal of organochloride pesticides in the field. However results must be interpreted with care as the concentrations of the pesticides were very small and many factors may have come into play in producing the results. These factors include possible problems with our sampling procedure. As the analysis is for microconstituents in the water, it is important to homogenize the samples perfectly and then split them into two samples for analysis purposes. This must be done perfectly every time or the results are incomparable due to the low magnitude of the results (personal communication Katherine Vammen 1999). Also, due to budgetary limitations we were not able to sample the quality of the filter material via blanks to determine if the filter material was contributing pesticides to the samples. For future studies it would be advisable if this was included as a routine sampling procedure. Spiked laboratory samples to compliment the field testing would also be advisable, and a longer more comprehensive sampling schedule.

Although from our study the filter shows no ability to remove pesticides from drinking water, its benefits are still very important. Fecal coliform concentrations in the field were greatly reduced from initial stages and clarity and taste of water were improved. There were reports of an improvement in health by some of the users and overall satisfaction with the filter was high.

Further study needs to be undertaken to decide if the filter truly has any impact on pesticide concentrations. Due to the fact that pesticides have unknown impacts on human health, any abilities of the filter would be of great interest. Although this is presently not available by CIRA, it would be useful for future studies to obtain a more comprehensive report of what types of pesticides are located in the sample areas and their concentrations prior to sampling.

Acknowledgements

We would like to gratefully thank and acknowledge a number of people for supporting us and for providing advice in the pursuit of this project ; David Bethune and Cathy Ryan of the University of Calgary and CIRA for their generous support and advice on all stages of the project ; Maria Elena Vargas, Katherine Vammen and the staff of CIRA for the use of the laboratory facilities, food and lodging, personal support, and overall assistance and contribution to the project; Dr. David Manz of Davnor Water Treatment Technologies Ltd.

for the kind use of his water filter design; Rusty Ritenour of Samaritan's Purse Canada for providing contacts and support through Samaritan 's Purse in Nicaragua ; Dexter Cuthbert and the staff of Samaritan's Purse Nicaragua for their advice and provision of supplies and technical assistance; the International Grants Committee at the University of Calgary for the funds to make this all possible ; Dr. Elisabeth Dixon of the Environmental Science program for her support throughout the project ; Dr. Angus Chu of Civil Engineering for the use of his laboratory equipment

Table 1 : Statistical Values for pesticide results

Pesticide	t-test	Normal dist ?	Mean diff (ng/L)	Std error mean(ng/L)	N
Dieldrin	0.802	yes	0.15	0.57	6
DDE	0.646	yes	0.087	0.28	9
DDD	0.5	no	-2.157	-2.157	10
DDT	0.87	yes	0.3	0.34	6
endrin*	0.94	no	-10.78	9.04	2

*only 1 sample

Table 2 : Relationship between pesticide removal and fecal coliform removal

pesticides	R ²	p
dieldrin	0.34	0.42
DDE	0.023	0.699
DDD	0.007	0.82
DDT	0.07	0.667

*endrin not enough values

Table 3: Relationship between pesticide removal and initial concentration

pesticides	R ²	p
dieldrin	.44	0.33
DDE	0.18	0.25
DDD	n/a	n/a
DDT	0.27	0.37

*endrin not enough values

Table 4: Fecal coliform removal

	t-test	normal dist?	mean difference MPN/100ml	std mean error MPN/100ml	N
Fecal coliforms	0.004	no	2415.06	1334.91	9

Table 5: Relationship between DO, pH, or temp and pesticide or coliform removal

	dissolved oxygen		pH		temperature	
	R ²	p	R ²	p	R ²	p
dieldrin	0.036	0.45	0.44815	.33	0.01	0.86
DDE	0.0059	0.84	0.15	0.30	0.05	0.15
DDD	0.01	0.78	0.039	0.58	0.047	0.55
DDT	0.022	0.808	0.102	0.37	0.19	0.46
endrin	n/A	n/a	n/a	n/a	n/a	n/a
coliforms	0.014	0.743	0.05	0.54	0.013	0.74

References

G. Palmateer, D. Manz, A. Jurkovic, R. McInnis, S. Unger, K. K. Kwan, B. J. Dutka, 1997. Toxicant and Parasite Challenge of Manz Intermittent Slow Sand Filter. John Wiley & Sons Inc.

K. Vammen 1999. Personal Communication. Method Detection Limits for Organochlorine Pesticide Analysis.

Appendix B

(Taken from Personal Communication, Katherine Vammen November 1999)

The Method Detection Limits for Organochlorine Pesticides Analysis at CIRA-UNAN are obtained according to EPA Appendix B, Part 136: "Definition and Procedure for the determination of the Method Detection Limit", Revision 1.11. The Method Detection Limit for each analite is:

α -BHC	=	0.09 ng.L ⁻¹
β -BHC	=	0.82 ng.L ⁻¹
Lindane	=	0.25 ng.L ⁻¹
δ -BHC	=	0.13 ng.L ⁻¹
Heptachlor	=	0.16 ng.L ⁻¹
Aldrin	=	0.41 ng.L ⁻¹
Heptachlorepoxyde	=	0.13 ng.L ⁻¹
α -Endosulfane	=	0.19 ng.L ⁻¹
Dieldrin	=	0.50 ng.L ⁻¹
pp-DDE	=	0.25 ng.L ⁻¹
Endrin	=	0.38 ng.L ⁻¹
pp-DD D	=	1.04 ng.L ⁻¹
pp-DDT	=	0.19 ng.L ⁻¹
Toxaphene	=	12.50 ng.L ⁻¹

In order to evaluate the measurement's uncertainty, CIRA-UNAN has developed a quality assurance protocol that includes the following parameters:

- **Precision:** The precision of the method is established by the replicate analysis of samples. In the laboratory each set of samples is analyzed, then 20% of this as duplicates.
- **Internal Standard:** The addition of IS is used to reflect the ability to fully recover surrogate compounds introduced to the sample at the beginning of the procedure. Routinely a known amount of the IS is added at the beginning of the analysis and then at the end the amount that was recovered is calculated (>60%). Confidence of the results is evaluated through the behavior of the IS.
- **Blanks:** Blanks represent an opportunity to evaluate and monitor the potential introduction of contaminants into samples during processing (glassware, reagents). At least one blank is analyzed for each set of samples.
- **Fortified Blank:** An aliquot of reagent water is spiked with known quantities of the interest analites. The fortified blank is analyzed exactly like a sample, and its purpose is to determine whether the methodology is in control, and whether the laboratory is capable of making accurate and precise measurements at the required Method Detection Limit. The recovered amounts must be > 60%.