OFF THE HOOK:

THE SOCIAL INEQUITIES INHERENT IN SAVANNAH RIVER MERCURY FISH ADVISORIES

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ACRONYMS/ABBREVIATIONS

ATSDR	Agency for Toxic Substance and Disease Registry
BMDL	Bench Mark Dose, Lower Limit
CDC	Center for Disease Control and Prevention
CRM	Certified Reference Material
CSFII	Continuing Surveys of Food Intake by Individuals
DMA-80	Milestone DMA-80 Direct Mercury Analyzer
EPA	Governmental Environmental Protection Agency (EPA)
EPD	Georgia Environmental Protection Division (EPD)
FDA	Food and Drug Administration
Hg_h	Mercury Hair Concentration
MACTECH	MACTECH Engineering and Consulting, Inc.
NHANES	Continuing Surveys of Food Intake by Individuals
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
Olin / Olin Corp.	Olin Corporation
QC	Quality Control
RCRA	Resource Conservation and Recovery Act (RCRA)
RfD	Reference Dose
RSD_r	Repeatability Relative Standard Deviation
RSD_R	Reproducibility Relative Standard Deviation
SCDS	Seyschlles Child Development Study
SQuiRTs	National Atmospheric Association’s Screening Quick Reference Tables
SREL	Savannah River Ecology Lab
SRS	Savannah River Site
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
WHO	World Health Organization United States Department of Agriculture

INTRODUCTION

Perhaps one of the most popular images of the adverse health effects of mercury is Lewis Carroll's 1865 children's novel *Alice in Wonderland*. The Mad Hatter in the novel earned his famed moniker due to the madness spurred from the mercury toxicity of his iconic hat. Hat makers from the 1800's through the early 1900's used mercury to process the leather bands that lined the hats. Although, the effects of methylmercury were not documented until the Minamata Bay incident in the 1950s and 1960s, the adverse health effects (in particular the effects observed through personality change) were widely acknowledged among the general public. Despite this prominent image, similar to past generations who were unaware of risks making hats or wearing hats, many people today remain unaware of the omnipresence of mercury.

This thesis builds upon my findings of mercury contamination in the Savannah River (summarized in Chapter I and Chapter II) by examining the mercury exposure from fish consumption in the Savannah River from a more holistic and interdisciplinary perspective. I examine the various complex problems surrounding elevated mercury levels in fish and fish consumption for Savannah River anglers (fishermen) utilizing a portfolio of disciplinary methods in order to address the interconnected and webbed-like nature of the subject matter.

During the past decade of research on this issue, I have only become more convinced that this story necessitates an interdisciplinary perspective. Hindsight being 20/20, I have learned that the subject matter as well as time and resource limitations make my project a rather ambitious task for a senior thesis. Therefore, despite my attempt to construct a full picture of this situation, there is inevitably a need for further research. Thus the departure of this thesis is, in fact, only the beginning of further inquiry. With that said, I think this thesis may be of use as a preliminary study for conducting more comprehensive research on Savannah River fish consumption. I believe this work provides several lessons about the difficulties inherent in interdisciplinary research.

Traversing Interdisciplinary Lines

In *Epidemiology and Culture* James Trostle argues, “disciplinary attempts to maintain exclusive control over knowledge domains can be counterproductive.” Trostle calls for an increased commitment to interdisciplinary research and mutual exchange and suggests we re-conceptualize “defined [disciplinary] borders” as “semi-permeable membranes” (2005:172). My thesis is but one attempt at this re-conceptualization.

Anthropology, in modern times, has become a discipline fascinated with studying tensions. This thesis lies among the rich literature of anthropology, which studies connections and tensions. The tension throughout my thesis is illustrated through the gaps and awkwardly assembled pieces which comprise my thesis. Due to these tensions, this work lies among modern ethnography, which highlights the tensions between seemingly disparate entities such as local and global processes and science and social sciences such as A.L. Tsing’s *Friction: An Ethnography of Global Connections*.

Though my thesis is full of tensions, there are two prime categories which these tensions fall under. The first develops from the complexity of the issue that this thesis is attempting to address. The other develops from epistemological divides within and particularly among disciplines. The interdisciplinary struggles within this thesis echo my indoctrination into seemingly bounded discipline epistemologies and practices.

With a few exceptions, each chapter reflects a differing disciplinary method. I begin (Chapter I) by telling the story of how I have come to this current research. I use a personal narrative style as a way of situating myself with the mercury research. Despite the interdisciplinary tensions that it creates, I believe this thesis is legitimized by its reflexive analysis; this legitimacy develops from my discussion of how I am situated within this study. Additionally, this reflexive analysis introduces the concepts of disciplinary power struggle and political economy, which resurface throughout my thesis. In Chapter II, I fill in the gaps left out due to the individualized perspective of Chapter I. This Chapter provides history and background on this Savannah River fishing consumption issue. Chapter III uses scientific discourses on mercury to provide the reader with the natural science background necessary to understand the following chapter. Chapter IV presents quantitative mercury analysis of the hair samples I took to assess mercury impact on Savannah River anglers. In Chapter V I build on the quantitative data presented in the preceding chapters, by providing a more qualitative analysis of the issues from my participant-observation and questionnaire data. My hope is that the combination of these multiple methods shall paint a more holistic picture of the subject. I pull together these threads by utilizing a political economy perspective in Chapter VI.

Instead of dismissing this work due to its disjointed feel, I encourage the reader to engage in the dominating tensions that pervade this work. Perhaps this thesis is useful as a starting ground from which we can begin to truly engage with complex issues which call upon multiple expertise and methodologies. If this work generates diverse discussions and questions I will consider it a success.

I have been wary of offering solutions within this work because I believe there are many questions we have yet to even pose. My greatest hope is that the process that I have attempted here could stand as example of how we can begin to more holistically engage in research which traverses the lines between social scientific and scientific research. No matter the discipline, the real work in research is rarely about answering the questions and almost always about asking the right question. Acknowledging this, the writing of this thesis has challenged me to engage with this topic in many new ways. Out of everything that has developed from this thesis I believe the most powerful product of this process is not the text itself, but my increasing ability to observe tensions, question dominant assumptions, and pose of new questions. I hope a reader of my thesis is left acknowledging the complexity of the subject and like me, continues to pose novel questions.

I. "MY STORY"

Standing on the banks of the Savannah River, the view is primeval and pristine. Water hickory, swamp dogwood, green ash, tupelo, bald cypress are just a handful of the canopy trees that line the river where Spanish moss hangs down to the water's edge from overcup oaks. The sun reflects in the wide water where the sounds of the river and land are, for once, stronger than the sounds of humans. Perhaps it is just me, but it seems that even the few folks present seem to speak more softly than they would elsewhere; I am not sure precisely why this is the case, but I suppose it has something to do with the strength of the water. The size and beauty of it all is somewhat overwhelming and unexpected; it gives perspective.

I had not realized until recently, on one of my return trips to the Savannah River to complete the research presented here, how much this river was a part of me. I spent a significant portion of my childhood growing up on this water. This is where I jumped from my first rope swing, rode on the back of my mother's whitewater kayak during river cleanup days, and in my early teens, followed the river from where I was born and raised down to where it converges into the Atlantic Ocean. Since this river is so much a part of the woman I am today, I feel I must first tell my story before I can tell the larger story of which I have come to be a part. Therefore, in this Chapter, I tell the story of my mercury research as I have experienced it. In Chapter II, I offer a broader and less personal perspective, history, and background. These approaches provide a more holistic picture of this "issue" and situate my research in larger contexts.

How It All Began

One could say it all began when I first conducted environmental research as part of a 5th grade group science fair project. Dr. *Frank* Carl (*Frank*), the Savannah Riverkeeper and long time family friend, suggested that we conduct water quality testing; following his guidance I conducted my first water quality testing (measuring dissolved oxygen, nitrates, pH, and phosphates) on Rae's Creek. Although I did not know it at the time, *Frank*'s mentorship on this project was only the beginning of a 12-year partnership that continues today. Due to this project and my River's Alive (water monitoring) trainings through the Savannah Riverkeeper, I had some knowledge of water quality testing by the time I reached high school science classes. There the promise of extra credit, in what I found to be difficult honors science classes, convinced me to undertake a science fair project. I never expected that the science fair projects I reluctantly conducted for extra credit would direct so much of my life. However, over the next three years *Frank* mentored me through three environmental Savannah River science fair projects[1] looking at the effects of point source pollution on the Savannah River, the last of which culminated in the mercury research presented here. During my Phase I and Phase II science projects on Savannah River, I attended the International Science and Engineering Fair as an observer and as a competitor respectively. I had the good fortune of traveling with Dr. Charles Jagoe (Chuck), an environmental chemist at the Savannah River Site's

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[1] Phase I. 2003-2004. Point Source Pollution on the Savannah River. / Phase II. 2004-2005. Biological Oxygen Demand on the Savannah River. / Phase III. 2005-2006. Chlor-alkali Plant Contributes to Mercury Pollution on the Savannah River.

Savannah River Ecology Lab (SREL) and judge at the fair. During phase I and phase II research, I grew interested in studying mercury when I learned that the Savannah River had fish advisories that were issued for mercury. My curiosity was further piqued when I heard of some perplexing result of a Savannah Riverkeeper study. Despite my interests, the project was not originally feasible because I lacked access to analytical instrumentation that could test mercury, however, this changed when Chuck offered to mentor me.

Developing Questions

This Savannah Riverkeeper study was designed to determine if heavy metals from the Department of Energy's Savannah River Site (SRS) (a nuclear power plant near Augusta, GA), were detectable at elevated levels in wildlife (bass and catfish tissue and opossum and raccoon hair) near the site compared to control samples upriver (for further discussion of this research see Chapter II:Savannah River Contamination). The quite unexpected results showed that upriver control samples had significantly higher mercury levels than SRS samples (Savannah Riverkeeper 2004). These perplexing results prompted two main questions: Why would there be more mercury upriver than downriver from a nuclear power plant documented to have tons of heavy metals onsite? What was upstream that contributed to the elevated mercury levels? To find answers, we surveyed permits of potential industries in the upriver area determining that a chlor-alkali facility run by the Olin Corporation was a likely contributor, because the facility utilized an antiquated methodology that produced considerable mercury pollution. Our hypothesis was supported when we learned that daily industrial reports suggested that, on average, over 500 pounds of mercury was "unaccounted for" each year in fugitive emissions[2] (Oceana 2006:4-6).

High School Science Fair Project

In order to test this hypothesis, I used a makeshift dredge sampler of duct taped PVC pipes and cloth to collect sediment samples from the bottom of the river. I collected samples from near Olin (which I expected to contain considerable mercury) and downriver from Olin. As a control, I collected samples upriver from Olin.

To analyze the sediment results in the Savannah River Ecology Lab (SREL) I first had to receive federal clearance to enter the Department of Defense's SRS. This necessitated a sanctioned absence from high school, extensive paperwork and fingerprinting, and an out-of-the-ordinary nuclear safety training course in which I was the only female in a room full of truck drivers. At SREL, under the direction of Chuck, the sediment samples were analyzed for mercury. If our hypothesis was supported, the sediment samples from near the Olin facility (i.e.- in the channel where Olin releases their waste) would show elevated mercury. Likewise, the control sediment samples (i.e. those upriver of Olin) would show low-to-no mercury.[3]

The results showed considerable mercury contamination. 560 ppb is the most toxic threshold for mercury sediment; at this level mercury is considered lethal and is

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[2] *Fugitive emissions* are those that are non-intended. Mercury is often released through evaporation into the surrounding environment because its volatile nature.

expected to kill all aquatic organisms (NOAA SQuiRTs 1999). The sediments from the Olin channel had mercury concentrations over 60,000 ppb (Smith et al. 2006). Therefore, mercury levels found in the channel were "lethal one hundred times over" and at least 60 times the upper threshold level. That is over three orders of magnitude higher than background (upstream) sediment concentrations. Additionally, downstream sediment was more toxic than upstream sediment suggesting that Olin was probably the reason for elevated mercury levels seen in bass, catfish, opossum, and raccoon species. I also investigated the mortality rate of macro-invertebrates (i.e. amphipods) to sediment exposure. Amphipods exposed to contaminated sediment had significantly high mortality rates. The survival rate of amphipods exposed to the mercury-contaminated sediment from the channel was approximately 50% after 24 hours. This suggests that the sediment from around Olin was toxic enough to kill about half of all amphipods that came into contact with it within 24 hours (Smith, Jagoe, and Carl 2006).

We summarized our conclusions in a publication for the Georgia Waters Resources Conference using the following language: "It is apparent that the extremely high mercury levels in the sediment of the Olin channel contribute to the mercury problems in the river, which are indicated through mercury triggered fish consumption warnings and amphipod toxicity. The levels of mercury found near the chlor-alkali facility violate the standards of the Resource Conservation and Recovery Act (RCRA) which dictates that the site be mitigated (superfund site)" (Smith et al. 2007:1).

Reporting the Findings

The Savannah Riverkeeper reported the findings to the Georgia Environmental Protection Division (EPD), the Georgia state division of the United States Governmental Environmental Protection Agency's (EPA). Jim McNamara, the EPD's Hazardous Waste Management Branch compliance officer whose responsibilities include overseeing the Augusta Georgia's Olin plant, responded to the findings in the *Augusta Chronicle*. In his response, McNamara hypothesizes the contamination, " 'may be historic,' ". He also says the Olin canal is "private property" and therefore outside of EPD's jurisdiction. The following *Augusta Chronicle* excerpt records McNamara's response:

> "Under the hazardous waste rules we [EPD] have not required them to clean up their canal, and we never required them to test that channel,' he [McNamara] said, noting that the canal is technically Olin's private property, and its canal is not regulated, as state waters would be.
>
> Generally, Olin's Augusta plant ranks at the top of the list in terms of consistent compliance with environmental regulations, Mr. McNamara said….
>
> 'As those plants go it's about as good as it gets, and it's the only facility of its size that ever aced an inspection – with no violations whatsoever,' he said, adding that the company could choose to clean the canal or restrict access to the area." [Pavey 2006a:1]'

McNamara's was correct in saying that Olin had been compliant with their permits. The Georgia state issued permit for Olin Corporation's Augusta plant allow for the release of 0.1 pounds of mercury per day- or about 7 pounds annually (Pavey 2006b).

The Changing Public Narrative

I used this research to compete in science and engineering fairs and consciously remained neutral, staying removed from the growing activism that developed around the project. I was concerned that activism would call into question the validity of my results. Results showing mercury levels to be elevated and over 100 times the lethal limit were uncanny enough. Furthermore, I was a high school student accusing a Fortune 200 company of gross environmental contamination, and my claim threatened local jobs. I was advised many times that meddling in activism would delegitimize my research. Heeding this advice proved worthwhile, as my science fair project continued to receive numerous awards, culminating in 2nd place honors at the Intel International Science and Engineering Fair. An asteroid ("Wootensmith" 21630) was named in my honor by the Lincoln Laboratories at the Massachusetts Institute of Technology. This high esteem had a positive influence on media coverage. The rigor and specialization of judging, particularly at the international level, made it difficult to question the legitimacy of my research. After the awards were covered in the *Augusta Chronicle*, I saw a major shift in public opinion, from a narrative of flawed high school research project causing a false scare into a quintessential underdog narrative of a high-school youth who stumbled upon corporate negligence and cover-up. Neither narrative tells the full truth. The change in the dominant narrative demonstrates the power that media has on public opinion. Despite my initial distance from activism, I became the centerpiece in this public narrative. It struck me as ironic that the world that required a detached and apolitical scientist also created a narrative in which the scientist became central to the story. The science needed to appear apolitical to be validated, yet the scientific results did not speak for themselves. It took a very political public narrative to confirm the validity of the science.

