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Benin, Research Grant
Summer 2009

A Cooperative Approach to Groundwater Protection in Benin: *Establishing the Link Between Land Use and Contamination*

I awoke to the French announcement that we had begun our final descent into Benin. Yawning and rubbing my eyes, I lazily looked through the window at the vast expanse below me: rivers and swamps intermingled in fields of brown and stippled with clusters and clusters of dwellings, separated from the vast black ocean by thin strips of immaculate white sand, glistening despite the darkness. Though we were flying over the largest city in the nation of Benin: Cotonou, the landscape was draped in darkness, only intermittently interrupted by artificial lights.

The complex dynamics of the water, of which I took my first somnolent glance from the airplane, was the exact reason that we came to Benin. Though the details and loci of the research of all of my group members were different, the overarching goal of our research was the same, improving the water supply of the people–a supply that in Cotonou is imminently threatened by a lack of proper infrastructure and urban sprawl, the magnamity of which was instantly visible, even from the air.

My work would not take place in Cotonou, rather, in the area around Dassa-Zoume in central Benin, where wells are threatened by preventable contamination: nitrates. I was only one person spending one month in the framework of a much larger 5+ year project seeking to use non-toxic fluorescent dyes, and natural temperature gradients to track the origin of the pollution. I had spent the previous six months in ardent preparation: primarily researching the various chemicals and techniques, and then developing a fluorometer, an instrument vital to the experiment, and my particular objective was to do preliminary groundwork and method development. Each groundwater system is different, and many physical facts (adsorption of the dye unto the soil, flow rates of the dye, water chemistry…)

must be known in order to design an effective experiment, and it was my objective to ascertain as much of this information as possible. Moreover, a particular objective of my (and all of the group's) work in the country was a cooperative approach, involving students from the Universite d'Abomey-Calavi, local water authorities, and the affected villagers themselves. The time had finally come for me to step out and do that which I had spent, literally, thousands of hours preparing to do.

My chest tightened with anticipation and exhilaration as the plane slowly wound through the air in descent, and after the droll landing announcements, we stepped into the darkness. Heat—intense and wet—plummeted inwards as the cabin doors were opened, and I was instantly covered in a cloak of perspiration that would remain for the entire trip. The utter chaos of the airport which we entered was a stark contrast to the punctilious order of the French; it seemed as though, during our seven hour journey, we had left the world behind and landed in a world of disarray and confusion.

When we finally escaped the labyrinth of the airport, hauled our luggage up 5 flights of un-air conditioned stairs, a bitter surprise awaited me. The fluorometer that I—who had never had an electrical engineering class, or built anything moderately electrical—had painstakenly toiled to produce lay in tattered pieces in my suitcase. Fortunately, however, I brought extra pieces with me, and over the course of several days, I rebuilt it. Moreover, my goal in constructing the fluorometer was to build something accurate but yet cheap and reproducible (industry instruments cost upwards of 3G), so that the technology that we enjoy in wealthy American labs could be accessible to people in developing countries. Having to rebuild the instrument in Benin demonstrated that the prototype that I had developed was in fact something that could be reconstructed, literally, anywhere.

Due to the limitations of our program (5 students under one professor), I spent my first week in Benin aiding my colleagues in their work: long days in the field digging holes to test the soil, and pounding probes in swamps, jungles, and neighborhoods to test the chemistry of the groundwater. Our work in the city took us on many adventures, to small villages in abandoned French coconut plantations, a village built completely on stilts on a lake, metropolitan neighborhoods and farms. These

excursions enabled us to communicate with countless locals who emerged from their houses to watch the strange work that we performed and to explain to them the goals of our work. Moreover, in communicating with them we received information that would be impossible to obtain otherwise: the seasonal patterns of water flow, which are invaluable in the design of computer models used to understand and protect the city's groundwater.

Eventually, the time arrived for professor Silliman and me to go to central Benin. We were accompanied by two professors from the Universite d'Abomey-Calavi, Dr. Yalo and Mr. Landrey, both Beninese geologists who were extremely familiar with our difficult work. The long and bumpy journey took us from the heart of a modern coastal metropolis out into the dry rocky rural lands of the nation, where the majority of people live in villages that their families have inhabited for centuries, far away from the water purification and sanitation services of the city.

