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Soil Safety Skepticism
(To What Extent Does the Prevalence of Heavy Metals Created from Traditional Vaccines for Diabetic Patients Harm South Florida's Environment Compared with Microneedle Patches?)

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Abstract:- This research investigates the environmental impacts of sharps waste (SW) disposal methods in South Florida (SF) and explores the potential of microneedles (MNs) as a sustainable alternative for Type 1 Diabetes (T1D) patients. Soil samples from a state park (control) and three incineration facilities (Fort Pierce, Fort Lauderdale, and Miami) were analyzed for heavy metal (HM) concentrations, including Chromium, Cadmium, Copper, Lead, Mercury, and Arsenic. The samples underwent chemical analysis at Eurofins Laboratory to determine HM concentrations (mg/kg) and pH levels. The findings revealed elevated levels of Copper, Lead, and Chromium in observational sites compared to the control, with Miami demonstrating the highest concentrations. Lead and Copper concentrations in Miami exceeded Florida's Residential Exposure (RE) limits, while Cadmium surpassed groundwater leachability thresholds, highlighting potential risks to human health and the environment. Despite small sample sizes limiting statistical significance, the study emphasizes the urgent need to address SW disposal's environmental consequences. MNs were identified as a promising alternative to reduce medical waste and its associated environmental hazards. This research advocates for the adoption of MNs to mitigate heavy metal contamination, enhance public health, and promote sustainable healthcare practices.

I. INTRODUCTION

Injections are a vital part of human existence. They are used to build immunity from dangerous infections and diseases, treat illnesses, and ensure billions of humans' survival. Injections and hypodermic needles, "a small syringe used with a hollow needle for injection of material into or beneath the skin," are also used to keep people receiving vital medicine to regulate their bodily functions and provide their bodies with their needs (Merriam-Webster Dictionary, 2020). Diabetes is an example of this.

abetes is a chronic illness that influences the process by which the body converts food into energy, and there are two specific types of diabetes. (CDC, 2022). Type 1 specifically, is an autoimmune reaction that inhibits someone's body from making insulin. It is genetic and uses vaccinations to administer insulin. The administering of insulin for type 1 diabetes (T1D) is most commonly self-administered through 6mm insulin syringe needles – the length of treatment is dependent on body mass index, and that is the most common (Needle length, n.d.). These needles hold 0.3ml of insulin and are made of stainless steel (Insulin Syringe with Needle, n.d.).

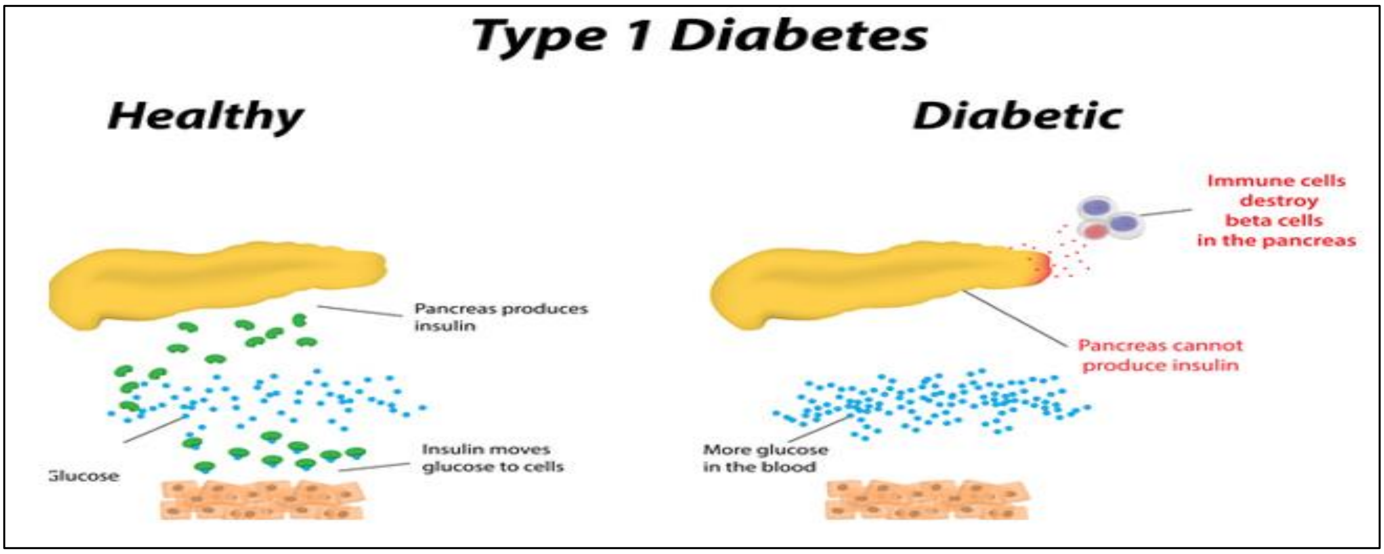

Fig 1: Infographic Showing How Type 1 Diabetic Patients Cannot Produce Insulin. It is an Easier Way to Understand the Correct Process that the Body Naturally Undergoes Compared to a Type 1 Diabetic Who Shows a Deficiency. (%22Type 1 Diabetes%22 Images – Browse 2,114 Stock Photos, Vectors, and Video, n.d.)

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There are 537 million people in the world who have diabetes, and 8.4 million who have type 1 (Gregory et al., 2022) (International Diabetes Federation, 2022). In South Florida (SF) specifically, there are approximately 2,076 people who have T1D (FDH, 2019). Most commonly, people must administer insulin up to 4 to 5 times daily (Services, n.d.). This data synthesized means that, on average, there are 37.8 million diabetic needles used in a day, 264.6 million used in a week, 1.0584 billion used in a month, and 12.7008 billion used in a year for T1D patients alone.

This large amount of needle usage can create adverse health effects. Nearly 14% of diabetic patients are misinformed on how to dispose of their needles properly and throw them in their regular trash cans at home or in public trash cans (Helping Diabetic Patients with Safe Needle Disposal, n.d.). Improper disposal is detrimental and there is only one safe way to dispose of bio-hazardous waste after use. This type of waste is called Sharps Waste (SW). SW includes syringes, needles, lancets, and broken glass.

When SW is improperly disposed of, it can end up in landfills, where people could accidentally prick themselves with a contaminated needle and be at risk for exposure to infectious diseases, including HIV, hepatitis A and B, and AIDS (Government of Canada, 2018). SW also negatively impacts the wildlife around us by contaminating groundwater sources.