Positionality and Epistemology

At the time I thought that after my results were validated I would be out of the picture. This was the first time I started to realize that as a researcher I was positioned in the middle of a larger tension. It would take me years to recognize that I was, by the nature of having been the researcher, a part of this story. I could influence it but it also had a life of its own. I still struggle with this as I have gone back to the field. Here I am attempting to reconcile these contradictory epistemologies and who I am in this larger story. Readers will see that my identity has fundamentally affected the research I have conducted and its impact. It is still difficult for me to realize that my identity as a privileged, young, white female affects this complex of issues. I speak about this struggle not in an attempt to address the issue with progressive political correctness but because I feel that my personal struggle reflects a larger societal struggle. I did not get to be an abstract technical voice; as I came to learn no one gets that opportunity. *This is a story of legitimacy and the contestation of idiosyncratic epistemologies. At its very root it is a story of power.*

Validating Our Results

The change in this narrative associated with the issue validated my project and increased interest in my results. As far as empirical evidence goes, the evidence was available if people wanted to look at it, such as the fact that my research used official EPA standardized methods and was conducted and validated at an official governmental lab. As a grassroots campaign developed around the issue and the public narrative of my research changed, I noticed a change in the tone of the press coverage. While EPD never countered the statement made by Jim McNamara, who had claimed that the channel was a non-navigable waterway and thus outside of the EPD's jurisdiction, EPD did inform Olin that they could either hire a certified monitor or EPD could monitor the channel. Olin chose the former. The only public announcement, I could locate, by Olin Corporation or the EPD about the hiring of a certified monitor was Olin's statement in the *Augusta Chronicle* that stated, " 'We're doing the sampling because we think it's the right thing to do' " (Pavey 2006a:1).

MACTECH Engineering and Consulting, Inc., a private consulting firm providing public and private engineering, environmental and construction services, analyzed the sediment. Their results were on average lower than those I found, however, the results were comparable to my own; they were within the same ballpark (Pavey 2006c:1). According to the *Augusta Chronicle* the report revealed levels as low as 110 ppb and as high as 69,000 ppb in the channel, with mercury levels highest closest to the wastewater outlet and lowest closest to the end of the channel which dumped into the Savannah River (Pavey 06/29/06:1). As the results were confirmed, Olin Plant Manager David Blair said to the *Augusta Chronicle* that "Olin is already discussing cleanup options with state regulators who would have to approve and supervise any remediation in the area" (Pavey 2006b:1). Based on MACTECH Consulting's results, EPD ordered a cleanup.

Grassroots Campaign

After competing in science fairs, I became involved in the growing grassroots campaign that developed around the mercury contamination. By the time I became involved the campaign was already well underway. The Augusta campaign was run principally through the Savannah Riverkeeper organization through news articles, press releases, increased public awareness, and editorials. Numerous other organizations joined, including Oceana, an environmental activist organization which determined that they were going to focus on mercury contamination from the few remaining chlor-alkali facilities. Oceana contacted us telling us they were interested in eventually sending Jon Pezold (Jon), a field organizer, to work on developing this grassroots campaign. Oceana worked in Georgia, Ohio, Tennessee, West Virginia, and Wisconsin and focused on five remaining chlor-alkali facilities[4] in the United States as well on pushing through the federal bill that would require chlor-alkali plants to convert to mercury-free technology. Oceana sent Jon numerous grassroots campaign materials including "Olin. Go Mercury Free" yard signs and, bumper stickers that read "Olin. Go Mercury Free," and red rubber ("livestrong" imitation) awareness wristbands, just to name a few. Public awareness resources reached new and younger populations. Various other groups joined the Save the Savannah River Campaign, including Sweetwater Brewing Company. Now in their

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[4] The five remaining plants were: Ashta Chemicals (Ashtabula, Ohio), ERCO Worldwide (Port Edwards, Wisconsin), Olin Corporation's plants in Charleston, Tennessee, and Augusta, Georgia, and PPG Industries (Natrium, West Virginia).

third year on the campaign, Sweetwater Brewing Company is raising funds and awareness through their "Give Your Liver To Save The River" Campaign.

The Cleanup Plan

During the two years following the validation of our results, Olin and EPD negotiated a cleanup plan. The estimated $3 million cleanup plan required that the channel be dammed at the river outfall and filled with clean dirt to encapsulate the mercury contaminated sludge. Wastewater effluent would be rerouted directly into the Savannah River rather than into the channel (Pavey 2008:1-2). The grassroots campaign became important during this negotiation period because there was a great debate about what type of remediation was appropriate. The campaign against mercury contamination in the Savannah River continued even after the cleanup plan was negotiated with Olin because the plan eased the liability of the Olin plant, it did little to actually alleviate the problem. The plan involved damming the original problem channel and redirecting the runoff from the plant to the river itself, which solved the problem of the contaminated channel. According to the agreement, Olin was not required to convert to mercury-free technology, nor were they required to deal with the fugitive emission problem. The antiquated process Olin was using became the focus of the renewed campaign.

Human / Environment Duality

After seven years of involvement with this project, I returned to this research for my senior thesis in order to address the documented *human* effects of mercury in the river. I was inspired to return to the project because several individuals and organizations have suggested that there is no evidence to demonstrate that mercury has adverse effects on human health. When an environmental writer from the *Washington Post* contacted me in February 2011, he was not interested in covering the story unless there was quantitative evidence of human effects. While I was surprised and disheartened that an *environmental writer* would make such a comment, I had heard it before. Comments such as these motivated me to undertake the research presented here.

I was surprised by how the mercury contamination issue was conceptualized and given meaning in society. During my research I observed that when various actors spoke about the mercury contamination they often distinguished between humans and the environment. This dualistic conceptualization was particularly common when actors spoke about the need for remediation. I was surprised that this dualism was shared by actors as diverse as Olin and the EPD/EPA. I have highlighted this duality because I believe how an issue is conceptualized determines what is seen or, equally important, not seen.

In the case of this mercury contamination I find discourses that separate humans from the environment problematic for two primary reasons: (1) By separating humans from the environment it is easy for one to accept the fallacy that the two entities are not complexly and integrally interconnected. (2) Mercury, particularly low-dose mercury exposure, is difficult to study in human subjects because the health effects are often inconspicuous, however, more easy to study in the environment. Therefore, conceptualizing the environment as distinct from human life can easily lead one to ignore "inferred causation" in favor of classifying mercury toxicity as either "causal" or "non-causal" to ill health. The classic epidemiological example of the link between smoking and lung cancer is a useful comparison. Epidemiological studies can never prove causation. Smoking has never been "proven" to cause lung cancer, however, as an increasing number of studies show the high correlation between smoking and lung cancer the association between smoking and lung cancer is increased. Mercury is an issue that can be more easily studied in the environment than in human trial due to the complex, varied, and inconspicuous nature of its health effects. Quantifying the amount of mercury in the environment may therefore be useful for public health initiatives.

The Power of Discourses

In the essay "Human Rights and Women's Health" *Lynn* Freedman provides a strong argument for the power of discourses that is reflected in the following quote.

> … to focus exclusively on formal law and state actors is to miss the most deeply rooted sources of women's oppression. The inequalities that shape so much of women's health are enforced not only through laws or even 'cultural' and/or 'traditional' practices, but also through the workings of *power in the discourses* that structure everyday life and are therefore reflected in health research, policy, and practices as well. Indeed, it is precisely because of their ability to appear so obvious and common sensical, to make socially constructed phenomena seem so self-evidently natural and inevitable, that discursive structures carry such enormous weight in shaping our worlds and the nature of our experience in them. Here the concept of hegemony is helpful. Hegemonic power is 'that order of signs and practices, relations and distinctions, images and epistemologies- drawn from a historically situated cultural field- that come to be taken-for-granted as the natural and received shape of the world and everything that inhabits it.' (Freedman 2000:430; as cited in Lock and Kaufert 1998:23; *emphasis added*).

I have included the above quote to introduce the discussion of women's health (explored in greater detail in Chapter V) and because I feel this quote eloquently explores the power of discourses. I suggested earlier that there are many conflicting epistemologies that surround this mercury contamination research. In order to begin to understand why actors act as they do I have found a discourse discussion useful. The breadth of this thesis limits my ability to do justice to a discussion on the power of discourses. However, I highlight and briefly analyze discourses throughout this thesis since these have a profound impact on how actors (be them individuals, institutions, or corporations) mediate mercury contamination.

I play with several differing theoretical framings throughout this thesis; yet, I have overall found a political-economic analysis most useful. The science (be that natural science or social science) of mercury contamination is inextricably linked to the politics of mercury contamination. The complexity of this mercury contamination issue has led me to attempt to tell the story using a variety of academic discourses. Although this thesis offers an incomplete model of interdisciplinary research, the attempt provides valuable lessons and may be useful as a preliminary study to determine how to better study the Olin mercury contamination issue in the future.

II. MERCURY ON THE SAVANNAH RIVER

Savannah River Geography

The Savannah River is one of the major rivers of the southeastern United States. Although the river technically begins at the confluence of Tugaloo and Seneca rivers in Georgia Piedmont region, the headwaters form in the Blue Ridge Mountains of Georgia, North Carolina, and South Carolina at Ellicott Rock, which is the point at which all three states meet. The Savannah River basin drains more than 10,500 square miles of surrounding land, of which "approximately 5,800 are in Georgia, 4,500 are in South Carolina, and 175 are in North Carolina" (Lenz 2000:1). Flowing southeast from the Blue Ridge Mountains, it defines the border between Georgia and South Carolina all the way to the Atlantic Ocean (Makhijani and Boyd 2004:17).

The Savannah River "flows through four physiographic regions: Blue Ridge Mountains, Piedmont, upper coastal plain and lower coastal plain" (Savannah Riverkeeper 2011) maintaining two distinct characters: "the impounded alluvial Piedmont stream north of Augusta [Georgia], and the natural flowing Coastal Plain river south of Augusta" (Lenz 2000:1). The river's headwaters begin in the Blue Ridge region (a region consisting of rugged mountains and ridges) making an abrupt drop in altitude/gradient of approximately 1,700 ft into the Piedmont region (GDNR EPD 2000:2-3). The Piedmont region of the Savannah River has swift water, shoals, deeply weathered bedrock, and a high concentration of clay sediment (commonly referred to as Georgia red clay due to its distinct color) (GDNR EPD 2000:2-5).

The boundary between the Piedmont and Coastal Plain regions is separated by “the Savannah River Fall Line”. A fall line refers to a sharp change in gradient that occurs due the geomorphologic faulting between the upland dense crystalline rock and more malleable sedimentary rock (GDNR EPD 2000:2-5). The Savannah River’s rapids and minor waterfalls are characteristic features of a river that flows over a fall line. The Savannah River Fall Line was the location of the North American coastline in ancient times. The occurrence of the Savannah River Fall Line often impedes river vessel travel, defining the limits of a navigable waterway, but generally proves useful for mechanical energy generation. The Savannah River Fall Line was of particular importance historically because it had a profound influence on the location of early European settlements as well as the types of industry and commerce that dominated the land surrounding the Savannah River. The growth of the city of Augusta was due to the geography of the Fall Line that prevented navigation further north yet provided ample power supply for mills. Due to the geographic resources, cities along the Fall Line (such as Augusta) grew substantially, becoming industrial centers. Today, the character of the upper section (north of Augusta, Georgia) has been altered due to several large dams, which create lake-like sections of the river. Parts of the river that were not directly affected by the dams are marked by class II white water and famous fossil oyster beds (Lenz 2000:1).

The section of the river where I conducted my research was right below the final dam (the New Savannah Bluff Lock and Dam) which is located about eight miles south of Augusta, Georgia and close to the beginning of the coastal plain section of the Savannah River. After this dam, the river becomes calmer and deep, with flat-surrounding flood plain land, creating a meandering path towards the Atlantic Ocean. There are an increasing number of sandy, beach-like shoals as the river approaches the coast through the coastal plain region.

Savannah River Political Boundaries

Both Georgia and South Carolina share ownership of the Savannah River, which delineates the political boundary between the two states. The terms of this ownership between Georgia and South Carolina have been fraught with controversy in past years. As one could expect, the division of this natural resource has complicated the matters of legal water rights, permit issuance, environmental cleanup, etc. Some of these political issues are highlighted in the issuance of fish advisories which are discussed in greater detail Chapter V.

Savannah River Contamination

According to 2007 data compiled from publicly available Toxicity Release Inventory (TRI), the Savannah River ranks as the fourth most polluted river in the country (Landers 2009:1). The 2007 "TRI chemical list contains 581 individually listed chemicals and 30 chemical categories, according to the US EPA. Companies voluntarily report their discharges of these chemicals on an annual basis" (Landers 2009:1). According to the *Savannah Morning News*, the data, which was complied by the non-profit group Environmental Georgia, uses crude methodology because it does not "account for companies that do not report nor does it account for non-point [non-direct] sources of pollutions such as agricultural runoff or discharge from municipal sewage systems. Nor does it take into account the size of the waterway or the varying toxicity of the chemicals listed" (Landers 2009:1).

Environmental Regulation

In the early 1970's Congress enacted the Water Pollution Control Act Amendments of 1972, commonly known as the Clean Water Act. The main objective of this legislation was to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Clean Water Act 1977:1251). Two approaches were established to achieve this goal: National Pollutant Discharge Elimination System (NPDES) and Total Maximum Daily Loads (TMDLs). NPDES permits put limits on the amount of waste that can be dumped in a body of water and are required for industries or municipalities that will be discharging wastewater into a body of water. The South

Carolina Department of Health and Environmental Control issues South Carolina NPDES permits while the Georgia Environmental Protection Division is responsible for producing Georgia Permits (Savannah Riverkeeper 2011). Currently, for the Savannah River there are "approximately 183 facilities… authorized to discharge wastewater into the Savannah River Basin pursuant to NPDES permits" (Georgia River Network [No Date]:4).

Fish Advisory Determination

Fish advisories are determined based on a calculated reference dose. A *reference dose (RfD)* is the amount of mercury exposure on a daily basis that will apparently do no harm. An RfD is chemical specific and species specific; for example, an RfD for mercury is independent of the RfD for lead and, an RfD for mercury in bass will be determined independent of an RfD for salmon.

RfD values for mercury are given in # of ug of mercury per 1 kg of body weight per day, and RfD's are determined by using toxicity study data. This data is used to determine the lowest level at which toxicity effects are detectable and then 1/10th of that amount is taken to establish the RfD level. Using a factor of 10 is determined arbitrary; however, it is commonly accepted and utilized within the field of toxicology. This uncertainty factor is intended to control for both experimental error and sampling error.

RfD determination uses a calculated *Benchmark Dose Lower Limit (BMDL)*. The BMDL calculations that are used vary. Both the equation for RfD and the equation for BMDL (with 2 common interpretation of the BMDL variables) are provided in *Equation I-II* provided below.

Equation I-II. Reference Dose Determination (RfD). Equations for RfD and BMDL.

RfD = **BMDL** / (**UF** x **MF**)

Where,

BMDL = Benchmark Does, Lower Limit 95%
UF = Uncertainty Factor = 10 (Experimental Error and Sampling Error)
MF = Modifying Factor = 1

BMDL = (**c** * **b** * **V**) / (**A** * **f** * **bw**)

Where,

c = concentration of BMD, 95% lower limit or actual lowest lower limit
b = elimination constant or lower end of mean range of mercury loss
V = whole body blood volume or mean volume of blood during pregnancy or mean volume of woman's blood early pregnancy
A = absorption factor or absorbance that is >95%
f = fraction of mercury intake that resides in plasma available for placental transport or range of plasma fraction that varies with time after exposure, from 40% to 4%. In fish consuming population with frequent exposures, this level maybe underestimated.
bw = body weight of average pregnant female [5]

Adapted from: Carl 2010:14

Variation in the determination of RfD's depends not only on differing interpretations of

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[5] Due to the variance in BMDL equations, I have included two commonly used examples for determining the RfD value for a pregnant female in the *Equation I-II* chart. The differing interpretations in the defined terms are separated by "or" in the chart *Equation I-II.*

equation variables (as can be seen in the above *Equation I-II*), but also on which toxicity studies are used to determine the RfD. There are 5 predominant mercury toxicity studies, Minamata Bay, Iraq, Seychelles Islands, Faroe Islands, and New Zealand (see Chapter III High-dose Mercury Exposures and Chapter III Low-dose Mercury Exposures) which are used by various agencies to determine RfD values for mercury. *Table I* summarizes the differences between FDA, ATSDR, and EPA RfD determinations.