It was when we arrived in Dassa-Zoume and spoke with the government bureaucrats in charge of overseeing and protecting the wells of the region that I came to realize that the disorder and confusion which we first met in the airport is in fact manifest in many aspects of Beninese society. The official was not ready to meet with us when we arrived, so we spent our first day collecting samples in 14 wells throughout the region and testing them for nitrates, chloride, total dissolved solids, hardness and ammonium–all factors which indicate the viability of water sources and which influence the design of tracer experiments.

The next day, we got to meet with the official with the goal of receiving the locations of sites of wells that had been closed due to nitrate contamination. After assuring us that he knew the locations of the sites by heart, we embarked on a long, mostly off-road fruitless journey. After a full day of driving, we only managed to find three sites, none of which was viable for our work. Moreover, our colleagues failed to bring a pump, an element that was integral to the experiments that I had previously devised. Disheartened and disappointed, the next morning we again met with the official and he gave us a list of the GPS coordinates of all wells closed due to nitrate contamination in the region. Predictably, his

coordinates were (quite literally) far from accurate, but eventually we found a village that proved suitable for our work.

The people all came out to greet us, and though we spoke no Fon (the principal language of central and northern Benin) our driver spoke it fluently, and the people spoke some French. Upon hearing that our goal was to reopen the well that they had so painstakingly drilled, they opened their arms to us, supplying us with chief chairs and as much water as we needed. We later found out that the water that they brought us was from rain catchments in the mountains–and thus a very precious resource–that they carried to us on foot from a half mile away.

Our experiments in this village, perched in a perfect area for my research interests: at the foot of a rocky bedrock outcrop, gave us a plethora of information about the temperature profile of the abandoned well, the adsorption of dye molecules unto the sediments, the hydraulic conductivity (a parameter related to the resistance of the soil to water permeation) and the effects of photo-degradation on the dyes. Moreover, we were able to test a new piece of geological equipment, the resistivity meter, to locate bedrock fractures, the channels connecting the well to the locations of pollution. In interviewing the people, our Beninese colleagues gained insight into faults in the design of the wells of the area which allowed for their easy contamination, a facet of information which will spur further research both at Notre Dame and in Benin. Arguably, however, the most important result of our work in this village lay not in any scientific measurement that we attained that day, but in the relationship that we developed with the people of the village that will provide the foundation upon which, alongside the scientific data we collected, future work to be performed that may one day render the well potable.

Professor Silliman had engagements with officials all over Benin, and thus, we could only stay for one more day in the Dassa region after the aforementioned primary success. We began the day as we had previously; the water official gave us the location of another village with a closed well, and after hours of searching we located it. Once again, we did experiments with the hydraulic conductivity, resistivity, dye adsorption unto soil media, and temperature profiling, all of which will be helpful, as

with the work of the previous day, in the design of a tracer experiment. A major obstacle that we discovered in this town, however, was the attitude of the people. From the moment we got there, everyone, men, women, and children asked and demanded gifts from us. "Yovo yovo ou est l'argent" (translation: white person, white person, where is the money?) they would shout. We quickly realized that a cooperative effort would be impossible with the people of the village, because, due to well-wishing foreigners, they had come to develop a dependent, rather than an egalitarian attitude towards westerners. Thus, though their village was scientifically ideal for our work, the goal of our research is not purely technical but also social and humanitarian, and we resolved to not return to that village for the future phases of the project.

The remaining two weeks of my time in Benin passed quickly, and I saw intensely beautiful savannahs and forests, teak trees and palms of every kind, and even a dancing monkey. When it came time to come home, I had gained a powerful insight into the way of life of people in a completely different part of the world, and witnessed/experienced (though to an extremely minor degree) the hardships of life in a 3rd world country, and I also got to experience tropical illness (not such a positive experience).Thus, I must say that I am wholeheartedly grateful to the Kellogg Institute. Their funding allowed me to explore a world with which I had only interacted via silver screens. Moreover, the preparatory work I did this summer changed me from a person who could hardly screw in a light bulb to a budding electrical engineer. The lessons I learned about the slow pace of research and technical work are of extreme value to me as a student. However the profound (though sometimes frustrating) benefit of working cooperatively with people of different languages and cultures will surely stay with me long after my days at the golden dome are done.