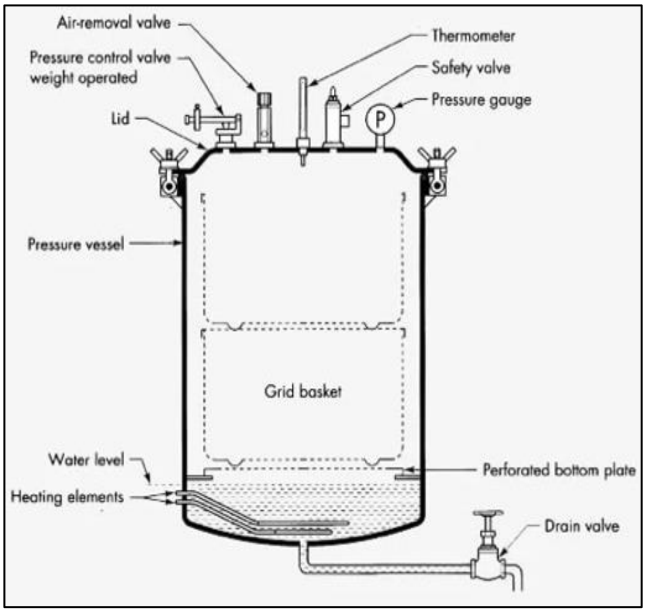

Fig 2: Shows Real-Life Examples of Autoclaves to Help us Understand their Varying Sizes and Types, which are Made for Different Purposes in the Medical Field, Whether they have a Minimal Capacity or Meet the Needs of an Entire Hospital. (Rijal, 2019)

SW has two main disposal methods. Firstly, there are autoclaves, the newer form of disposal. "Autoclaves are sterilization devices that use steam under pressure to kill bacteria, viruses, and other microorganisms on instruments and equipment" (Autoclave Machine, 2022). They are the environmentally friendly option for disposing of SW because they do not cause adverse environmental effects like carbon emissions and have been increasingly used recently. However, their main fault is that they sterilize SW rather than dispose of it (Sastri, 2017). This creates further waste that must be thrown out, which is non-toxic to humans but is still waste, which creates more waste in landfills. This is why there is a need for better solutions than this, one that eliminates the physical waste of SW and one that does not create a biomedical hazard when disposed of.

Fig 3: Iilustrates the Makeup of an Autoclave and Shows What Each Part Controls, but Ultimately Shows its Inability to Incinerate Sharps Waste and its Sole Use of Steam Sterilization. (yasminlp, 2024)

Fig 4: Shows a Photograph of an Incineration Site and a Sharps Incinerator. It Simultaneously Shows the Adverse Environmental Effects of Incineration, as Shown by the Release of Gas and Ash into the Air at the Top of the Incinerator (Hospital Incinerator #1 by Robert Brook/Science Photo Library, n.d.).

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The second method of disposal is through incineration. Incineration rids waste of its bio-hazardous materials by removing harmful pathogens that were once on the needles. Incineration is the most effective option for the disposal of SW; however, it contributes to pollution and health problems. The incineration of SW emits toxic gases like carbon monoxide, and nitrogen and sulfur dioxide into the atmosphere. It also leaves bottom ashes, the non-combustible residue of combustion, in SW incinerators, which leaves high concentrations of heavy metals (HMs) behind. Additionally, the aerosol remanence of HMs is incredibly toxic and harmful, as highlighted in the research paper by Sabiha-Javied where he explains that “tiny metal particles in the air increase the risk of inhalation related diseases” (Sabiha-Javied et al., 2008). HMs are metallic elements with high atomic weights and densities, including Lead, Mercury, Cadmium, Arsenic, Chromium, Copper and others. HMs can be toxic in elevated concentrations and pose environmental and health risks due to their persistence and potential for bioaccumulation in organisms.

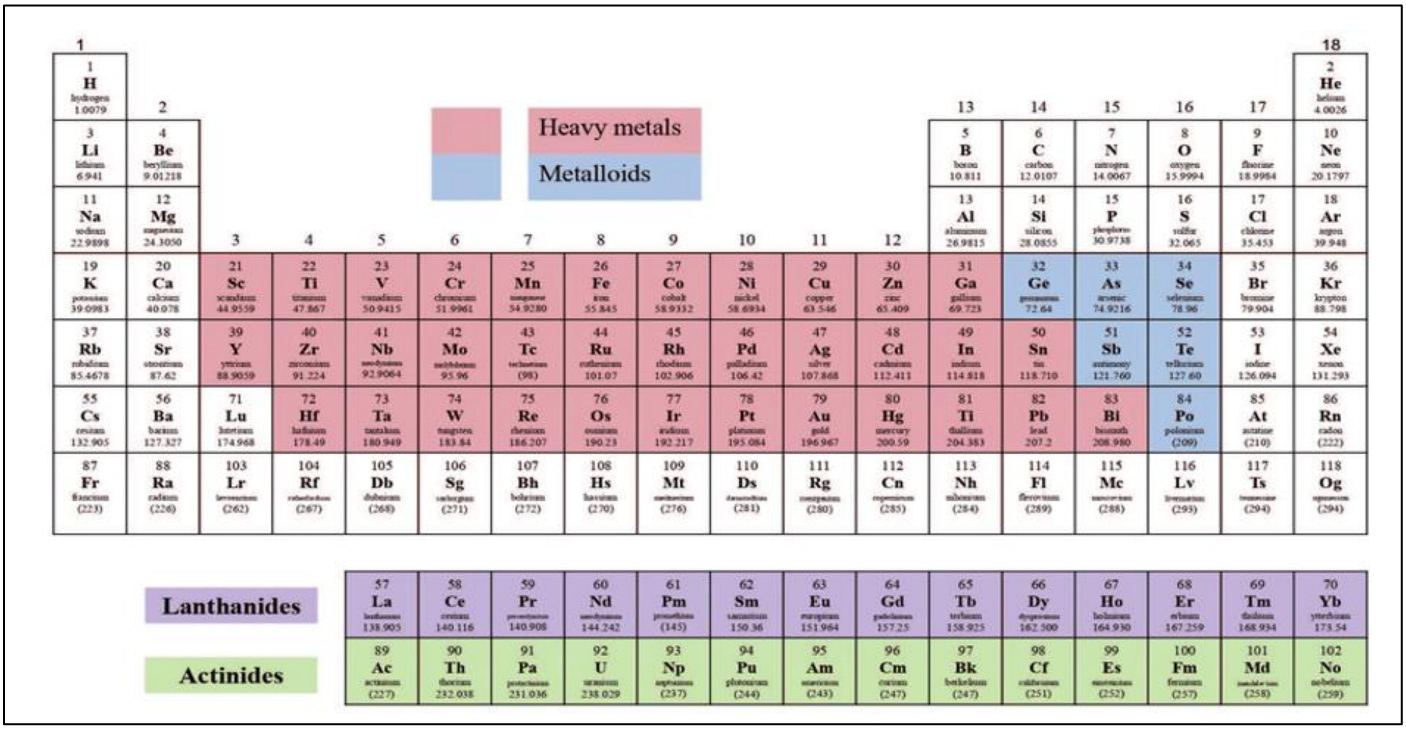

Fig 5: Shows an Image of the Periodic Table of Elements to Show Where the Heavy Metals are Located and to Name the Other Heavy Metals that I did not Already Name in the Literature Review.
(Periodic Table of Heavy Metal by SteveHNo96 on Deviant Art, 2012)

As detailed, both the proper and improper disposal of needles associated with diabetes are hazardous to the environment. This practice must be continued despite the environmental damage because T1D patients need insulin to survive and because “Diabetes is the eighth leading cause of death in the United States,” creating a significant problem for nations across the globe (CDC, 2022). However, a solution has been proposed. Vaccine microneedle (MN) patches are being introduced to the medical field and are proven beneficial.