Table I. Differing RfD Determinations by Agency

Agency Name:	Used data from:	Notes:	RfD value
FDA	Minamata Bay Study(s)	Adult poisoning with adult endpoints	0.0005 mg/kg/day
ATSDR	Seychelles Island Study(s)	Seychelles Island Study(s) showed no significant effects	0.0003 mg/kg/day
EPA	Faroe Island Study(s)	Fetal poisoning, learning effects in 6 yr. olds	0.0001 mg/kg/day

Adapted From: Carl 2010: 13-14

Savannah River Mercury in Wildlife Studies and Savannah River Fish Advisories

There are a few sources of data that suggest mercury may be elevated more than fish advisories currently account for. The original Savannah Riverkeeper study (referenced in Chapter I) that sparked my interest in testing the Olin sediment, showed elevated mercury levels in bass and catfish. Bass around Olin had mean mercury levels of 0.51 mg/kg while channel catfish had mean mercury levels around 0.36 mg/kg

(Savannah Riverkeeper 2004). In addition to the Savannah Riverkeeper research, a study by Westinghouse showed mercury concentrations in fish offsite of SRS ranged from "a high of 1.629 mg/g in bass… to a low of 0.016 mg/g in mullet" (Makhijani and Boyd 2004:42; cited in RAC 2001:14-21). The Savannah Riverkeeper and the Westinghouse data each suggest that both the South Carolina and Georgia issued fish advisories for the Savannah River are inadequate. Correlations between Savannah Riverkeeper study results and levels for current fish advisories are provided below in *Table II*. *Table II* uses the South Carolina and Georgia fish advisory guidelines to equate mercury level by weight to the corresponding fish advisory suggestion (one meal/wk or one meal/ mo.)

Table II. Mercury in Savannah River Fish

Fish (# in sample)	*Tissue Mercury* Mercury Level: **>0.3 mg/kg** Advisory: **One meal/wk**	*Tissue Mercury* Mercury Level:**>1.0 mg/kg** Advisory: **One meal/mo.**
Catfish (35)	17	1
Bass (36)	24	1
Bowfin (3)	1	0

(*Frank* Carl 2010:9)

Literature Review: Previous Studies on Savannah River Anglers & Fish Advisories

Joanna Burger et al.'s "Science, Policy, Stakeholders, and Fish Consumption Advisories: Developing a Fish Fact Sheet for the Savannah River" provides a summary analysis of prior research on the Savannah River. The goal of this paper was to develop a "simple, readable and attractive fish fact sheet that contained information on consuming fish from the Savannah River" (Burger 2001:508). Joanna Burger, the paper's lead author, has conducted the most extensive research on Savannah River anglers to date. I am including the following lengthy quotation because it summarizes the existing research on Savannah River anglers succinctly.

> The overall results of the fishing and consumption study can be summarized as follows: Ethnicity and deduction were the two factors that contributed the most to explaining variations in the number of fish meals per month, serving size, and total quantity of fish consumed per year. Blacks fished more often, ate more fish meals, ate larger serving sizes, and consumed more fish per year than did whites. Although few women were interviewed their consumption patterns did not differ markedly from men. Blacks also traveled shorter distances to fish, had significantly lower incomes and spent fewer years in school than whites. Anglers with incomes below $20,000 ate fish slightly more times per year than those with higher incomes. Although education and income were correlated, education contributed more to explaining differences in fishing and consumption behavior than did income. Fishers who did not graduate from high school ate fish more often, ate more fish per year, ate more whole fish, and had lower incomes than those who graduated from high school. Depending upon the species of fish, children began to eat fish between the ages of 3 and 5 years.

> Using the data on meal size and fish consumption rates for each individual indicates that: (1) people who eat fish more often also eat larger portions, (2) a substantial number of people (72 of 258) exceed the fish consumption threshold (19 kg/year) used by the SCDHEC to compute risk to recreational fishers, (3) some people (24 of 258) consume more than the subsistence level default assumption (50 kg/year) used by SCDHEC (1666), and (4) blacks consume more fish per year than whites, putting them at greater risk from potential contaminants in fish (Figure 3). Overall, ethnicity age, and education (but not income) contributed to variations in fishing behavior and consumption. Clearly, a higher proportion of blacks are consuming more than 19 kg/year, compared to whites (Figure 4).
>
> Even though 62% of the fishers are aware of the advisories issued by SCHDEC, over 80% believed the fish were safe to eat. Fewer blacks, low-income people, and people who had never worked at SRS knew about the fish consumption advisories, compared to others. Sources of information about the contents of advisories included newspapers television, and other people. Few people said they learned about the advisories from doctors, public health officials, or the printed brochures (Burger 1998).

The culmination of Burger et al.'s research was the publication of a fish fact sheet for Savannah River anglers. The development of this fish fact sheet involved consensus-building among differing regulatory agencies in which, scientific data was used as a basis for alternative parties to discuss the differing risk assumptions and reach regulatory agreement. Further discussion of Burger et al.'s research in comparison with my own is discussed in Chapter IV.

III. SCIENTIFIC DISCOURSES ON MERCURY

Methylmercury (which I will refer to as both methylmercury and simply mercury) causes adverse health effects on humans. The most notable effects are neurological, however, there is increasing evidence for adverse cardiovascular and immunological effects.

Kinetics and Metabolism

The dominant source of mercury exposure for humans is contaminated fish and seafood consumption. When methylmercury is consumed it is "almost completely absorbed into the bloodstream and distributed to all tissues [particularly the central nervous system] within about 4 days. The "blood-to-hair ratio of methylmercury in humans is approximately 1:250" (WHO 1990:13).

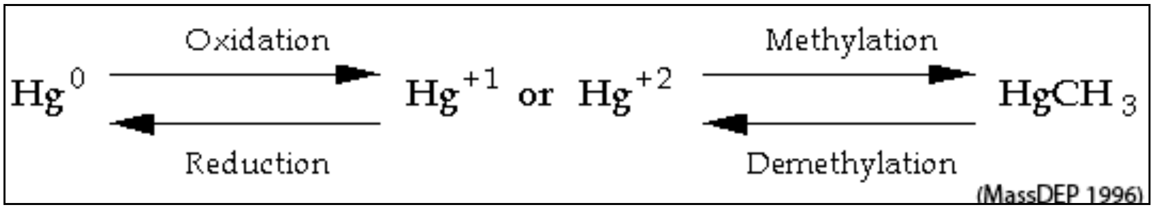
Dietary methylmercury can also pass the placental barrier reaching the fetus and fetal brain (Borum et al. 2001:ix). Effects of methylmercury are different on adults compared to fetuses and infants. The comparison of mercury content in maternal blood compared to cord blood shows mercury to be higher in cord blood. Additionally, lactating females have a shorter half-life than non-lactating females suggesting that a major mode of mercury excretion for lactating females is via breastmilk (WHO 1990:14-15). Evidence such as this helps to explain why methylmercury exposure is poses a higher risk to "sensitive populations." For mercury, specifically, sensitive populations include fetuses, children, pregnant women (due to fetal exposure), and women who may become pregnant (due to fetal exposure from mercury remaining in the maternal body prior to conception).

In utero exposure to methylmercury poses a two-pronged risk. First, mercury exposure *in utero* will pose increased risks because mercury exposure will likely disrupt critical developmental processes. *In utero* development consists of several critical periods; if development does not occur during these critical periods it cannot occur later. This risk is furthered by the rate at which methylmercury passes the placental barrier. A fetus is exposed to mercury at an estimated 10 times the rate of adult exposure (WHO 1990:14-15). Congenital Minamata disease occurs at lower exposure rates of methyl mercury than (adult) Minamata disease. Children born to pregnant women exposed to methylmercury *in utero* show more severe symptoms than their mothers. Fetal hemoglobin, which has an increased affinity to methylmercury compared to maternal hemoglobin, is thought to increase fetal susceptibility and decrease maternal susceptibility to the adverse health effects from methylmercury (Sullivan 2001:875). Data collected following the Minamata Bay incident suggests that the developing fetus may be 5-10 times more sensitive to methylmercury than an adult (Clarkson 1993:36). The increased exposure rate (due to fetal hemoglobin's increased affinity to methylmercury) combined with the fact that a fetus is at a critical developmental period *in utero* is why *in utero* methylmercury poses a two-pronged health risk.

The Chemistry of Mercury

Mercuric toxicity depends on its chemical makeup as well as the mode of exposure. Fish consumption is the primary source of methylmercury, the particularly harmful form of mercury, exposure for humans. Nearly all mercury in fish is methylmercury (WHO 1990; cited in Trudel and Rasmussen 2006:1891). To understand why methylmercury is the particularly harmful form, it is important to how the chemical makeup of each mercury form affects how it "interacts" in the environment. It is possible for mercury to have one of three possible valence states: Elemental/metallic, ionic, organic mercury. Methylmercury is formed from elemental mercury when it undergoes two types of chemical transformation: (1) oxidation (2) methylation.

Figure I. Common Mercury Transformations



(MassDEP 1996)

- <u>Elemental mercury or metallic mercury</u> (Hg^0) is the pure form. Elemental mercury was the type traditionally used in thermometers. It is a silver-white liquid at room temperature and therefore commonly referred to as "quicksilver." This form of mercury is rarely found in animal organisms because it is relatively non-reactive due to its limited solubility in water. This form will slowly evaporate if not encapsulated. Most atmospheric mercury is in the elemental form where it can stay for as long as one year.

In the atmosphere it can be widely dispersed and transported traveling thousands of miles. If properly cleaned after a spill, elemental mercury is not toxic to humans. If, however, this mercury is not properly stored it will change chemical properties overtime becoming a more harmful form of mercury such as methylmercury (Borum 2001:5-2). This conversion is discussed in more detail in the environmental chemistry section (p. 35).

- Ionic mercury (Hg^{+} / Hg^{2+}) is a reactive gaseous mercury due to its high reactivity and increased solubility in water. Due to these physical properties ionic mercury is more commonly found in nature, however, it remains in the atmosphere for a shorter period of time. As a result, it tends to be deposited locally. When elemental mercury is *oxidized* (becoming charged) it transforms into ionic mercury. Ionic mercury is formed from elemental mercury when the electrons in elemental mercury are elevated to higher energy states making mercury charged. There are two forms of ionic mercury: mercurious salt (Hg^{+}) and mercuric salt (Hg^{2+}). Hg^{+} is rare. In contrast, Hg^{++} is relatively common and is the dominant species in aerobic environmental conditions. Specifically, it is commonly found in the sediment.

- Organic mercury ($RMercury^{+}$) is formed when mercury combines with organic elements. Specially, *methylation* occurs when an organic methyl or hydrocarbon group is added to elemental mercury. There are two forms of methylmercury: methylmercury and dimethylmercury. Dimethylmercury ($CH_3Hg\ CH_3$) is chemically synthesized and is extremely dangerous[6].

Methylmercury is the form of organic mercury most commonly found in the environment. Inorganic mercury is converted to methylmercury by micro-organisms over time. The conversion is a naturally occurring process, however, it can be accelerated by anaerobic conditions, higher temperatures, and lower pH (Borum et al. 2001:xv).

Dr. Binyamin Rothstein explains the process of how methylmercury bioaccumulates in the body saying,

> Organic mercury accumulates in the liver. Since the liver is the primary organ for detoxification of the body, it filters out heavy metals and tries to process them through the feces. However, beyond a certain threshold, the liver is unable to cope with high levels of mercury exposure and begins to become a "toxic waste site." Normally the liver produces glutathione (which is the body's most potent antioxidant) to detoxify itself and protect it and the rest of the body from harm. Mercury, however, consumes glutathione and diminishes the liver's ability to detoxify itself. (Rothstein 2005:159).

Once methylmercury is in the human body, if not detoxified by the liver, it forms a methylmercuric-cysteinyl complex that mimics the essential amino acid, methionine. Due to the mimicry, methylmercury becomes recognized by metal transport proteins such as methionine and is transported throughout the body. (Kerper, Ballatori, and Clarkson 1992:262).

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[6] The death of Dartmouth College chemist Karen Wetterhahn highlighted the toxicity of dimethylmercury. Her death was caused by dimethylmercury exposure from inadvertently dropping a few drops on her latex glove

Table I (below) provides a summary of mercury bioavailability by species in humans. The high rate of methylmercury uptake by the gut and the high rate at which methylmercury crosses the blood-brain barrier and/or placenta demonstrate why it is considered the particularly harmful form of mercury.

Table I. Bioavailability of Mercury in Humans

	Elemental Mercury	**Ionic Mercury**	**Organic Mercury**
Uptake by Gut (%)	<10	7-15	>95
Uptake by Lungs	Readily	minimal	?
Cross Blood-Brain Barrier and/or Placenta	Poor	poor	readily
Cross Skin	Poor	poor	poor

Adapted from: Carl 2010:7

Table III. Physical Properties of Mercury

	Elemental Mercury	**Ionic Mercury**	**Organic Mercury**
Water Solubility (g/L)	$5.6 * 10^{-5}$	69	0.10
Fat Solubility	High	Low	Very high
Estimated Half Life (days)	*58*	*30-60*	*70 – 80; biphasic*

(Carl 2011:13)

Environmental Chemistry

The methylation of mercury is mediated by various forms of microorganisms. Certain environmental conditions increase the rate of methylation. Methylation of mercury is affected by chemical factors such as pH, dissolved oxygen, temperature, and the presence of organic substrate and/or sulfides. Additionally, methylation is affected by biotic factors. Methylation of mercury is elevated in anoxic environments. Commonly mercury settles in sediment and, through time, is methylated into methylmercury and then into the food chain.

Biomagnification of Mercury

Methylmercury can accumulate in the tissues of organisms via a process called *bioaccumulation*. Once in tissue, mercury travels up the food chain as *high trophic* animals (animals on the top of the food chain) consume *lower trophic animals* (animals low on the food chain). The relatively long half-life of mercury (approximately 70 to 80 days[7]) causes mercury to become concentrated higher in the food chain. This process of *biomagnification* means that higher mercury levels are found in animals higher in the food chain.

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[7] According to Borum et al. there are 5 studies that assess the clearance half-lives of methylmercury. Three studies suggest a half-life of approximately 70 to 80 days (Aberg et al. 1969; Bernard and Purdue, 1984; Miettinen, 1973). Smith et al. reported a half-life of 44 days for adult males treated intravenously with mercury. Al-Shahristani and Shihab (1974) calculated a "biological half-life" for 48 subjects who had ingested contaminated seed grain (Iraq exposure) by determining mercury distribution along hair strands. They determined that the half-life ranged from 35 days to 189 days with a mean of 72 days. (Borum et al. 2001:2-5).

Sources of Mercury

Mercury in the environment comes from both naturally occurring phenomena as well as anthropogenic sources. Naturally occurring sources account for an estimated 1/3 of worldwide air emissions and include volcanic eruptions and releases from the ocean. Anthropogenic, or human caused, sources account for the remaining two-thirds of worldwide air emissions. These include coal combustion (such as is used in coal burning power plants), waste incineration, cement plants, gold mining, textile industry, and chlor-alkali plants (Seingeur 2004; Mason and Sheu 2002; cited in EPA 2011:1-2).

The World Health Organization (WHO) estimates that combustion of fossil fuels (natural and anthropogenic) contributes to 25% of total airborne mercury emissions. The EPA estimates fossil fuels contribute 50% to 75% of total airborne mercury. In the US most airborne mercury is from combustion sources. Combustion sources such as medical or municipal incinerators or coal-fired boilers account for more than 80% of mercury emitted from point sources (Commission on Life Science 2000:15-16). EPA and state guidelines for medical waste disposal and incineration (such as for mercury thermometers) have led to major reductions in medical incinerators; airborne emissions have declined by an estimated 85%-90% in recent decades, with more than 50% of that reduction after 1990 (EPA 2011:1)

- Chlor-alkali Plants: Chlor-alklai plants use an antiquated process to produce chlorine and caustic soda using a mercury-cell. The chlor-alkali process was developed in 1894 to make chlorine and sodium hydroxide by pumping salt-water through a vat of mercury. Chor-alkali plants are well known for their fugitive emissions of mercury (Oceana 2006:6). Theoretically, mercury is supposed to be re-circulated through the system. However, due to the volatile nature of mercury, a certain amount of mercury evaporates. This evaporated mercury becomes lost from the system and enters the environment. This is why chlor-alkali plants report their unaccounted losses of mercury to the EPA; these unaccounted losses are also referred to as *fugitive emissions*.

Since the development of mercury-free membrane technology, the number of chlor-alkali plants has increasingly declined. The two types of mercury-free technology can be divided into diaphragm-cell technologies and membrane-cell technologies. Although the diaphragm-cell technology was invented as early as 1851, the lack of available electrical generation capacity limited the use of this technology in chlorine and caustic soda production until breakthroughs in electrical generation were achieved (O'Brien, Bommaraju, and Hine 2005:18). Membrane-cell technology has been growing since it was first introduced in 1975 because of its ability to produce higher quality caustic soda and its lower energy requirements compared to diaphragm-cell technologies (William Smith 2005:438). In addition to being mercury-free, the membrane-cell technology is more economical (due to lower energy costs) than the mercury-cell technology. This modern mercury-free technology is now being used by more than 90% of the US chlorine industry. In the US, five plants accounted for the remaining estimated 10% of plants still using mercury-cell technology (Mahan and Savitz 2007:9).

Mercury Emissions / Olin

Chlor-alkali plants were the number one source of mercury air emissions in 2003 in seven of the eight states where they operated; Georgia's Olin plant ranked second (Oceana 2006:4-6). Using EPA data from 2003, Oceana determined that "the average mercury-based chlorine plant released five times more mercury than the average mercury-emitting power plant" (Oceana 2006:6). In 2003, Olin Corp's Augusta, GA plant released a total of 856 lbs[8] of mercury into the environment according to self-reported emission estimates given to the EPA (Oceana 2006:4).

High-dose Mercury Exposures

Mercury exposure epidemics in Minamata Bay, Japan (1956), and Iraq (1971) have provided us with the most comprehensive understanding of the adverse neurological health effects. Observations of these epidemics demonstrated adverse effects on the fetal nervous system and were used to determine toxikenetics of high-dose mercury exposures.

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[8] The total 856 lbs of mercury emissions are from 563 lbs of fugitive emissions, 169 lbs of stack emissions, and 10 lbs into the water. (Oceana 2006:4)

Borum et al. describe the general health toxicology of methylmercury learned from the epidemics of Minamata Bay and Iraq:

> these epidemics [Minamata Bay and Iraq] led to observation of methylmercury effects on the fetal nervous system. High-dose human exposure results in mental retardation, cerebral palsy, deafness, blindness, and dysarthria *in utero* and in sensory and motor impairments in adults. (2001:X)

Minamata Bay, Japan

The first and most extensive epidemic of high-dose mercury exposure occurred in Minamata Bay, Japan, between 1953-1960. It was caused by Chisso Corporation's acetaldehyde producing plant, which released of inorganic mercury via industrial wastewater into the Minamata Bay. Inorganic mercury was converted to methylmercury. Methylmercury bioaccumulated in fish and shellfish, which were regularly consumed by the local population. The first symptoms of what became known as "Minamata disease" were recorded in 1956 when a young girl, and later her sister, presented with unknown symptoms. The sudden death of many local cats led to an investigation of the contamination in which investigators brought cats into Minamata in 1957. Borum et al. describe study's findings saying, "within 32 to 65 days after arrival the cats developed similar symptoms (e.g. excessive salivation, violent rotational movements, inability to walk in a straight line, and collapsing death or voluntarily jumping into the sea to drown)" (Borum et al. 2001:3-2).

“Minamata disease” eventually led to over 1,500 deaths with more than 2,200 cases officially recognized (Borum et al. 2001:3-2). The health effects of the Minamata Bay epidemic were widely documented (Harada 1978). Due to this, the foundational research on mercury toxicity and its health effects was established. The early stages of the “disease” were marked by gross central nervous system disturbances affecting 88 people in the area. Out of those 88, 12 died within 100 days, while others remained permanently disabled (Borum et al. 2001:3-2). Borum et al. state, “examination of the post-mortem brains of severely affected patients revealed marked brain atrophy (55% of the normal volume and weight, with lesions in the cerebral cortex and cerebellar cortex, and changes in the nerve fibers, cystic cavities, and spongy foci ” (Harada 1995; cited in Borum et al. 2001:3-3). The Minamata incident also revealed the delayed onset of mercury poisoning. In some cases symptoms of Minamata disease appeared more than five years after methylmercury consumption ceased. This research also led to the study of congenital effects of mercury exposure. For cases of maternal exposure, symptoms were delayed until five to eight years post-partum. At the time of symptoms’ emergence, maternal hair mercury level ranged from 1.82 ppm to 191 ppm while that of offspring ranged from 5.25 ppm to 110 ppm (Harada 1995). Births following the epidemic showed high incidences of cerebral palsy and infantile “Minamata disease” (Borum et al. 2001:3-4).

Basra, Iraq

Some 90,000 metric tons of improperly labeled methylmercury-treated grain arrived in Basra, Iraq in the fall of 1971 from Mexico and the United States. The grain, treated with methylmercury fungicide, was distributed throughout rural areas. Since it was distributed late in growing season it was baked into bread and consumed by an undocumented number of people. Similar to the Minamata Bay epidemic, the first case of methylmercury poisoning was not recorded until late December 1971. Within two months more than 6,500 hospital admissions were linked to mercury poisoning and more than 450 hospital deaths were recorded (Borum et al. 2001:3-5). Overall, approximately 60,000 people were exposed and over 2000 died (Sterner 2010:362). Since pregnant women were included in the exposed group, significant research on the effects of *in utero* mercury exposure was conducted on the populations affected in Basra, Iraq.

Low-Dose Mercury Exposures

In addition to the Minamata Bay and Iraq studies, the National Research Council (NRC) and the EPA consider three epidemiological prospective longitudinal developmental cohort studies for their quantitative risk assessment: the Seyschlles Child Development Study, 1981-1994 (SCDS), the Faroe Islands study, 1986-1994; and the New Zealand study, 1982-1985. All three studies assessed cohorts of children exposed to methylmercury *in utero*, used maternal hair (the Faroe Islands study also assessed maternal cord blood), and assessed, albeit in differing ways, the relationship between prenatal metylmercury exposure and neuropsychological function during childhood. The Faroe Islands study and the New Zealand study revealed dose-related responses to methylmercury, however, the SCDS found no evidence of impairment due to methylmercury exposure. *Table IV* provides an overview of these three low-dose cohorts.

Table IV. Summary of Low-dose Mercury Exposure Studies

Study Name	**Seychelles Islands**	**Faroe Islands**	**New Zealand**
Size	779 mother-infant pairs	1022 births	237 children
Exposure	Fish & Shellfish	Fish & Shellfish / Whole meat & blubber	Fish & Shellfish
Maternal Exposure Assessment	Maternal hair (collected upon delivery)	Cord blood Maternal hair	Maternal hair
Level of Prenatal Exposure	Mean (SD): 6.9 ppm (4.5 ppm)	Mean cord blood concentration = 24,200 mg/kg Up to 174 ug/L	Range: 0 mg/kg – 6 mg/kg
Age of Child at Assessment	5.5 years & 9 years	7 years & 14 years	4 years & 6-7 years

Assessment Summary	Global IQ[9] / Performance tests at 6, 19, 29, and 66 months / Neurodevelopmental tests at 66 months	Domain-specific testing[9] / Neurobehavioral outcomes, developmental patterns, immunologic outcomes	Early sensorimotor deficits such as retarded walking, decreased scores on developmental tests
Excluded	Mothers and children with disorders highly associated with adverse nerurodevelopment eg. epilepsy, traumatic brain injury	Children with neurbiological disorders through to be independent of mercury exposure eg. epilepsy, Toretts syndrome etc.	Not specified
Main/Commonly Referenced Studies	Cernichiari et al. 1995; Davidson et al. 1995; Myers et al. 1995; Shamlaye et al. 1995	Grandjean et al 1993; Grandjean et al 1994; Grandjean and Weihe 2007	Kjellstrom et al. 1986; Crump et al. 1998; Kjellstrom et al. 2003

(CENR, OSTP and The White House 1998:4; Stedeford et al. 2005:522)

Biological Monitoring of Mercury

Hair

When human are exposed to methylmercury it becomes incorporated into the hair.

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[9] While there is substantial literature on comparing theses three studies. However, one of my leading hypothesizes about why the Seychelles Island study and Faroe Island study obtained different results has to do with the difference in assessment. The Seychelles Island study used standardized measures of Global IQ (based on the Iraq high-does exposure) whereas the Faroe Islands study used domain-specific testing. It has been suggested that *in utero* low-dose mercury exposure may be no effects on overall IQ but may have effects on domain-specific functions such as “memory deficit, motor delay, or effects on the complex domain involved in formulating behavior called executive function. Thus, it might be that the effects of methylmercury at lower doses are domain-specific and only detectable by domain-specific tests used in the Faroe Study, but not with the more general tests used in the Seychelles Study” (CENR, OSTP and The White House 1998:4)

Because this incorporation is irreversible, hair analysis is a useful way to monitor the record of mercury exposure. Mercury becomes trapped in the hair due to its affinity for sulphur in disulfide bonds. Hair is made partly of a protein called keratin which contains the sulfur-containing amino acid cysteine. Cysteine often forms disulfide bonds, binding the keratin together. When mercury is present in the blood, it will form disulfide bonds with cysteine in the growing hair shaft. Due to this process scalp hair is widely regarded as a useful indicator to measure methylmercury exposure. Since mercury is stable once incorporated into hair, it can give a longitudinal history of methylmercury blood levels (Phelps et al. 1980; WHO 1990; cited in Borum et al. 2001:2-7).

One limitation of total species mercury hair analysis is that hair assays do not determine the speciation of mercury present. To determine what fraction of total mercury is methylmercury, investigators often consider environmental and occupational exposure patterns. Mercury in hair is often assumed to be methylmercury unless there is reason to believe the subject was exposed to a different form. This is because methylmercury is one of the only mercuric forms to enter the blood stream. Another limitation of hair analysis is that mercury levels may be confounded by several factors including the hair's absorption of mercury vapor from the environment, hair treatments, and hair growth rate (Borum et al. 2001:2-7). Further study is needed to access the true extent of these confounding factors, however, with proper methods and experimental design these influence of these confounders can be greatly minimized. Questions of occupational mercury exposure and use of hair treatments are often asked to minimize the first two mentioned confounders. The confounder of hair growth rate would be important to consider if assessing for the presence mercury in a particular time period.

Blood

In the body, mercury binds to the sulfurs in hemoglobin. Blood (which contains hemoglobin) distributes methylmercury throughout the body and thus maybe a good way to measure a short-term acute exposure. However, blood levels, unlike hair levels, will not reflect a person's exposure over longer periods of time. Blood monitoring is preferable over hair monitoring in cases of elemental or inorganic mercury exposure. To assess elemental mercury exposure, mercury is measured in the blood hematocrit and compared to concentrations in the whole blood and plasma. This assessment allows one to calculate the red blood cell to plasma mercury ratio (Borum et al. 2001:2-6).

IV. HAIR COLLECTION DATA AND ANALYSIS

Background

Previous research done with the Savannah Riverkeeper and the Savannah River Ecology Lab discovered considerable mercury pollution from Olin chlor-alkali facility in the Savannah River. The results reveal considerable mercury contamination with the channel sediment mercury concentrations over 60,000 ppb. (Smith, Jagoe, and Carl 2006). In 2006, Olin Corporation released more than 800 pounds of mercury into the environment (Oceana 2006:4). Although cleanup is mandated there are no restrictions placed on future contamination and mercury from Olin continues to contaminate the Savannah River on a daily basis. Mercury is a neuro-toxin that can cause severe health effects (ATSDR 1997). Once mercury is released into the environment it becomes methylated and bioaccumulates up the food chain, and the primary mode of exposure to methylmercury in humans is through fish-consumption (ATSDR 1997).

Anecdotal evidence suggests that many people consume the fish they catch in the Savannah River near Olin. Currently fish consumption warnings for mercury do exist for several fish species in this area, however, they are not publically posted on the Georgia side of the river. Previous research conducted by the Savannah Riverkeeper show significantly higher levels of mercury in fish in the Savannah River within several miles of Olin compared to fish collected from the river along side the Savannah River Site[10] (Savannah Riverkeeper and SREL 2004:1). Data from this study shows higher mercury levels in upriver fish than is permissible under the current fish advisories. This suggests further sampling maybe necessary to amend fish advisories.

Purpose

Further research on the societal costs of this contamination is needed at this time. Since research suggests that fish advisories for this area may be under estimated, there needs to be additional research into potential mercury toxicity and fish consumption practices of individuals who fish near this contamination. Joanna Burger has determined that subsistence fishermen along the Savannah River are at greater risk than the general population for mercury exposure (Burger, Gaines, and Gochfeld 2001:533).

Using scientific data in combination with medical anthropological methodology and theory I have explored this contamination's impact on the community. I have attempted to map a conceptual picture of its possible health related effects. In order to begin to understand this, it was necessary to see if there were detectable levels of mercury in people who consume fish close to the contaminated area on the Savannah River. For the quantitative aspect of my thesis I have attempted to study if there is a correlation

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[10] Hg levels of catfish and bass caught near Olin were compared to catfish and bass caught near the Savannah River Site by the Savannah Riverkeeper and the Savannah River Ecology Laboratory (2004). Mercury concentration in tissue was determined for the obtained fish. Results demonstrated there to be significantly higher mercury levels in fish near Olin as compared to fish near the Savannah River Site.

between mercury hair concentration and fish consumption through administering questionnaires and conducting voluntary hair sample testing.

My research presented in this section was gathered between the months of June 2010 and February 2011. After receiving Mount Holyoke College Internal Review Board approval to conduct human subject research from Savannah River anglers who fish and consume fish from the Savannah River in the vicinity of the mercury contamination, I gathered hair samples from voluntary participants. In addition to gathering hair samples participants were asked to complete questionnaires, detailing background information on socioeconomic status, fish consumption practices, and knowledge of fish advisories.

Hypothesis

While fish consumption warnings do exist for the South Carolina sides of the Savannah River they are not posted on the Georgia side of the river. I hypothesize that many people who fish near the mercury contamination in the Savannah do not know of these warnings. Furthermore, I hypothesize that people who fish on the Savannah River consume more fish than the general population and are therefore at an increased risk of having elevated mercury levels.

I wish to extend Joanna Burger's observation about Savannah River subsistence Anglers increased risk to mercury exposure, to determine if increased risk translates into higher levels of hair mercury concentrations.

Methods

Participants

Savannah River fish consumers and controls were obtained through voluntary recruitment. Savannah River fish consumers (“**Savannah River anglers”** or **“anglers”**) are defined as people fishing in the Savannah River near the Olin contamination area who consume the fish they catch. **Controls** are defined as individuals living in the general Augusta, Georgia area who do *not* consume fish from the Savannah River. A total of 16 anglers and 20 controls were collected, however, analysis was completed on a total of 16 anglers and a total of 19 controls. Select Savannah River anglers and controls were dropped because there was an inadequate amount of hair supplied/collected in the sample. Anglers were recruited from three primary locations: The New Savannah Bluff Lock and Dam Park (33.373162, -81.941493), the area surrounding The Bob Baurle Boat Ramp (33.35977, -81.94048), and on the Savannah River itself (using a boat). Posters about the study were posted at fish cleaning stations, in restrooms, and common fishing locations within the park and surrounding the boat ramp. Controls were recruited from three primary locations: posters hung at the Medical College of Georgia, at Augusta Mortgage Company, and at The Matador Styling Shop For Men.

Data Collection

Institutional Review Board approval was obtained through Mount Holyoke College. All subjects were explained the intent of the study prior to participation. Recruited Savannah River anglers and controls completed (1) a consent form, (2) a questionnaire, and (3) provided a scalp hair sample. Participants were given the option to complete forms independent of investigator or to have forms read orally.

The questionnaire in this study was formulated using five mercury consumption questionnaires developed by the CDC and the USDA (CDC 1988-1994; CDC 1988-2003; USDA 1989-1994; USDA 1994; USDA 1995). Questionnaires were designed to gather information concerning fish consumption practices and knowledge of fish consumption warnings. The questionnaire asked about personal information to facilitate appropriate matching of Savannah River anglers and controls (i.e. inquiry of age, sex, weight, and factors that determine socio-economic status). Information including but not limited to geographic sources, species, frequency, and quantity of fish consumed was gathered to better understand fish consumption practices; common dietary/nutritional techniques such as pictures of fish species were used to minimize recall error. Participants were also asked about their awareness of fish consumption warnings.