II. LITERATURE REVIEW

A. Diabetes

The prevalence of T1D will continue to grow in our modern world, with “by 2060, the number of U.S. adults with diagnosed diabetes [being] projected to nearly triple” (Lin et al., 2018). This will create significant environmental effects as diabetic needles are a source of ecological damage. In a study by Karla in 2015, they measured the entirety of the syringes used for T1D patients and found that each syringe weighs 3.28g. When excluding the syringe needle, which contributes to SW, significant plastic waste is generated, approximately 600,000kg (3g × 200million syringes) a year (Kalra et al., 2015).

There have been many studies enumerating the improper disposal methods and practices of T1D patients. A study from Pakistan and India by Majumdar in 2015 found that “more than 90% [of] patients discarded them [diabetic syringes] into the household-bin” (Majumdar et al., 2015). This is not a single account, as studies done in the U.S. provide evidence that only 59% of subjects disposed of SW correctly, and in studies done in Ethiopia where, “31% of respondents threw sharps on the street when they travel outside,” (Thompson & Cook, 2021) (Basazn Mekuria et al., 2016).

The ignorance of the correct disposal of SW can be attributed to a lack of education worldwide about the dangers of SW and misinformation from healthcare providers, such as in Majumdar’s study, he found that only 14.1% of patients in New Delhi, India, had received any education about the proper disposal of SW (Majumdar et al., 2015). This can be

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compared to Thomason's and Cook's study in 2021, where they gathered information from 13,289 patients requiring insulin across 423 centers in 42 countries, finding that 48% of respondents reported recapping needles and discarding them in household trash, while 40% disposed of sharps in community trash, underscoring the need for improved education on proper SW disposal (Thompson & Cook, 2021).

Coupled with record high prices of insulin, any other type 1 diabetic device for administering insulin is significantly more expensive, and the majority of the population who have diabetes can only afford standard insulin-delivering needles ($12 to $30) (Insulin et al. for Diabetes | Diabetic Pen Needles for Sale, n.d.). As noted by the National Library of Medicine, authors Crossen, Xing, and Hoch detail that the "Mean annual cost of T1D care increased from $11,178 in 2012 to $17,060 in 2016, driven primarily by growth in the cost of insulin ($3,285 to $6,255) and cost of diabetes technology ($1,747 to $4,581)" (Crossen et al., 2020).

Fig 6: Image of the Different Insulin Delivery Devices Offered for Type 1 Diabetic Patients, Including the Standard Insulin Syringe, Followed by an Insulin Pen, Jet Injector, and Insulin Pump. The Standard Insulin Syringe is the Lowest-Priced Option, while the others are More Expensive Options. All are Effective for Insulin Delivery. (StoryMD, n.d.)

The rising costs for medical technology that need to be accessible to millions of people create another factor as to why a solution is necessary for the continued help of this population. Some patients can receive medical coverage through Medicare or private insurance (Financial Help for Diabetes Care, n.d.). However, the majority of T1D patients (38%) might not qualify for Medicare or private insurance. People cannot pay their increasing medical expenses, which highlights the economic issues diabetic patients are also facing (Walker et al., 2015). Both economically and environmentally, traditional methods of treating diabetes need to be changed.

B. Heavy Metals

The incineration process of disposal of diabetic needles is a vital practice. The SW must be incinerated, so humans will not be at risk of potential exposure to pathogens. However, in his research, Sabiha-Javied again finds that during this process, metals cannot be destroyed, so fly ash and bottom ash are released or left in the incinerators, which also has adverse effects on the environment because the concentration of metals is much higher and dangerous than before the incineration (Sabiha-Javied et al., 2008).

This pertains to SW from diabetic needles because, as found in Kipsengeret Koros's thesis for their master's degree in Kenya, "the high concentration of chromium [in the fly and bottom ash in the incinerator] resulted from incineration of stainless steel "sharps" which contained a significant amount of Chromium (Koros, n.d.). which goes along with stainless steel's chemical makeup of "about 18 percent chromium" (Koros, n.d.) (USGS Mineral Resources Program, 2010). Stainless steel is made with Chromium to "toughen steel and increase its corrosion resistance, especially at high temperatures" (USGS Mineral Resources Program, 2010).

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Fig 7: Shows Real-Life Images of Fly Ash and Bottom Ash Compared to One Another. Fly Ash (Left) is the Finer Powder Made from Incineration that Goes into the Air and has Higher Concentrations of Heavy Metals. Bottom Ash (right) is the Coarser Ash Left at the Bottom of an Incinerator with Lower Concentrations of Heavy Metals. (What Is Ashcrete?, 2022)

Fly ash and bottom ash are the byproducts of incinerators and are microscopic particles resulting from pulverized SW. Bottom ash is the larger, coarser particles collected at the bottom of the combustion chamber, typically with lower HM concentrations. Fly ash is the fine particles carried in flue gases during combustion, often containing larger concentrations of hazardous HMs. They are both toxic and acidic and can contain radioactive matter, such as “lead, arsenic, mercury, cadmium, and uranium” (Fly Ash - Energy Education, n.d.). The Environmental Protection Agency (EPA) has been warning against fly ash and bottom ash and notes that “significant exposure to fly ash … increases a person’s risk of developing cancer and other respiratory diseases” (Fly Ash - Energy Education, n.d.). To contribute to this, Koros evaluated the toxicokinetics and toxicodynamics of Arsenic, Cadmium, Chromium, Lead, Copper, and Mercury, finding that they are toxic. When humans are exposed to them, workers and residents, there have been notable increases in cancer and have also been found to have increased dermal, cardiovascular, respiratory and inhalation-related diseases, gastrointestinal, neurological, and developmental effects (Koros, n.d.).

Combined with these adverse effects for humans, they also affect the environment. Fly and bottom ash disposal is the main contributor to the negative impact, as ash is often disposed of in wet ponds or landfills. Fly ash can move through environments and bioaccumulate in different systems through leaching. “Leaching is a process that occurs when fly ash is wet, and it simply means that the toxic components of the ash dissolve out and percolate through water.” This means the ash can move into groundwater systems and contaminate drinking water (Fly Ash - Energy Education, n.d.). Combined with water runoff and groundwater, the ash contaminates and bioaccumulates “freshwater fish [and] … crops.” This bioaccumulation is further exemplified in the 2019 paper by Hazrat Ali, noting examples such as the Minamata disease (MD) and itai-itai disease that occurred because of mercury-contaminated fish and cadmium-contaminated rice. HMs are not supposed to be consumed in high concentrations and become a detriment to human lives (Ali et al., 2019).