Sample Collection and Preparation

Approximately, one-half-gram hair sample was obtained (by cutting with stainless steel scissors) from participants and stored in a zip-lock bag for later testing of mercury content. Only scalp hair samples were obtained. There were only two subjects that had hair samples longer than one inch (Sample # 16 and Sample # 24). Since all other participants had short hair (with the exception of Sample #16 and Sample #24) all hair samples were cut close to the scalp and all were approximately the same length. Participants with inadequate scalp hair for collection were not considered for the study.

All participants were debriefed and given a copy of the consent form. Savannah River angler subjects given a copy of where to find information on Georgia, South Carolina, and federal fish advisories.

Hair samples were washed using the International Atomic Energy Agency (IAEA) recommended hair sample preparation technique of stirred contacts with 25 mL portions of acetone, water, water, acetone, water successively (IAEA/RL/41-H 1977:10). Samples were air dried in a hood on filter paper, and stored in clean plastic bags.

Mercury Quantification

Hair mercury concentrations were quantified at the Harvard School of Public Health's trace metals toxicology lab using a cold vapor atomic absorption spectrometer. A Milestone DMA-80 Direct Mercury Analyzer (DMA-80) was used for cold vapor atomic absorption spectrometry. A range of 0.02 grams – 0.05 grams of hair was quantified using an analytical balance and placed into a quartz sample boat for analysis. The mass of the sample was entered into the computer prior to sample run so that subsequent concentration calculations could be made accordingly. To detect total mercury, this method dries and degrades the sample using thermal decomposition, preconcentrates the mercury using gold amalgamation, and quantifies the mercury using atomic absorption spectroscopy. Following gold amalgamation the mercury is carried through absorbance cells positioned in the light path of a wavelength atomic absorption spectrophotometer. Mercury vapor is measured in both a long pathway length and short pathway length absorbance cell. Therefore, the same quantity is measured twice using differing sensitivities. This allows for accurate measurement within a range of at least four orders of magnitude (EPA method 7473 2003). Mercury concentration was determined as a function of absorbance using a wavelength of 253.7 nm. Differing weights of certified reference material (CRM) GBW 09101 (human hair; Shanghai Institute of Nuclear Research, Academia Sinica, China) were used to formulate a matrix-matched calibration curve. The calibration curve was used to for quantitative determination of total mercury in samples.

Validation Data Sets

Quality Controls

Quality Control steps included running a procedural blank and a certified reference material (CRM) GBW-07601, cryogenically homogenized human scalp hair (Institute of Geophysical and Geochemical Exploration Langfang, China) following every 10 sample runs. The mercury determination approach was validated, since all quality controls feel within the 22% error expected range. The relative standard deviation[11] (RSD) of 6.83% is less than 10% suggesting good precision.

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[11] Relative Standard Deviation = (Standard Deviation/Average)(100)

Table V. Quality Control Standards

HUMAN HAIR CRM	MERCURY CONCENTRATION (mg/kg)
Expected	*0.360 +/- 0.079 mg/kg*
Measured	0.376
Measured	0.378
Measured	0.352
Measured	0.353
Measured[12]	0.318
RSD	*6.82%*

Repeatability & Reproducibility

Repeatability and reproducibility were both assessed using relative standard deviation. Repeatability was determined by calculating relative standard deviation-*r* (RSD_r) from within laboratory data. Reproducibility was determined by calculating relative standard deviation-*R* (RSD_R) from among laboratory data.

Repeatability

The DMA-80 method for hair mercury analysis measures *total* mercury. Total mercury quantification can be considered a limitation in mercury hair sample analysis because hair is an archive of mercury exposure. This may result in variation of mercury along the hair length, which is due to the time at which mercury exposure occurred. This is because even though a duplicate hair sample may come from the same person, it may

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[12] The measured value of 0.318 mg/kg was determined for the reproducibility data only not for the presenting hair mercury quantification. Since this value is substantially lower than the others this suggests that the RSD value for the reported hair mercury samples is lower than 6.82%. See *Table V* for the reproducibility data.

not have come from the same time period. For example, in a hair sample that covered a years length of time, uni-seasonal consumption of mercury contaminated fish would likely lead to concentrated mercury in one quarter of the strand and low levels in the other three quarters of the strand. While this effect maybe beneficial for estimating the time of mercury exposure, it may be problematic for obtaining repeatability of data. To determine the repeatability of data a specific method (described in more detail below) was used.

To minimize this effect, investigators often tie a string around the obtained hair sample to denote the scalp end. This was not done in my hair collection, nor would it be easy to do since most participants had short hair. However, repeatability testing was conducted on one hair sample (sample 24) that was long and braided. To conduct repeatability measurements a lock of hair is cut into two equal sections along the short edge creating section 1 and section 2. Sections 1 and 2 were then divided into two sub-sections (a & b). To determine repeatability statistics sample 1a was run in comparison to sample 1b and 2a in comparison to 2b. See *Figure II* below.

Figure II. Repeatability Sectioning of Hair Sample

When samples represent the same period of time should show similar levels if there is high repeatability. Therefore sample 1A should be close to sample 1B and sample 2A should be close to 2B. As seen in *Table VI*, the low RSD_r levels of 2.04% and 2.96% suggest high repeatability was possible with this method.

Table VI. Repeatability / Reproducibility Data: Sample 24

Time Period 1	*Mercury Concentration (mg/kg)*	*Time Period 2*	*Mercury Concentration (mg/kg)*
Segment 1a Close to scalp	0.171	Segment 2a Not close to scalp	0.171
Segment 1b Close to Scalp	0.176	Segment 2b Not close to scalp	0.164
Time Period 1	0.173 +/- 0.003	Time Period 2	0.167 +/- 0.004
*RSD_r	2.04 %	*RSD_r	2.96 %
*RSD_R = 2.89%			

*RSD_r = *Repeatability Relative Standard Deviation*
RSD_R = *Reproducibility Relative Standard Deviation*

Reproducibility

In addition to repeatability there was high reproducibility. High reproducibility suggests that participants were exposed to mercury on a consistent basis. There are two forms of evidence that demonstrate this high reproducibility. As can be seen in *Table VI*, reproducibility can be determined through the RSD_R comparison of segment 1A and segment 1B to segment 2A and segment 2B. The reproducibility can be determined by comparing the RSD_R among groups (as opposed to with-in groups or repeatability). The RSD_R among groups is 2.89%. Since this data was only determined for sample 24, we can say there was high reproducibility for sample 24. However, comparing two randomly obtained samples from one participant can provide more comprehensive evidence that there was high reproducibility. For select randomly chosen samples mercury quantification was completed twice. The data is shown in *Table VII*.

Table VII: Reproducibility Data

Mercury Test I (mg/kg)	Mercury Test II (mg/kg)	% RSD
0.116	0.114	1.328
0.454	0.426	4.471
0.230	0.238	2.467
0.442	0.417	4.131
0.518	0.607	11.138
0.908	1.242	22.022
0.0375	0.046	15.076
0.685	0.655	3.190
0.075	0.076	1.321

As can be seen in *Table VII*, the precision of reproducibility ranged from 1.32 % to 22.02%. While the standard deviation was up to 22%, overall the RSD values were very low. There were three RSD values (11.138%, 22.022%, and 15.076%) that were higher than the expected RSD of 10% or less. The samples with elevated levels likely suggest that these individuals had less consistent fish consumption practices than other individuals. However, the raw numbers for Test I vs Test II in the three high RSD samples are within the same range. This suggests the samples were somewhat reproducible or that individuals had fairly consistent exposure to mercury. Presumably, this means that participants have fairly consistent fish consumption practices.

Data Analysis

Demographic Data (Occupation, Education, Income, Race)

Several demographic (*Table VIII*) trends exist for Savannah River angler and control participants. Data obtained on occupation, education, and annual income suggests there are socioeconomic differences between the Savannah River angler and control groups.

Table VIII. Demographic & Racial Data (Savannah River Anglers and Controls)

ID #	**Savannah River angler/Control**	**Occupation**	**Education**	**Income / yr.**	**Race**
	Savannah River **angler**: consume Savannah River fish **Control**: do not consume Savannah River fish	**Professional/Technical** **Labor** skilled/unskilled **Homemaker** **Student** **Retired** **U/A**: Unavailable **Other**	**No High**: Did not graduate high school **GED**: Graduated high school/GED **Some College**: Attended some college **College**: Graduated college or higher **U/A**: Unavailable	**A**: <$10,000 **B**: $10,000 – 19,999 **C**: $20,000 - $50,000 **D**: > $50,000 **U/A**: unavailable	**White**/ Caucasian **Black**/African American **Asian** **U/A**: Unavailable
1	Control	Professional/Technical	College	U/A	White
2	Control	Professional/Technical	College	U/A	White
3	Control	Professional/Technical	College	U/A	White
4	Control	U/A	U/A	U/A	White
5	Control	Professional/Technical	College	D	White
6	Control	Professional/Technical	College	U/A	White
7	Control	Professional/Technical	U/A	U/A	White
8	Control	Student	College	D	Asian
9	Control	Professional/Technical	College	U/A	White
10	Control	Retired	U/A	U/A	White
11	Control	Professional/Technical	College	D	White
12	Control	Professional/Technical	College	D	White
13	Control	U/A	U/A	U/A	White
14	Control	Professional/Technical	College	D	White
15	Control	Professional/Technical	College	D	U/A
16	Control	Homemaker	College	D	White
17	Control	Professional/Technical	College	D	White
18	Control	Labor	U/A	U/A	White
19	Control	U/A	College	D	Black
20	Control	Professional/Technical	College	U/A	White
21	Angler	Other	GED	C	White
22	Angler	Retired	College	D	White
23	Angler	Retired	U/A	U/A	Black
24	Angler	U/A	U/A	U/A	U/A
25	Angler	U/A	GED	C	Black
26	Angler	Professional/Technical	Some College	C	Black
27	Angler	Labor	Some College	C	White
28	Angler	Labor	No High	A	Black
29	Angler	Professional/Technical	GED	D	U/A
30	Angler	U/A	U/A	C	Black
31	Angler	Labor	GED	C	Black
32	Angler	Professional/Technical	GED	D	White
33	Angler	Retired	GED	C	U/A
34	Angler	Labor	GED	C	White
35	Angler	U/A	No High	C	White
36	Angler	Professional/Technical	GED	C	Black

Occupation

Demographic data concerning *occupation* (*Table IX*) shows that the control group consisted predominantly of participants who self-defined their profession as "Professional/Technical" (13 out of 20, or 65%). In contrast to the control group, the most common self-identified occupation descriptors for the Savannah River angler group were "Labor-Skilled/Unskilled" (4 out of 16), "Professional/Technical" (4 out of 16), and "Retired" (3 out of 16).

Table IX. Demographic Data: Occupation

Condition		**Frequency**	**Percent**
Controls	Homemaker	1	5.0
	Labor skilled/Labor unskilled	1	5.0
	Professional/Technical	13	*65*.0
	Retired	1	5.0
	Student	1	5.0
	Unavailable	3	15.0
	Total	*20*	*100.0*
Savannah River Anglers	Labor skilled/Labor unskilled	4	25.0
	Other	1	6.2
	Professional/Technical	3	18.8
	Retired	3	18.8
	Technical	1	6.2
	Unavailable	4	25.0
	Total	*16*	*100.0*

Education

The demographic data on *education* (*Table X*) shows that controls had much higher educational attainment compared to Savannah River anglers. Out of a total of 20 control participants, 5 left this section unanswered and 15 chose the highest category for educational attainment (graduated college or higher). Therefore, 100% of the controls that provided educational attainment data chose the highest educational attainment category. In contrast to the control group, Savannah River anglers (aka. anglers) had less education overall. When questioned about the highest level of educational attainment 50% (8 out of 16) of Savannah River angler participants chose “graduated high school/GED” (3rd highest educational attainment category). Two Savannah River angler participants self-identified in each of the educational categories above and below “graduated high school/GED”. Only one Savannah River angler participant chose the highest educational category so only one Savannah River angler is comparable to the control group.

Table X. Demographic Data: Education

Condition		**Frequency**	**Percent**
Control	Graduated College or Higher	15	75.0
	U/A	5	25.0
	Total	*20*	*100.0*
Angler	Graduated College or Higher	1	6.2
	Some College	2	12.5
	Graduated High School/GED	8	50
	Did Not Finish High School	2	12.5
	U/A	3	18.8
	Total	*16*	*100.0*

Income

The demographic data on annual family income (*Table XI*) also shows differences between Savannah River angler and control groups. Out of the control groups who responded, 100% of control participants choose the highest annual family income option. In contrast to controls, 10 out of 16 or 62.5 % of Savannah River angler participants (71.4% of Savannah River angler participants who responded to the question) chose the second highest income option on the survey ($20,000-$50,000). Of the remaining 6

Savannah River angler participants, 3 matched the annual income of the control participants, 1 had an income of less than $10,000 and 2 declined to answer the question.

Response Bias Among Control Participants: Eleven out of 20 control participants did not respond to the annual family income question. This large response bias (which can be seen to a lesser degree among other demographic questions) can largely be attributed to the manner in which controls were administered their survey. Most control participants were administered their survey while receiving a haircut. Although, I was able to ask several participants to fill out this data after their haircut, due to scheduling conflicts I was unable to obtain these data for the large majority of control participants.

Table XI. Demographic Data: Annual Family Income

Condition		**Frequency**	**Percent**
Controls	Greater than $50,000	9	45.0
	Unavailable	11	55.0
	Total	*20*	*100.0*
Savannah River anglers	Less than $10,000	1	6.2
	$20,000 - $50,000	10	62.5
	Greater than $50,000	3	18.8
	Unavailable	2	12.5
	Total	*16*	*100.0*

Race

The racial makeup of the Savannah River angler and control groups differs. All Savannah River angler and control participants, if they specified racial data, self-defined either "White/Caucasian" or "Black/African American," except for one control participant who self-defined as "Asian". The racial data (*Table XII*) was therefore dichotomized into "Majority" (i.e. "White/Caucasian") or "Minority" (i.e. "Black/African American" or "Asian"). Seventeen out of 20 control participants were defined in the majority racial group. The racial makeup of the Savannah River angler group was more diverse than that of the control group as 6 out of 16 Savannah River angler participants were defined in the majority and 7 out of 16 participants were defined in the minority.

According to 2000 census data, the racial demographic makeup for Augusta-Richmond Country demographics was 44.9% White/majority and 55.1% minority or 50.4% Black and 4.7% non-Black or non-White (US Census Bureau 2000). Therefore, the racial makeup of the control group was not reflective of the county. Although the Savannah River angler study participants were reflective of the county's demographic makeup, as discussed in Chapter V, this does not reflect the demographic makeup of the Savannah River angler population, which is predominant minority.

Table XII. Racial Data

Condition		**Frequency**	**Percent**
Controls	Majority	17	85.0
	Minority	2	10.0
	U/A	1	5.0
	Total	*20*	*100.0*
Savannah River Anglers	Majority	6	37.5
	Minority	7	43.8
	U/A	3	18.8
	Total	*16*	*100.0*

Racial Response Bias Among Savannah River Angler Participants: The results of my study suggest that the racial makeup of Savannah River anglers is relatively balanced 6 majority to 7 minority among Savannah River angler participants, however, there was a large response bias that must be considered since it suggests this may not be a representative sample. I had difficulty obtaining participation from study participants, particularly those of minority background.

Participant observation data (presented and explained in greater depth in Chapter V) supports Joanna Burger's research findings that Blacks consume more fish and more high mercury fish than their White counterparts (Burger et al. 1999:1). The data I obtained is not a representative sample of the Savannah River fishing population. This initial research suggests there will likely be significant response bias among minority Savannah River anglers. Further study should take steps to minimize non-response bias among minority participants and balance the racial demographics of the control group to the larger Richmond County population.