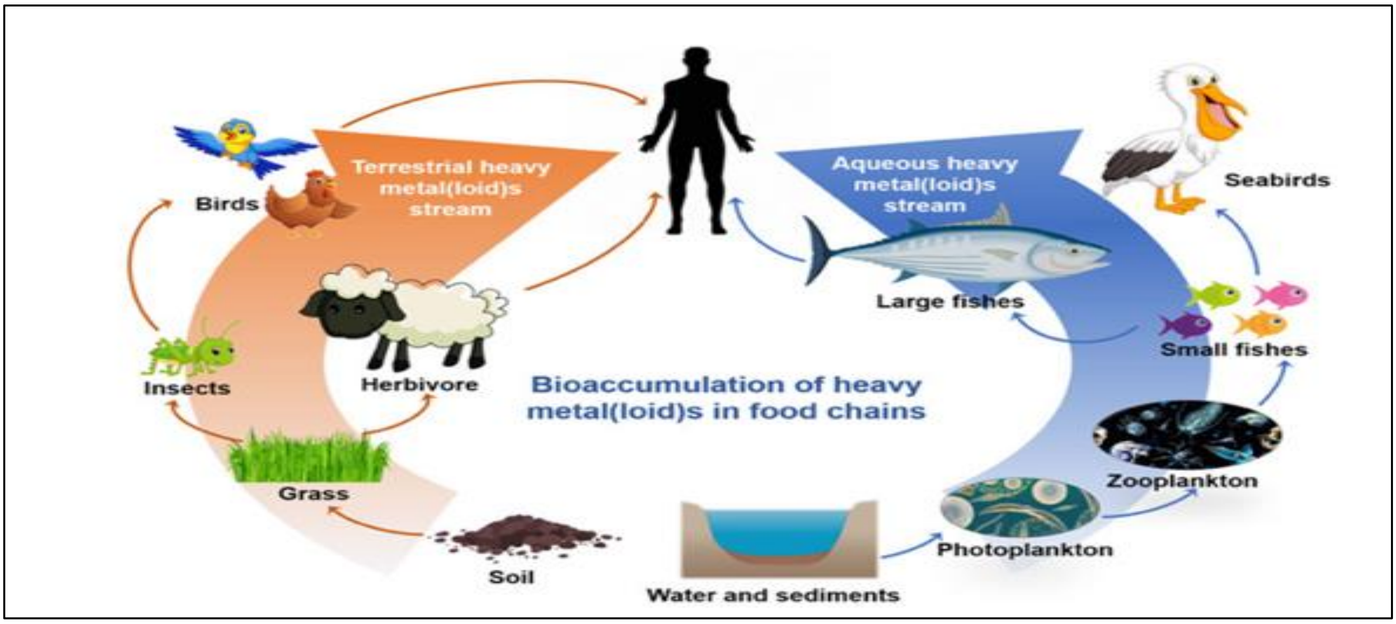

Fig 8: Depicts an Infographic of one Bioaccumulation Process in Organisms and Shows How the Metals Absorbed in One Organism Can Transfer to other Organisms through the Natural Food Cycle and Environmental Processes. (Ding et al., 2022)

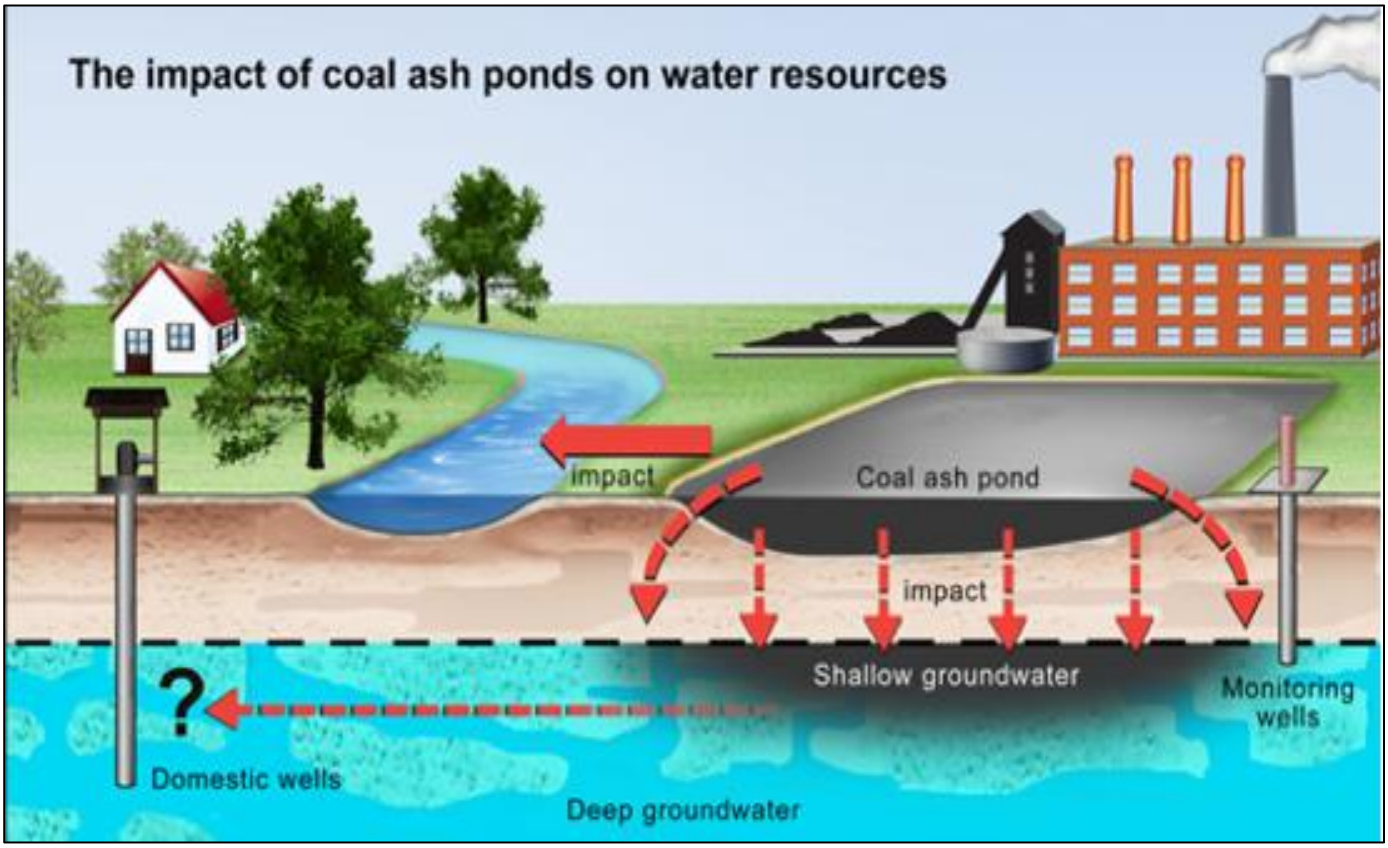

Fig 9: Depicts a Computer-Drawn Image of Coal Ash Ponds Leaching into Groundwater and Polluting the Waters Around the Coal Site, which Shows how the Process of Groundwater Leaching from the Heavy Metals in the Soil Around Sharps Waste Facilities from Fly and Bottom Ash is Hazardous and Harmful to the Ecosystems Around Facilities, as it Pollutes not only the Air with Heavy me but also Pollutes the Water that People Drink and the Life that Lives in and Around Groundwater Systems and Waterways Near Facilities. (staff, 2016)