Sex & Anthropometric Data

Sex and anthropometric data obtained for Savannah River anglers and controls included weight, height, age, and sex data *(Table XIII)*. Height and weight were considered since such factors, particularly weight, play a part in one's ability to process mercury. Age was considered because there is evidence to suggest that due to the body's increasingly limited ability to process mercury out of the body, increasing age in adult individuals may lead to higher levels of mercury. Sex data was obtained as a descriptor of the study population.

Participants were predominantly male; three out of 20 controls and 1 out of 16 Savannah River anglers were female. Savannah River anglers and controls were generally within the same range for anthropometric data *(Table XIII)*. The standard deviation for weight was greater in the control group than in the Savannah River angler group, however, median and mean values of similar suggesting this standard deviation likely has little overall effect. Control participants were generally older than Savannah River angler participants; the control group had higher mean and median averages (57 years, 59 years) compared to the Savannah River angler group (46 years, 47 years). The sex demographics are not reflective of the Savannah River angler population. Future study should consider ways of more closely matching Savannah River angler study participants with control study participants based on weight, height, and age.

Table XIII. Anthropometric Data & Mercury Hair Concentration

ID #	***Angler/Control Status***	***Weight (lbs)***	***Height (inches)***	***Age***	***Sex***
1	Control	178	69	68	M
2	Control	170	68	52	M
3	Control	210	72	32	M
4	Control	318	72	74	M
5	Control	200	70	31	M
6	Control	185	69	58	M
7	Control	170	71	67	M
8	Control	112	63	23	F
9	Control	185	71	58	M
10	Control	185	70	78	M
11	Control	175	70	74	M
12	Control	205	72	48	M
13	Control	200	70	58	M
14	Control	171	74	69	M
15	Control	408	76	35	M
16	Control	160	68	47	F
17	Control	205	70	61	M
18	Control	230	72	72	M
19	Control	220	67	59	F
20	Control	165	67	70	M
21	Angler	300	69	25	M
22	Angler	225	67	64	M
23	Angler	159	66	56	M
24	Angler	169	71	46	M
25	Angler	159	67	53	M
26	Angler	215	68	63	F
27	Angler	160	69	26	M
28	Angler	167	68	50	M
29	Angler	210	66	49	M
30	Angler	220	70	48	M
31	Angler	186	71	46	M
32	Angler	185	68	33	M
33	Angler	183	66	67	M
34	Angler	170	69	20	M
35	Angler	180	72	41	M
36	Angler	240	73	45	M

Table XIV. Central Tendencies of Anthropometric Data

Condition		N	**Minimum**	**Maximum**	**Mean**	**Median**	**Std. Deviation**
Controls	*Weight (lbs)*	20	112	408	203	185	62.2
	Height (inches)	20	63	76	70.	70	2.8
	Age (years)	20	23	78	57	59	16.1
	Valid N (listwise)	20					
Savannah River Anglers	*Weight (lbs)*	16	159	300	196	184	38.0
	Height (inches)	16	66	73	69	69	2.2
	Age (years)	16	20	67	46	47	14.0
	Valid N (listwise)	16					

Central Tendencies in Mercury Hair Concentration Data

As can be seen in *Table XIVI* and *Figure III*, compared to control subjects, Savannah River anglers had total higher mean and median mercury levels (Mean, 0.31:0.40) (Median, 0.24:0.40), however, this was *not* a statistically significant difference. Hair mercury concentration of the raw data was compared between control and Savannah River angler participants; no other factors were controlled for in this comparison due to the limited sample size.

Table XV. Descriptive Statistics for Mercury Hair Concentration

Condition		N	**Min.**	**Max.**	**Mean**	**Median**	**Std. Dev.**
Control	*Hg_h (mg/kg)	20	0.03	1.05	0.31	0.24	0.29
	Valid N	20					
Anglers	*Hg_h (mg/kg)	16	0.04	0.91	0.40	0.40	0.25
	Valid N	16					

*Mercury Hair Concentration: Hg_h

Figure III. Mercury Concentration of Savannah River Anglers vs. Controls

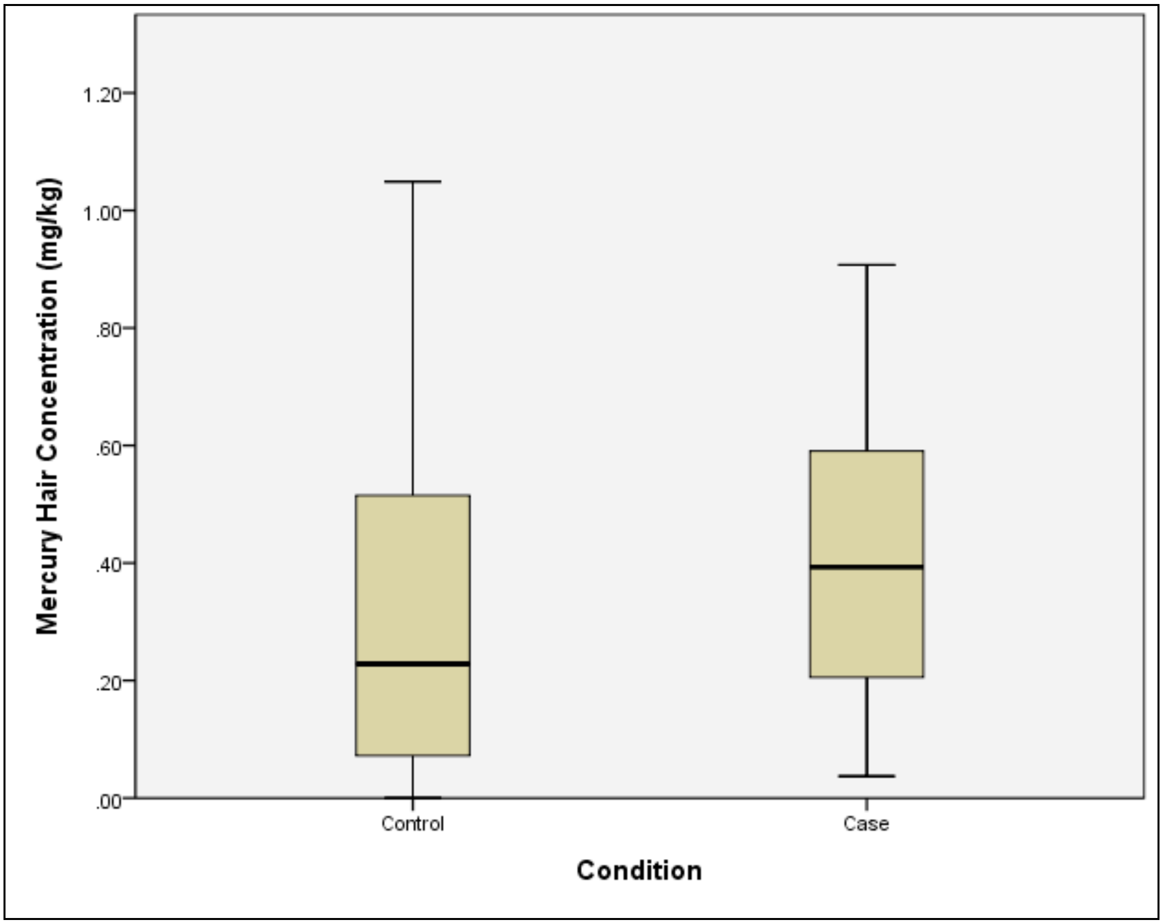

Figure IV and *Table XVI* compare Savannah River angler vs. control mercury hair concentration data excluding all sushi consumers, all participants who were not from the Augusta area, and all Savannah River anglers who consumed less than 50% of their seafood/fish from the Savannah River. Sushi consumers had higher levels of mercury than other controls. All sushi consumers except one specified that they eat tuna sushi. While the elevated mercury levels in controls were a surprising finding, this is understandable since tuna is a high trophic fish. Anglers who were not from the Augusta area or for whom Savannah River fish consumption accounted for less than 50% of their total fish consumption were also excluded in this comparison to minimize the presence of confusing mercury from high trophic commercial fish with mercury from Savannah River fish.

Although it would have been preferable to use only Savannah River anglers who consumed 75% or more of their total fish from the Savannah River, the participation bias and the small sample size greatly limited our ability to run such an analysis. However, results do show stronger differences between controls and Savannah River anglers within adjusted data. Mean and median results were almost double or more the level in Savannah River anglers compared to controls. I hypothesize that sushi consumption levels of the control group are not representative of the general population. Further study should attempt to obtain a control group that is more representative.

Figure IV. Adjusted Levels For Hair Mercury Concentration Comparison

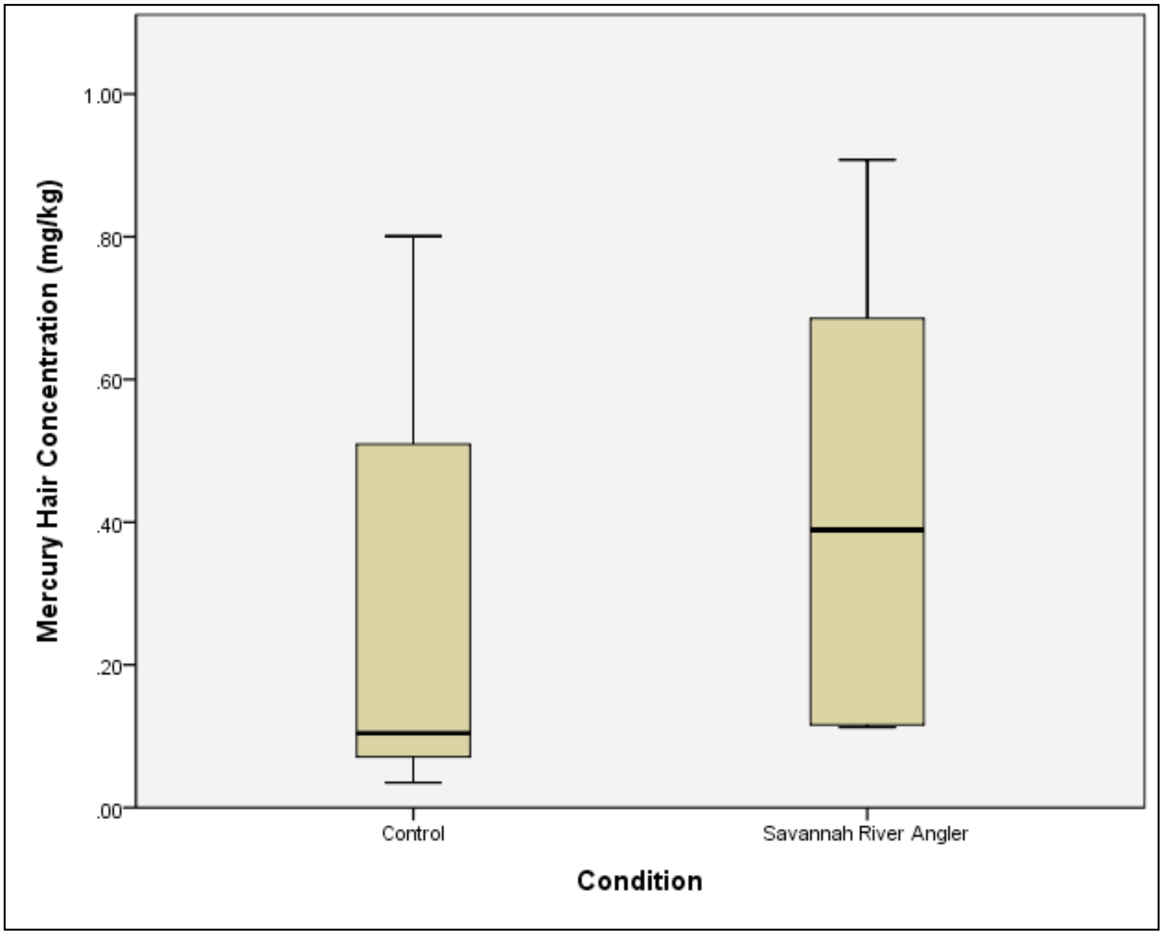

Table XVI. Adjusted Comparison for Hair Mercury Level

	Condition	N	Min.	Max.	Mean	Median
Hg_h (mg/kg)	**Control**	13	0.03	0.80	0.26	0.10
	Angler	6	0.11	0.91	0.46	0.39

Limitations

Limited resources played a large part in the results I was able to obtain. Compared with Joanna Burger et al.'s research (see Chapter II, Literature Review: Previous Studies on Savannah River Anglers & Fish Advisories) my study had substantially lower rates of participation. Several indicators suggest that this was likely because participation in my study was contingent on providing a hair sample. As discussed in other sections of this thesis, several factors (almost all linked to provision of hair sample) likely contributed to participation bias in my study. Participant-observation research and Burger et al.'s research suggests that the Savannah River anglers who participated in my study do not represent the larger angler population. This compounded with small sample size makes the results of my study appropriate to be considered a preliminary study. The results of my study point out several methodological issues that should be addressed in a larger more comprehensive study.

Participant-observation data (see Chapter V) and data by Burger et al. supports my hypothesis that Savannah River anglers consume more fish than the general population and are therefore at an increased risk of having elevated mercury levels. Additionally, my hypothesis that many people who fish near the Olin mercury contamination do not know of these warnings was supported (see Chapter V). Despite the efforts made by Burger et al. to develop a fish consumption fact sheet for the Savannah River, my research suggests this fact sheet or general information presented in the fact sheet has not reached many anglers (see Chapter V).

In order to better assess if Savannah River anglers are at increased risk of exposure, I suggest future study design ensure that Savannah River angler study participants more closely reflect the overall Savannah River angler population. Additionally, I suggest investigators need to carefully consider what matching factors should be used for obtaining control participants. Determining these factors will require more focused study questions (e.g., should control participants be matched to very closely to Savannah River angler participants or should they reflect the general population of Augusta-Richmond county?).

Small sample size compounded with the numerous factors that affect hair mercury concentration severely limited by ability to assess my original question: Does Savannah River angler's increased risk to mercury exposure translate into higher hair mercury concentration? The elevated mean and median mercury levels of Savannah River anglers compared to control participants does not rule out my hypothesis that increased risk of mercury toxicity translates into higher hair mercury concentration in Savannah River anglers. Considering the limitations in my study (i.e.- participation bias, non-comparative controls, non-representative study sample, limited participation, and inappropriately calculating for the complex factors that affect hair mercury concentration), further study is warranted to assess the relationship between risk and hair mercury concentration in Savannah River anglers.

V. EMBODIED DISCOURSES & QUALITATIVE ANALYSIS

Policymakers have placed responsibility for health education and maintenance predominantly on individuals primarily through their implementation of fish advisories. Analysis of current fish advisories on the Savannah River reveal that educational campaigns have been wholly inadequate in reaching those at most elevated risk, namely Savannah River subsistence anglers and their families. Furthermore, even if educational materials were to reach intended audiences, the comprehension of these materials is likely to be limited. Educational-based models intended to minimize mercuric effects in humans commonly assume that individuals act as rational individual actors distinct from social structures. This assumption lends itself to the formulation of educational campaigns that target behavior change without accounting for structural inequities. Fish advisories are problematic because they focus on individual behavior rather than community standards or regulation of corporate behavior. This chapter analyzes various aspects of education campaigns and concludes that educational campaigns that focus on individual behavior-change are inadequate to prevent mercury toxicity in sensitive populations.

In this chapter I explore the embodied consequences of fish advisories, continually highlighting structural inequities through a theoretically grounded discussion of embodiment, utilizing a Savannah River angler case study, and a discussion of the structural weaknesses of fish advisories. Through this exploration it is possible to examine the complex implications of fish advisories. Despite the varying complexities this examination brings forth, structural inequity is a recurring theme. I transition to a macro-scale analysis, whereby the nuanced presentations of structural inequity established throughout my micro-scale analysis can be combined and understood within the theoretical framework of political economy. This framework accounts for the complexities observed in the micro-scale analysis and provides the position necessary to speak about policy solutions.