As researchers Khaledian, Lim, and Oyen noted, "The pH conditions in different environments can influence the release, dissolution, and mobility of heavy metals," creating a better or worse environment for environmental contamination (Yones Khaledian et al., 2017) (Lin et al., 2017) (Oyem & Oyem, 2022). PH levels affect the mobility of HMs from fly ash and other sources; metals such as Chromium, Cadmium, and Copper dissolve more readily in acidic environments, whereas Lead may be released in alkaline environments (Does PH Has Correlation with Heavy Metals?, Research papers) (Elbana & Selim, 2011). Furthermore, research indicates fly ashes from hazardous waste and SW have much higher concentrations of harmful HMs than fly ashes from municipal solid waste, which highlights the importance of proper treatment before landfilling to avoid contaminatin g the environment (Zhao et al., 2009).

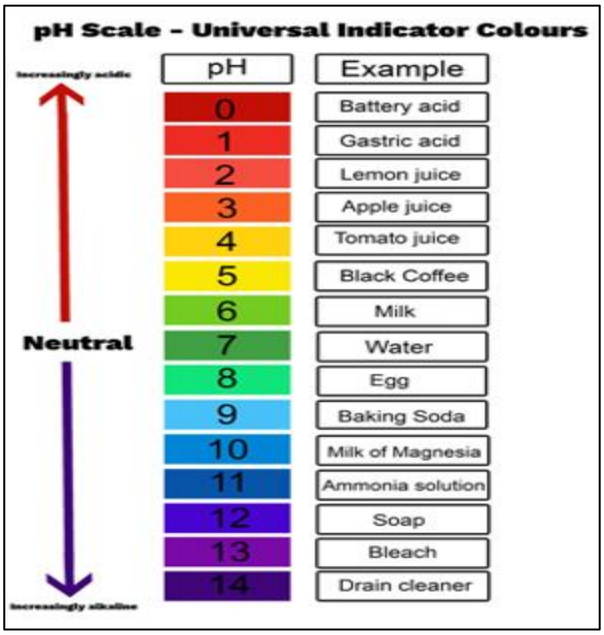

Fig 10: Illustrates the Universal pH Scale, Which can be Used to Determine the Alkaline or Acidic Properties of a Sample or Material, such as those Listed in the Image. The Most Acidic is Battery Acid, and the Most Alkaline is Drain Cleaner. (Vanstone, 2023)

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C. Clean Air Act

The Clean Air Act (CAA) is a U.S. federal law controlling air pollution (EPA, n.d.). Enacted in 1963, with significant amendments in 1970, 1977, and 1990, it empowers the EPA to regulate and set standards for air quality, emissions limits, and pollutants to protect public health and the environment (US EPA, 2019). The Clean Air Act limited incineration in the United States (U.S.); however, it was only enacted in the U.S., so all other continents still have unrestricted incineration. Moreover, in the U.S., the CAA only limited and regulated incineration; not removing it altogether. Sharps incinerators are still prevalent in the U.S.; there are just fewer than before (Environmental Law Institute, 2012).

D. Microneedles

Microneedle patches (MNPs) are "a type of transdermal patch that has been embedded with an array of tiny needles to deliver the drug solution. Every MNP has an adhesive layer that sticks to the skin and needles that puncture the skin to facilitate drug delivery" (House, n.d.). MNPs eliminate the pain, bruising, and healing that follows receiving a vaccine. The feeling is similar to Velcro's rough side rather than a sharp needle. These vaccines go into the subcutaneous layer of skin, not the muscle, which is a more effective method of relaying medicine to the body because the skin acts as the first layer of defense and can identify danger, targeting the pathogens immediately upon entry into the body.

MNPs are better for the environment, as they limit the waste associated with creating and administering regular vaccines. They are hard, small, gel-like patches that are 3-D printed (Chen et al., 2018). MNs are created by molding the specific MN, whether solid, hollow, coated, dissolvable/dissolving, or hydrogel-forming, and creating a sugar or salt solution containing the medicine. MNPs have been clinically tested and introduced to limit these problems and create better outcomes for diabetes patients.

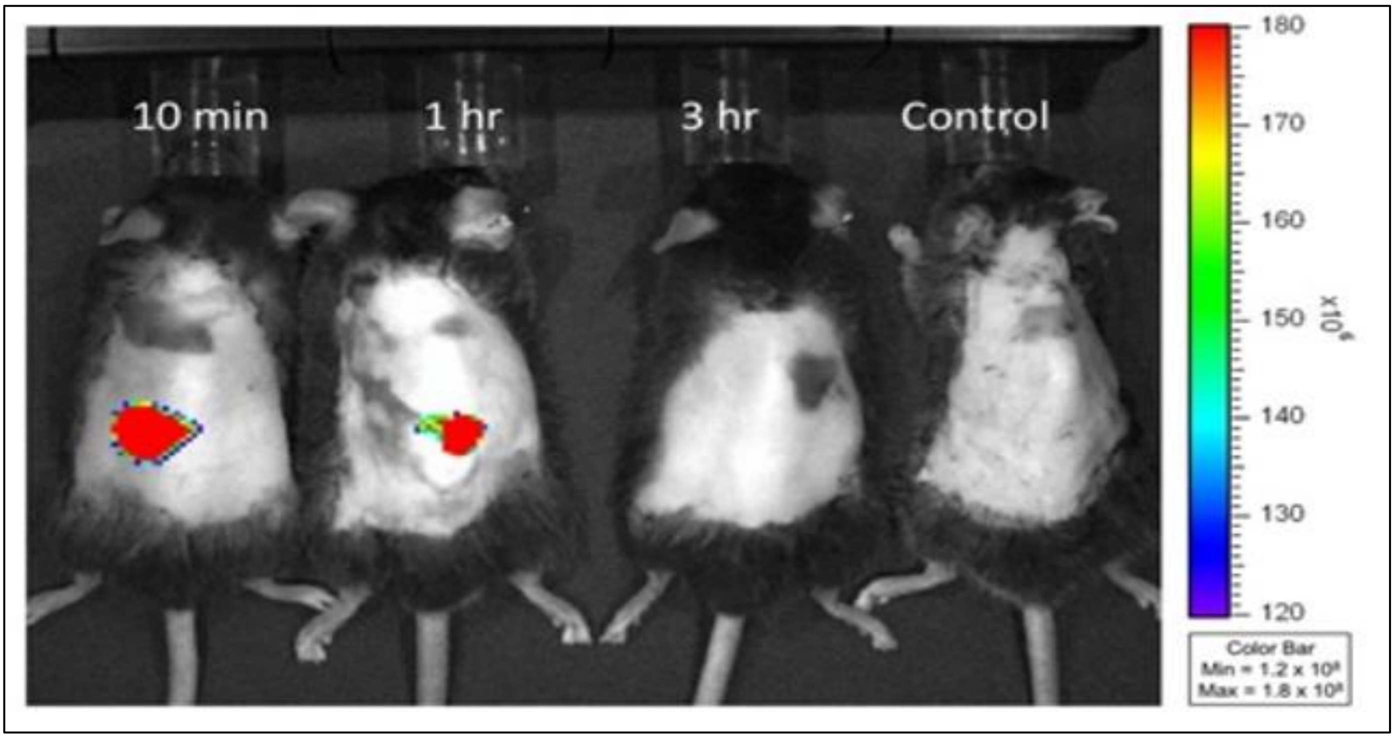

Fig 11: Shows the Process of the Loaded Microneedle Dissolving after Initial Contact for Insulin Delivery, Compared to the Control Variables of Rats with no Insulin Given. Photos are taken after 10 Minutes, 1 Hour, and 3 Hours of Contact, where there is no Longer a Microneedle and the LMN has Wholly Dissolved on the Rat's Skin. This Process Shows the Success of LMNs in Insulin Delivery. (Chen et al., 2018)

Diabetic patients will specifically need to use hollow micro-needles patches (HMNP), "used to inject liquid formulations into the skin" (Chen et al., 2018) (Kim et al., 2012). HMNPs have been used to treat diabetes and have worked efficiently, such as on diabetic rats, who responded well to the medicine administered. Loaded micro-needles (LMN) also can be used for insulin delivery and are "Drug-loaded microneedles are made of water-soluble or biodegradable materials encapsulating drug that is released in the skin upon microneedle dissolution," offering another benefit: they dissolve on the skin (Sartawi et al., 2022) (Kim et al., 2012). The LMNs act like a sticker, staying on the skin while administering the insulin; no peeling off is necessary. LMNs take three hours to dissolve completely into the skin, reducing the waste associated with regular needles from vaccines and making LMNS and MNs a proposed solution that can benefit the environment and diabetics (Zhao et al., 2021).

E. Gap in Research

In most studies on this topic, there is a notable lack of comparison between the environmental effects of utilizing HMNP's for diabetic patients and the effects of using traditional needles. This has occurred partly because definitive conclusions about the environmental effects of traditional needles have yet to be drawn. Existing discussions primarily attribute the adverse environmental effects of traditional needles to improper disposal practices, overlooking the adverse effects of proper disposal practices. This, along with the need for more research on the environmental effects of hollow microneedle patches, has made it difficult to compare the environmental effects of these methods. These gaps still need to be addressed and have yet to be specifically investigated in the context of Florida or SF. This leads to my question: To what extent does the prevalence of heavy metals created from traditional vaccines for diabetic patients harm South Florida's environment compared with microneedle patches?

F. Methods

Many sources in this research address bottom ash and test both for contaminants of HMs, such as Koros and Sabiha-Javied. This led me also to aim to test the bottom ash in SF as well; however, that process was an undertaking that I could not quite achieve because of limited access, due to the CAA, and patient and hospital confidentiality. However, during this failed process, I found that one company in SF has a conglomerate on SW incineration that does most of all sharps disposal in SF, including autoclaving and incineration. I also acquired the multiple locations of their corporation.

While not being able to test the bottom ash themselves, due to the confidentiality of customers at this company, I thought back to the research on soil and groundwater and coupled that with the locations of SW sites and decided the rout of methodology would be taking soil samples around the sites to see if the sites fly ashes were contaminating the soil, therefore also leaching into the groundwater below. These locations were in three different areas in the tri-county east SF (West Palm Beach County, Broward County, and Miami-Dade), and the three samples were from Fort Pierce, Fort Lauderdale, and Miami.