Savannah River Fish Advisories

My research on the Savannah River clearly demonstrates the inadequacy of fish advisories as well as highlights several embodied realities that clearly influence one's ability to follow an advisory. While I do not focus specifically on the embodied consequences for women in this study (due mainly to access issues) the aforementioned problematization of embodiment provides a theoretical grounding for the embodied realities I explore in this study. My analysis of current Savannah River fish advisories illustrates how these policies are inadequately implemented, analyzes their structural weaknesses, and explores the larger inequity that results from prevention models that rely predominantly on individual behavior-change. Prior to discussing the structural weaknesses of fish advisories and their inequitable consequences, I argue in this section that even if educational campaigns and individual risk assessment were solutions, the present campaigns on the Savannah River are not giving individuals the resources they need to make informed decisions. The present fish advisories for the Savannah River are inadequate for two primary reasons: they are not reaching the populations of interest and they are incomprehensible to the average person.

Methods

In an attempt to address this issue, I set out to interview and survey Savannah River Anglers by approaching them at their fishing locations. My research there was not always met kindly and thus there is substantial participation bias, as many Savannah River subsistence anglers did not choose to participate in the study providing a hair sample and completing a questionnaire. Having spoken with many Savannah River anglers over this research period, many of whom decided not to participate, I have included anecdotal qualitative information from my many conversations obtained through my participant-observation at the river. The data presented in the following sections has come from the questionnaires as well as notes I took following participant-observation. Such data illustrate many of the complex issues that are not revealed in the quantitative data due to factors such as study design, participation bias, and inadequacy of quantitative methodology for assessment.

The Savannah River Anglers

Seven out of 9 Savannah River anglers who provided a sample for hair analysis and completed a questionnaire responded “Yes” to the question: “Do you have any knowledge of fish consumption warnings?” Of the 7 who had knowledge of fish advisories, 5 self-identified as “White”, 2 provided evidence that they knew where to access information on fish advisories, and only 1 mentioned knowledge that fish advisories on the Savannah River were written for mercury. All participants who answered affirmatively to the question, except for the 2 who provided more extensive examples, wrote very general explanations on what fish advisories were for. Answers to this question included: "?", "for good health", for the "environment".

Participant-observation data suggests that this angler sample is not representative of the Savannah River angler population as a whole. Savannah River anglers who were most likely to participate in the study (and therefore overrepresented) could be described by the following descriptors: White, male, non-Augusta area residents, higher socioeconomic status (compared to other Savannah River anglers), and/or less regular consumers of Savannah River fish (compared to other Savannah River anglers).

There was considerable resistance to my presence as a researcher. When I started asking for hair samples, I was met with many smiles and laughs. The first day I spoke with over 30 individuals and obtained only 2 hair samples (one of which was from an out of towner). In response to my request for a hair sample, the Tuskegee Syphilis experiment was referenced twice that first day. Both times it was mentioned a question was directed at me, asking if I knew "what the Tuskegee Syphilis experiment was?" While this came as a major surprise initially, this response helped me to begin a more reflexive process of thinking. As I came to be more accepted within the community, questions of reflexivity became more central. Recognizing that my race, sex, age, and education level affected the research, is important to keep in mind when considering the findings of this research.

After some time, local anglers began to speak with me more and though this I began to learn many things both about the community itself and about how I was perceived in it. People were generally willing to speak about fishing practices, but the request for hair samples brought up much a lot of distrust of my intentions, as they were wary. Common hypotheses of what would be done with the collected hair, hypothesizing that I was actually out to collect included DNA gathering or test for drugs.

My proposed study design did not take into account many cultural factors of the Savannah River angler population. There were several women who expressed interest in participating, however, the propensity to supplement personal hair with exogenous sources of hair (aka- “weave”) limited my ability to obtain usable hair samples. Additionally, for religious reasons several anglers suggested that they would be willing to provide a blood sample, but not a hair sample. When I further inquired about this I was told that many people who fish in the Savannah River believe in “rooting”. Rooting, as it was explained to me, is a form of voodoo in which someone consumes another person’s hair and is then able to control him or her. Considering my difficulties collecting hair samples from Savannah River anglers, further study may want to consider alternative culturally sensitive methods for conducting mercury research.

Speaking with anglers about fishing taught me a lot about why they fished. Most anglers were retired and said they used fished several times a week to take home and cook. Although specifics of income were not widely spoken it became clear through conversations that many anglers fished to supplement their nutritional needs. Angler’s increased time and low income due to retirement pushed them to consider alternative ways of obtaining food. Fish was considered by many Savannah River anglers not only to be healthy but also to be an opportunity to save money and a chance to become part of a community.

Reaching the Population of Interest

The populations of interest in a fish advisory are the populations most who are likely to be affected by consuming fish with elevated mercury levels. The population of interest for Savannah River fish advisories includes any individuals who consume fish caught from the Savannah River. From my research this often includes Savannah River anglers and their kinship networks, defined predominantly as the nuclear family but for some Savannah River anglers this including extended families.

The Georgia-EPD and the Georgia Department of Natural Resources (EPD/DNR) issue fish advisories annually. The general advisories are printed in paper booklets and magazines issued available for fisherman free of charge at most fishing stores. The booklets include fish advisories along with hunting season start and end dates, permit requirements, and general catch and release guidelines (EPD/DNR 2010). More comprehensive advisories and guidelines are also available online. These include an expansion of the booklet issued advisory for anglers and select advisories and guidelines for women who consume fish (EPD/DNR *Electronic Document*).

Tonya Bonitabus, the Savannah Riverkeeper, explained the difference in posting of fish advisories between Georgia and South Carolina (verbal interview, August 2010). Georgia and South Carolina share the Savannah River, however, the majority of the public fishing areas close to the known mercury pollution are on the Georgia side of the river. Georgia requires that fish advisories be written in the free booklet and posted online, whereas South Carolina state law mandates that relevant fish advisories must be posted on signs at all public docks[13]. Therefore, the one public dock on the South Carolina side, which is near the contamination, does have a sign which provides catch and release and consumption guidelines. Georgia, however, has no posted advisories since the posting of advisories is not legally mandated.[14]

Furthermore, my field notes and analysis of data from questionnaires administered to anglers fishing and consuming fish caught from the Savannah River near the mercury contamination revealed that approximately 40 of 48 individuals had *no* knowledge that fish consumption advisories existed[15]. Of the 8 individuals who knew

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[13] To clarify, public docks do not include all public fishing areas. Public fishing is not mandated to occur off public docks. Commonly Anglers fish in public parks but not off of public docks. Individuals, when asked about their preference for fishing locations, often explained they preferred not to fish off public docks because it was a high traffic area. I explain this distinction to show that even though South Carolina does post the fish advisories at public docks, this method is unlikely to reach Anglers.

[14] Interview with Tonya Bonitatibus also explained that while environmental groups such as the Savannah Riverkeeper have posted Georgia state issued advisories at public docks in Georgia, the advisories were taken down by the Environmental Protection Division and the Department of Natural Resources, who together issue the fish advisories in Georgia, since there had not been a legal mandate which requires the posting fish advisories. (August 2010).

[15] For determining the estimated statistic that "40 our of 48 individuals had *no* knowledge that fish consumption advisories existed" I did not include individuals (at least 20 based on my notes) who confused catch and release requirements for fish consumption advisories. Many anglers knew the catch and release requirements. I heard from many that Georgia DNR came around to anglers from time-to-time and ticketed all anglers with fish that did not fit the catch-and-release guidelines. After observing that many anglers were well aware of catch-and-release guidelines, I began to ask anglers specifically about their knowledge of catch-and-release guidelines. All anglers who I asked about catch-and-release guidelines were able to tell me specifics about fish species and size.

that fish consumption advisories existed, seven are represented in my survey and the remaining individual who was willing to participate did not have sufficient scalp hair to provide a sample due to diabetes. Only 4 individuals were aware of what the advisories were for or could provide *any* information of how to gain access to fish advisories (Smith 2010).

It is apparent that the existing advisories for South Carolina, but particularly for Georgia, are physically inaccessible to individuals who are at risk of adverse health effects from mercury.

Comprehension of Fish Advisories

The physical inaccessibility of current Georgia fish advisories is further confounded by the presentation of fish advisories. Current Georgia fish advisories are unnecessarily complex, making comprehension particularly difficult, especially for those most at risk.

To determine the specific fish advisory for where someone is fishing on the Savannah River it is necessary to know the geography and the proper names (which sometimes differ from common names) of river locations (EPD/DNR 2010). There are five sections of the Savannah River for the Georgia issued fish advisories. These sections are labeled:

Savannah River: Above & Below New Sav. Bluff Lock & Dam
Savannah River: Chatham/Screven Cos.
Savannah River: Effingham Co.
Savannah River: Tidal Gate
Savannah River: New Savannah River Bluff Lock Dam to
    Savannah Estuary.

For example, if someone knows only the name of the public boat dock where (s)he is fishing, this will only be helpful in determining the relevant fish advisory if the name is one of the starting or ending locations for the advisory. When speaking with anglers about my research I was commonly asked to explain about the mercury contamination. In my discussions with Savannah River anglers I often referred them, as required by the IRB, to the Georgia and South Carolina fish advisories. There were many requests for regulation booklets. Since Savannah River anglers explained to me they did not have access to the Internet and/or, for numerous reasons, expressed that obtaining a booklet on their own would be difficult, I began to keep state issued books with me providing Savannah River anglers with the booklets. When I used the booklet as a reference with participants I observed that several Savannah River anglers had difficulty determining the correct sections of the Savannah River to reference. This compounded with other problems I observed show how the complexity of Georgia fish advisories presentation hinders accurate interpretation.

For every specified section of a water body[16] in the advisories several pieces of information are given in chart format. This includes the species name of a fish, different lengths of fish, and one of four different recommended meal frequencies: no restriction, one meal per week, one meal per month, or do not eat. In the free booklet an asterisk

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[16] Advisories are sorted into different water bodies and if these water bodies are sectioned based on geography and proper names of river locations. To locate the advisory for the area where this research was conducted one must first look for Savannah River and then locate the area by looking for the description “Below New Savannah River Bluff Lock and Dam” and above “U.S. Hwy 301”.

beside the recommended meal frequency suggests readers look at the corresponding asterisk at the bottom of the page which notes,

> because there is considerable variation in how much mercury these large predatory fish contain, people who are considered to be especially sensitive to the effects of mercury (pregnant women, nursing mothers and young children) may wish to limit their consumption further (EPD/DNR 2010).

Perhaps the most important warning for those most at risk is given at the top of the page in fine print (without a linking asterisk at the top of the page). The difficult to locate addendum to the advisory states, “sensitive populations should not consume *any* fish from the Savannah River basin advisories” (emphasis added) (EPD/DNR. 2010). These examples clearly demonstrate the confusing presentation of advisories in the free booklet.

Standardizations: Current Georgia fish advisories are poor health tools because they are calculated for men with a select weight (150 pounds), build, diet history (no more than two fish or seafood meals a month), and who consume a select meal size (one meal is assumed to range from ¼ to ½ pound of fish (4-8oz)) (EPD/DNR. Electronic Document). Fish advisories are only accurate for individuals who meet the standardization. Since these standardizations are not mentioned and the free fish advisory booklet does not explain how guidelines should be read, advisories are inadequate for most individuals including those considered at highest risk (i.e., sensitive populations).

Language and Literary Obstacles: My research revealed that several individuals who fish and consume fish on the river were functionally illiterate and several were non-English speakers. This suggests it is necessary to develop advisories that are accessible to individuals who are functionally illiterate and/or non-English speakers.[17] The need to verbally administer surveys as well as the analysis of survey data demonstrates that many participants had low literacy levels. The following sample responses from sample #24 demonstrates this:

> Q1a. Does your family eat fish you catch? Yes No
> A1a. [no response]
> Q1b. If you selected Yes, please list the ages of family members that are children or women of childbearing age who eat fish.
> A1b. 6 Family member eat Fish in my hoase.
> Q2. Of fish consumed in the past month what percentage was caught?
> A2. bass
> Q3. How often do you fish below the dam on the Savannah River?
> A3. 3 time a mouth
> Q4. If you consume caught fish, where are the fish caught at that you usually eat?
> A4. at The bam
> Q4a. What percentage of fish that you catch is caught there?
> A4a. Bass Brim
> Q4b. Why do you choose to fish in that particular spot?
> A4b. Get a big ome some Time
> Q5. What are the estimate sizes of the fish you catch to eat?
> Q5. 4 poun

Present fish advisories are insufficient at reaching their educational goals. The compounding problems surrounding accessibility and interpretation of current Georgia

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[17] While a Spanish translated advisory is available online there are no advertised suggestions/directions to access this online advisory in the free booklet or in public areas.

fish advisories make fish advisory educational attempt wholly inadequate. While it is obvious that these advisories need to be amended and strengthened, this must be done with an understanding of the broader complexities that determine risk behavior. The embodied language, literary, and educational obstacles that anglers who consume contaminated fish from the Savannah River maintain helps to explain why current Georgia and South Carolina fish advisories fail at their intended goal. Furthermore, these embodied experiences lead to larger structural inequities. Embodied consequences primarily result from social circumstances and structural factors, not individual decisions. Limited individual control is largely determined by structural inequities such as poverty. Placing the onus on the individual disregards the structural inequities that influence the individual, which, in effect, further disables the groups the advisories are written for because the issues are rarely solved until the root issue is dealt with. This method of health education, therefore, is likely to yield limited results. Additional structural weaknesses inherent in fish advisories, which I speak about in more depth in the following section, help to explain why they are inadequate for minimizing mercury exposure.

The Structural Weaknesses of Fish Advisories

Faulty Reasoning

Educational campaigns assume that if individuals know the risks they will act to minimize them. Restated, “the logic behind their (health educator’s) health risk messages relies on the assumption that if risks are understood, individuals will emphasize the negative possibilities of risk taking and will rationally act to change their smoking practices" (Oaks 2001:98). In the case of fish advisories, this reasoning suggests that if people know consuming fish is bad for their health or the health of their potential children, they will not consume fish. The thought that if people know they will not do it is an example of faulty reasoning because it assumes that rationality is the same for all individuals. This assumption neglects to take into account the complex processes often at work that lead individuals to make one choice over another. From my research these complex processes include but are not limited to: food availability, poverty, educational attainment, employment, racism. One angler I spoke with explained it was not necessary for her to be on welfare if she fished, as this covered the grocery costs, and was healthier. Although she was clear to say there is nothing wrong with welfare she suggested with much pride that people like her were lucky because they could be self-sufficient since they could catch their own food. While embodied consequences (as previously discussed) play a large part in an individual's negotiation of health choices, a more complex understanding of why this reasoning is based on faulty assumptions is through a theoretically based understanding of risk and inequity.

Risk and Inequity

Social inequity is embedded in notions of risk. As Vinh-Kim Nguyen and Karine Peschard state,

> Risk is visible in different prevalences of diseases and outcomes between social groups. Risk... can be said to be a measure of social violence, capturing how power distributes unevenly down the social ladder. (2003:457)

Although risk can be useful there must be a careful balance in how risk is used. Risk can often limit one's ability to understand the complexity of social inequities and can be used to direct individual behavior change inappropriately. Even educational campaigns have been criticized for relying too heavily on the idea of risk, assuming that educational initiatives are sufficient to manage behavioral change. This assumption is reductionist and can make matters worse, because it blames individuals who are low on the social ladder and makes them victims of stigma. "Bluntly put, governmental technologies of risk blame the poor and magnify uncertainty for the rich with different embodied consequences" (Nguyen and Peschard 2003:458). Since epidemiological studies often rely on discourses of risk, sectioning and defining "at risk" populations, there is a need for increased research into the peculiarities of those populations, questioning the basis of their "at risk" status. Probing questions of risk will assist in a broader understanding of why particular decisions are sometimes made and other times not. Understanding why particular behaviors are made will be essential for developing successful campaigns to alter behavior. There is a significant need for context specific research to understanding how Savannah River anglers mediate fish advisories and fish consumption in order to develop health campaigns that account for the environmental conditions that affect behavior. While in this chapter I explain why it is necessary to enact upstream preventative solutions, educational campaigns are also necessary to minimize the existing mercury, which cannot be removed from the environment. In order to develop efficacious health campaigns, understanding why certain groups are considered at elevated risk and the understanding the processes that cause these individuals to be at elevated risk will be important. Determining groups at elevated risk is certainly necessary to improve educational campaigns, however, relying solely on traditional risk categorizations, such as minorities are at high risk, is likely to further existing problems since risk alone does not explain the structural inequities that cause individuals to be at elevated risk. Relying on risk to target populations without dealing with the structural inequities that create individuals at risk status is likely to increase the problems with the most at risk individuals experience because they, in effect, are held responsible for structural factors that are often outside their control.