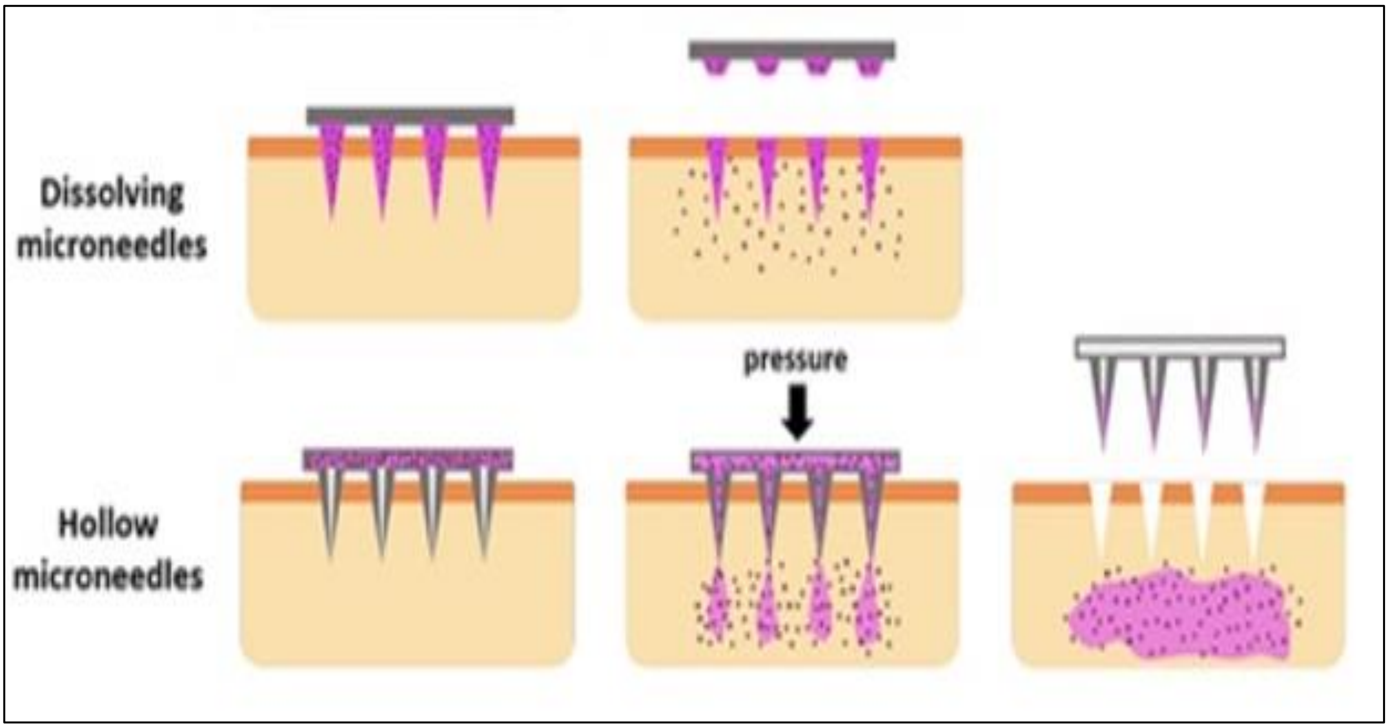

Fig 12: Demonstrates the Process Both Loaded (Dissolving) Microneedles and Hollow Microneedles Undergo to Deliver Insulin and Other Medicines. The Purple Depicts Insulin, the Microneedles are the Silver Structures, the Orange is the Tissue Barrier, and the Yellow is the Underlying Structures. They are Different Processes: LMN (Dissolving) is Left in the Skin, while HMNs Puncture the Skin, Deliver Insulin, and are Left Intact. Both Ultimately Achieve the End Goal of Insulin Delivery and Show Promising Solutions to the Problem. (Rzhevskiy et al., 2018)

A control sample of a state park with uncontaminated soil would also be taken to compare the data to and see if the observational sites had contaminants in them. The control sample was randomly selected from a pool of state parks in SF. Samples were collected with a newly purchased sterile shovel and sterile four-ounce jars.

Throughout the research, I compiled a list of HMs mentioned previously in Koros and Sabiha-Javied's works that I would test the soil samples for. This list includes if they are carcinogenic (cancer-causing) and what organ or system of the body they harm if exposure is sustained (C.L.B.G.C.R.T.O.S.E., n.d.).

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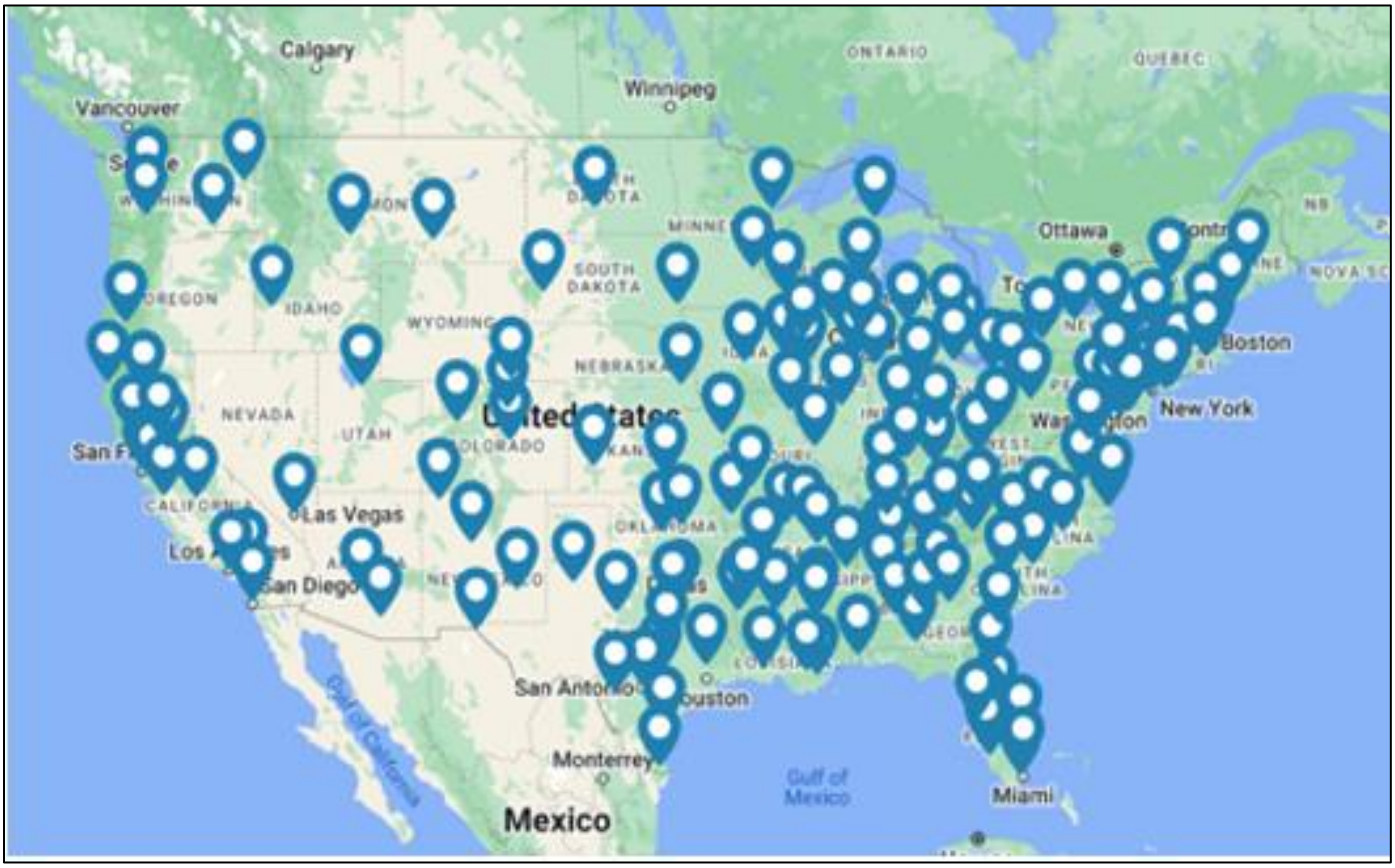