Statistics: From Populations to Individuals

The notion of risk is helpful in understanding the effects of mercury contamination on a population level, but can be problematic particularly when applied on an individual level. The effects of chronic mercury contamination are very similar to the effects of smoking during pregnancy because the health consequences are often ubiquitous but non-causal. Oak's analysis of the problems inherent in applying population statistics to individuals is therefore relevant. Oaks states,

> A main difficulty of the health educator's mission is that smoking is a risk to fetal health; by definition, the consequences of smoking are uncertain.... assessments are based on the study of a population of pregnant women and cannot predict a medical event for an individual pregnant woman or her baby-to-be. The nature of risk means that health educators cannot present pregnant smokers with guarantees. (2001:95)

This analysis builds off the central limit theorem which argues looking at a population we can use the mean to see that behavior x is likely to cause adverse health effects. If we take just one person, however, we cannot see that if they do behavior x it is likely to cause adverse health effects because an individual is not a mean. It is faulty reasoning to apply statistics made at a population level to individuals.

Additionally, reducing the problem to one behavior is problematic because individuals do not live in vacuums. As Oaks further explains,

> Scientists attempt to isolate smoking during pregnancy from other prenatal risk factors to estimate the chance of specific pregnancy outcomes, yet they cannot adequately account for the less easily measured risk factors in women's lives that also influence fetal health, such as stress and social support. (100).

This again highlights the problem of social inequities that confound in risk assessment. Therefore, while I do believe risk assessment is needed to conceptualize the adverse effects of mercury toxicity on health, risk is problematic when it is applied to individuals and becomes the crux of public health efforts. The critique of statistics to better understand the health problems associated with mercury exposure. Statistics are useful tools to explain macro-level health problems and can be useful to push for change on a population level but should not and cannot be accurately applied to individuals.

Negotiating Social Inequities

Returning full circle to what I have referred to as educational campaigns' faulty reasoning, I wish to fully address the implications this reasoning has on larger structural inequities. As stated earlier, educational campaigns are based on faulty reasoning because they neglect to see that interpreting risk is a negotiation between different factors. What is in fact happening is that people are negotiating choices about nutrition. Oaks presents how social inequities are neglected in individual focused behavior change when she argues,

> Stress on the idea that each person can control her or his health by making rational choices severely limits attention to the relationship between individuals and the social conditions of their lives... When health professionals assume this perspective, they fail to consider the ways in which social circumstances and structural factors, such as poverty, racism, domestic violence, and so on, do not allow women to control their lives. Consideration of the socioeconomic conditions of women's lives challenges the notion that each individual can control her health status by choice. Social inequities, not just individual actions, contribute to or constrain health and well-being. (2001:89)

Her analysis is applicable to my study, because anglers who consume fish from the Savannah River are of low socio-economic status (Burger et al. 2001:501; Smith 2010). On the whole, they have limited nutritional choices. Informal interview data as well as several questionnaires suggest that many are subsistence fishing. Anecdotal evidence suggests that limited income was a primary determinant for some individuals consuming fish from the Savannah River. While I heard many similar stories, several Savannah River anglers explained that they began to fish more once they were retired to supplement their limited income. This evidence suggests that some individuals who fish on the river may be asked to choose between eating mercury contaminated fish or not eating. Certainly this is not the same set of choices someone of an upper socio-economic status would have to make. Furthermore Oak's extrapolation would likely apply to individuals fishing and consuming fish from the Savannah River as well. She suggests, "many low-income pregnant women lead such 'high-risk' lives that changing just one aspect... does not sizably reduce their overall health risk status" (2001:100). On a different note, the low socio-economic status of Savannah River anglers is likely to limit their ability to shop at upper class grocery stores such as Whole Foods, where methylmercury fish advisories are posted.

Oaks analyzes the problem with current health education saying, "the health education field is based on models that focus on individual behavior change, health educators are directed to target individual behavior, not social inequities" (2001:90). While it is not well detailed what specific social inequities affect individuals consuming fish from the Savannah River, this research is of pressing need to develop effective solutions for minimizing mercury exposure. I argue that the efficacy of relying solely on fish advisories to prevent adverse health effects from mercury through fish consumption is limited. While educational campaigns are necessary to prevent harm from already existing mercury in the environment and ecosystem, the larger focus needs to be at a community/societal level, not an individual level. Indirect determinants that factor into individuals' ability to make health choices also need to be addressed. The priority focus, however, need to be regulatory.

Since all the sections presented thus far have highlighted structural inequities, albeit in differing forms, I will now move from toward a more macro-based discussion of structural inequities.

VI. POLITICAL ECONOMY

The reason structural inequity has been a common theme in the various analyses presented thus far is because it explains why mercury policy to date has been inadequate. In this chapter I utilize a political economy framework to enable a theoretically grounded discussion of solutions. To define political economy I borrow the following definition written by *Lynn* Morgan, cited by Linda M. Whiteford in her essay "Political Economy, Gender, and the Social Production of Health and Illness":

> … a macroanalytical, critical, and historical perspective for analyzing disease distribution and health services under a variety of economic systems, with particular emphasis on the effects of stratified social, political, and economic relations within the world economic system. [Morgan 1987:132; as cited in Whiteford 1996:247].

Although my present analysis does not address the breadth of Morgan's definition, my analysis touches on several concepts delineated in the above definition. I argue that patterned inequity, in the form of elevated risk to mercury exposure, is created and sustained by larger social categories or social institutions (including the government and the private corporate sector). Emphasizing economic systems provides valuable insight into the Savannah River mercury pollution issue.

Downstream / Upstream Metaphor

John McKinlay presents the "downstream/upstream" metaphor, distinguishing between "downstream"- short-term immediate fixes and acute treatment- and "upstream"- preventative health- in the classic public health parable he attributes to Irving Zola. The story recounted by McKinlay proceeds,

> My friend, Irving Zola, relates the story of a physician trying to explain the dilemmas of the modern practice of medicine: "You know", he said, "sometimes it feels like this. There I am standing by the shore of a swiftly flowing river and I hear the cry of a drowning man. So I jump into the river, put my arms around him, pull him to shore and apply artificial respiration. Just when he begins to breathe, there is another cry for help. So I jump into the river, reach him, pull him to shore, apply artificial respiration, and then just as he begins to breathe, another cry for help. So back I jump back in the river again, reaching, pulling, applying, breathing and then another yell. Again and again, without end, goes the sequence. You know, I am so busy jumping in, pulling them to shore, applying artificial respiration, that I have *no* time to see who the hell is upstream pushing them all in (McKinlay 1975, emphasis in the original).

From this parable McKinlay further develops the metaphors of downstream and upstream warning. "One must be wary of the *short-term nature* and *ultimate futility* of such downstream endeavors" (emphasis in the original). McKinley argues it is necessary to reorient focus from downstream— where "individuals and groups... are mistakenly held to be responsible for their condition"- in favor of a upstream political and economic focus,- where "the activities of the 'manufactures of illness'- those individuals, interest groups, and organizations which, in addition to producing material goods and services, also produce, as an inevitable byproduct, widespread morbidity and mortality" are held accountable. McKinlay concludes that such a reorientation,

> would minimally involve an analysis of the means by which various individuals, interest groups, and large scale, profit-oriented corporations

> are ‘pushing people in,’ and how they subsequently erect, at some point downstream, a health care structure to service the needs which they have had a hand in creating, and for which moral responsibility ought to be assumed. (McKinlay 1975)

This metaphor and analysis provide the groundwork for a discussion of political economy whereby health effects can be analyzed, not just in terms of individual embodiment, but also from a perspective of structural inequity. By using a political economy framework a discussion of moral responsibility can be applied not just to individual actors (as I have shown is the case through the issuance of fish advisories) but also to the structures that enable mercury pollution.

Upstream “Manufacturers of Illness”

Focusing primarily on the chlor-alkali facility and governmental regulation of this facility I will illustrate how these structures, borrowing from McKinlay, “manufacture illness.” This macro or upstream analysis is particularly necessary to put forth solutions, since the complexity of issues surrounding this contamination requires multi-pronged/multilevel solutions- not merely individual level solutions.

To date the policy’s emphasis has been on individualization of health risk over broad scale regulation. This individualization can be seen predominantly in the issuing of fish advisories over tightening of regulatory guidelines for industries. As Michael Bender and Jane Williams point out, “the logical step to minimize health problems associated with mercury would be to curtail anthropogenic sources of mercury through setting emission limits, however, this has not been done” (1999:417). Leadership on mercury regulation has been minimal at the federal level (Selin 2005:19).

My previous research on mercury in the Savannah River has demonstrated the inadequacy of regulatory permits. The results of this research have demonstrated there is considerable mercury contamination in the Savannah River circa the chlor-alkali plant where sediment mercury concentrations exceed 60,000 ppb (Smith et al. 2007:4). The National Oceanic Atmospheric Administration's S.Q.R. tables set toxicity standards for mercury. The upper-most toxic threshold effect begins at 560ppb which is the level at which mercury is considered lethal and is expected to be lethal to all aquatic organisms. (*Anonymous.* NOAA S.Q.R.T). Therefore, mercury levels found circa the Olin plant are "lethal one hundred times over" and at least 60 times the upper threshold level. This facility has been compliant with their EPD permit for the past thirty years. Over the last quarter of a decade, Olin has discharged about 25% of its allowed daily mercury discharge (Smith et al. 2006:46). The considerable toxicity, and the fact that additional research revealed mercury is building in the community and has a cumulative toxic effect, suggests regulatory limits are disturbingly weak since this chlor-alkali facility has been discharging only 25% of its allowed discharge of mercury.

Particularly telling is the regulatory response since this research was published. My findings were reported to EPA/EPD, which initially stated that the waterway was private and thus restricted from their jurisdiction. Only after discussions, press conferences, and data that were published for an international audience, was the channel defined as a "navigable waterway" subject to EPA standards. EPD then informed this facility that they could either hire a certified monitor or EPD could monitor the channel. This chlor-alkali facility chose the former. Mac Tec, a private engineering firm, analyzed the sediment and came to similar conclusions. EPD then declared that the site had to be cleaned up; however, they have also stated that a cleanup plan, no matter how good, does not solve the problem because the contamination continues. The implemented cleanup plan has required this facility to isolate the channel leading into the Savannah River where the highest levels of mercury sediment were found. However, the continued production of chlorine by this plant has not been regulated. Instead of directing outflow into the channel the cleanup plan has allowed for the facility to redirect waste directly into the river. Clearly the EPA/EPD's complacency to protect mercury emissions demonstrates a policy focus that protects corporate interests over public interests.

Perhaps most astounding is the ease with which conversion could curtain mercury emissions. Chlor-alkali facilities use an antiquated methodology for producing chlorine, which uses mercury as a cathode. Theoretically the mercury is supposed to be re-circulated within the system, however, chlor-alkali facilities are known for their fugitive emissions, in which volatile mercury is released into the environment (Gayer and Hahn 2007:29). This facility is one of only four chlor-alkali facilities left in the United States. Nonetheless, in a study conducted by Oceana in 2002, revealed that the remaining plants released five times more mercury than the average power plant into the atmosphere. Chlor-alkali facilities can be converted cell by cell, which prevents local jobs form being affected and allows for the company to pay for the conversion over time. Moreover once a conversion has taken place, the cost of production for chlorine goes down. It is therefore more economical to use mercury-free membrane technology.

Curtailing mercury emissions is very important as a preventative health measure since mercury released now into the environment will have health effects in years to come. The solutions for minimizing mercury emissions are relatively simple since there are alternative and more economical ways for producing chlorine. Clearly there is a need for upstream focused policy that addresses the manufacturers of illness.

Solutions: Downstream / Upstream

The appropriate solution for dealing with this mercury is two-fold: downstream and upstream solutions. Downstream solutions are necessary to implement since mercury is in the environment and cannot be removed from the environment. Most likely these solutions would come in the form of educational campaigns. Based on the previously presented theory and angler study, it is evident that these short-term solutions need to be rolled out in a manner that effectively reaches populations of interest and need to be restructured so they most effectively account for social determinants, which clearly affect individuals' intent and ability to follow fish advisories. This restructuring must be a context specific process in which the complex issues surrounding embodiment will need to be appropriately addressed. To address downstream problems, a call for individual behavior change is not sufficient, instead behavior change must be facilitated. Central to facilitated behavior change is campaigns that address socially imbedded lifestyles. These campaigns must offer environmental supports that facilitate individual behavior change. For example, environmental supports for individual behavior change could include providing alternative fishing locations or food sources for individuals who subsistence fish from contaminated areas in the Savannah River. Development of facilitative behavior change models necessitates continual research into the context specific realities that address socially embedded lifestyles.

Solutions, however, cannot be restricted to downstream endeavors but must also include upstream efforts. As McKinlay appropriately argues, addressing structures that "manufacture illness" is necessary for any comprehensive change to occur. The transparently obvious action would be to stop use of an antiquated technology. The contamination could be halted through either the conversion of the antiquated plant or the closing of the plant. Curtailing mercury from antiquated sources and well as increased regulation of mercury emissions will be important in the future. For this to occur, governmental regulation needs to be appropriately scaled up to control corporate polluting.

Conclusion

The United States government's current actions (or lack thereof) suggest that it is protecting corporate interests over public health. The government's focus on individual behavior-change instead of toxin regulation and the extremely poor implementation of education campaigns are largely due to government complicity to protect mercury emissions and corporate profits while privatizing the health risks associated with consuming contaminated fish. Upstream solutions are necessary to bring about environmental equity and therefore social justice. Even if educational campaigns were perfect, they would still be limited in their efficacy due to confounding factors (such as social determinants) that are not addressed in health campaigns. Further anthropological research is needed to better understand these complex factors so that health campaigns (including behavioral-based campaigns) and regulation can be improved.

In this chapter I have illustrated some of the complexity that surrounds this public health issue. The complexity of the situation warrants multi-pronged solutions. It will be important in developing future solutions to be aware of the possible negative consequences of over reliance on educational campaigns to promote individual behavior-change. Furthermore, with limited regulation the amount of mercury getting into the ecosystem is building everyday. This combined with the long-term developmental delays due to mercury exposure will make it increasingly hard for individuals who are affected (which is predominantly individuals in lower socio-economic classes) to navigate the mercury health recommendations. The moralizing consequences and adverse health effects of continuing the present policy actions are likely to increase mercury exposure along social fault lines leading to a markedly more stratified society.

EPILOGUE

In December 2010 while writing this thesis I received an early morning phone call from the current Savannah Riverkeeper, Tonya Bonitatibus. She told me the news that Olin would be phasing mercury out of their Augusta plant; this happened about 30 minutes before the official press release was given. The phase out of mercury is estimated to take approximately three years. Presently, discharge is still going directly into the Savannah River, polluting the river with mercury on a daily basis. While it is fortunate that the mercury will be phased out, an estimated 21,000 pounds of mercury will likely pollute the environment from the Olin Augusta, Georgia plant within the phase out period (if all goes according to schedule).

In the upcoming years when the sources of the mercury contamination is gone, the focus can change to clean up and mitigating the effects of the mercury already in the river. The change from a split focus of fighting to stop Olin from continuing to pollute and addressing the mercury already in the river and the ecosystem can be consolidated.

In many ways this story provides an example of how a grassroots environmental campaign can be successfully run in a place like Augusta, Georgia. Perhaps it could be of some use for someone interested in a similar effort. It can certainly be told in a way that reflects Margaret Mead's famous saying "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has." However, it would be dishonest to conclude on such a note. Certainly, great change has come out of this work; yet, the issues surrounding Olin's mercury contamination are still complex and interrelated. I feel that this work is far from over. Minor successes have been achieved, but many more are necessary.

I feel like one of the largest successes over the course of this project is where I have come from since I have begun this work. The need for an interdisciplinary approach in this thesis was clear to me from the beginning, however, the attempt to integrate disciplines has really taught me how specific, complex, and difficult such a process can be.

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