Fig 13: Locations of Sites in the United States

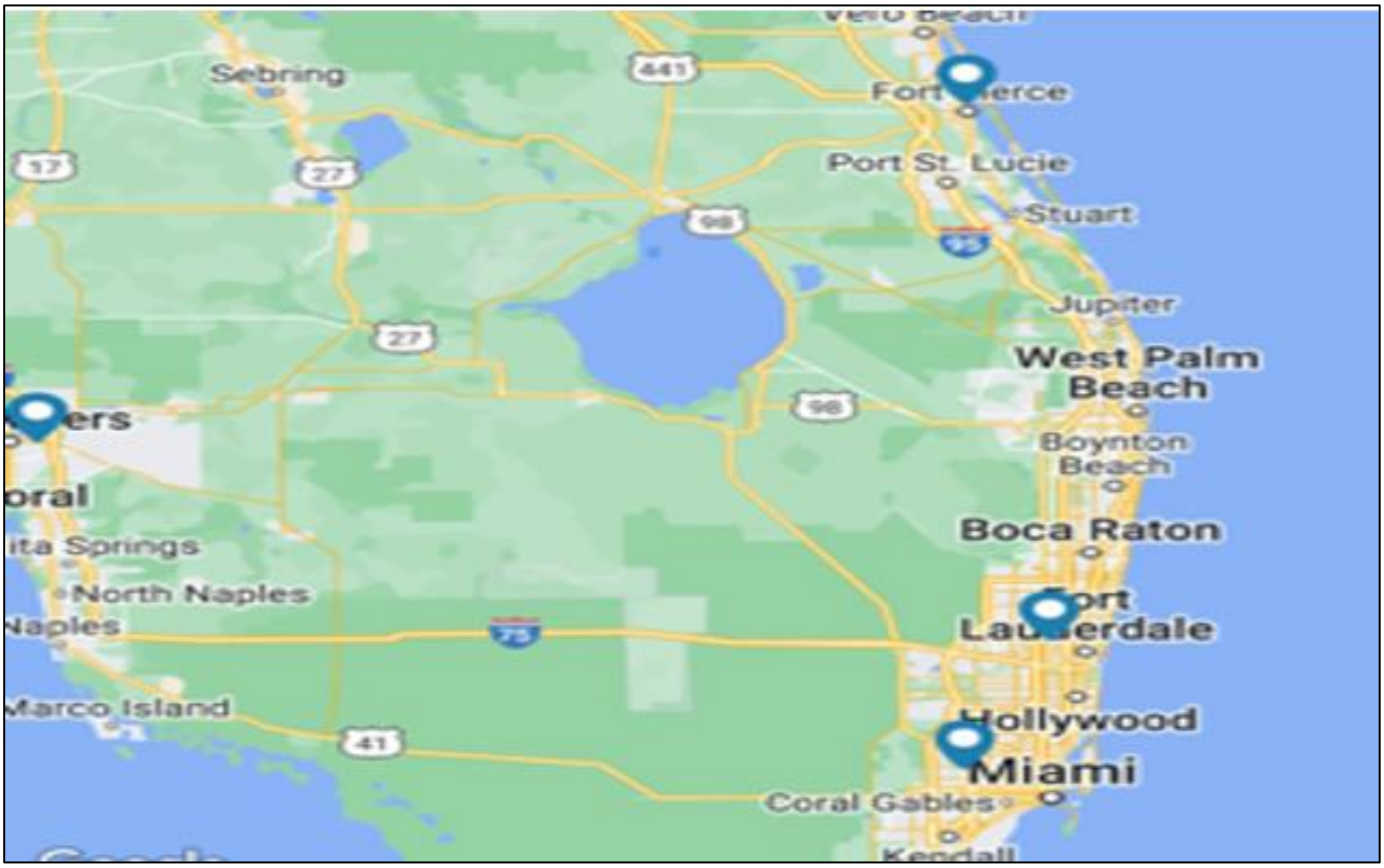

Fig 14: Locations of Sites in South Florida

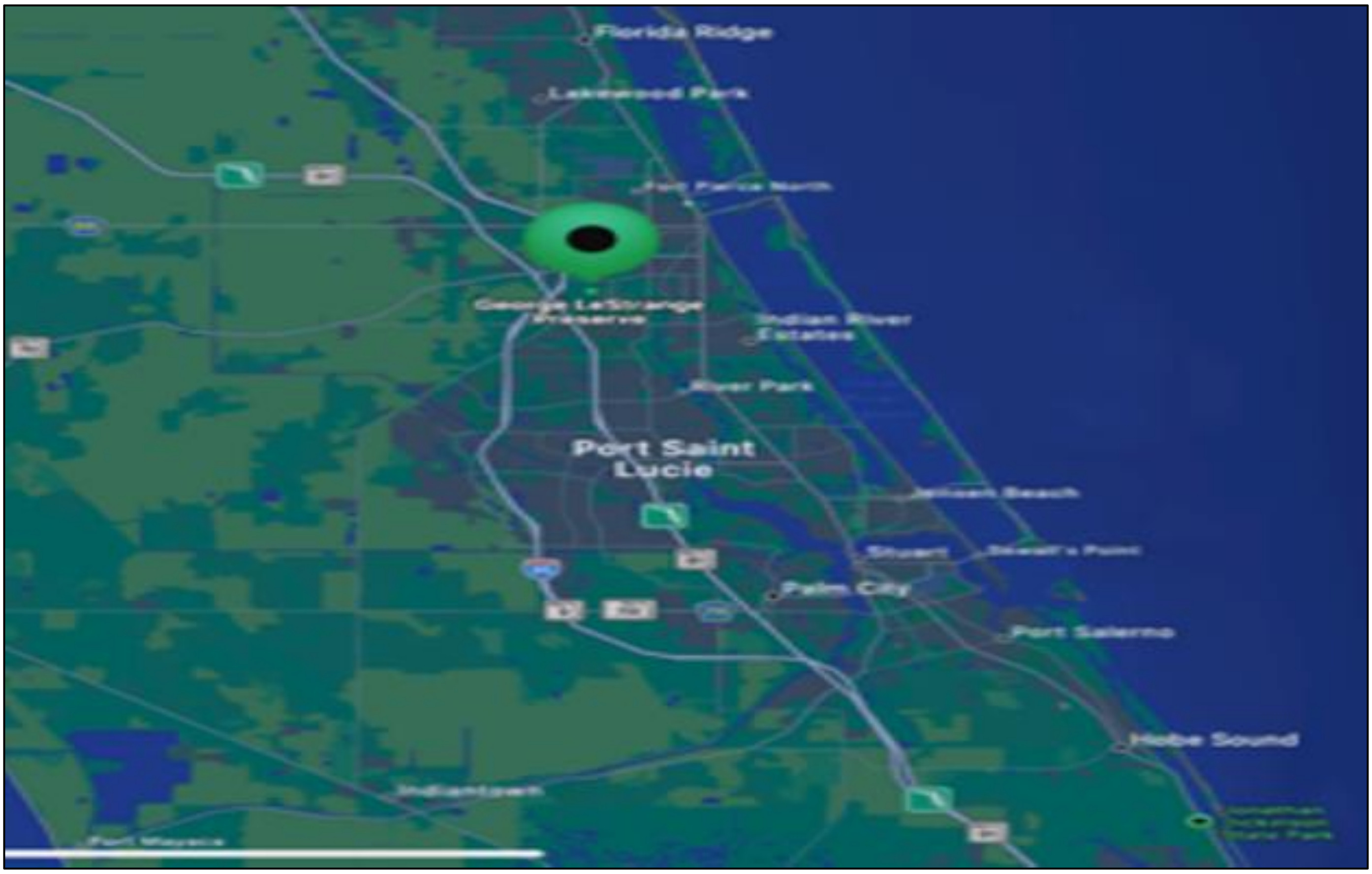

Fig 15: State Park Site (Control Variable)

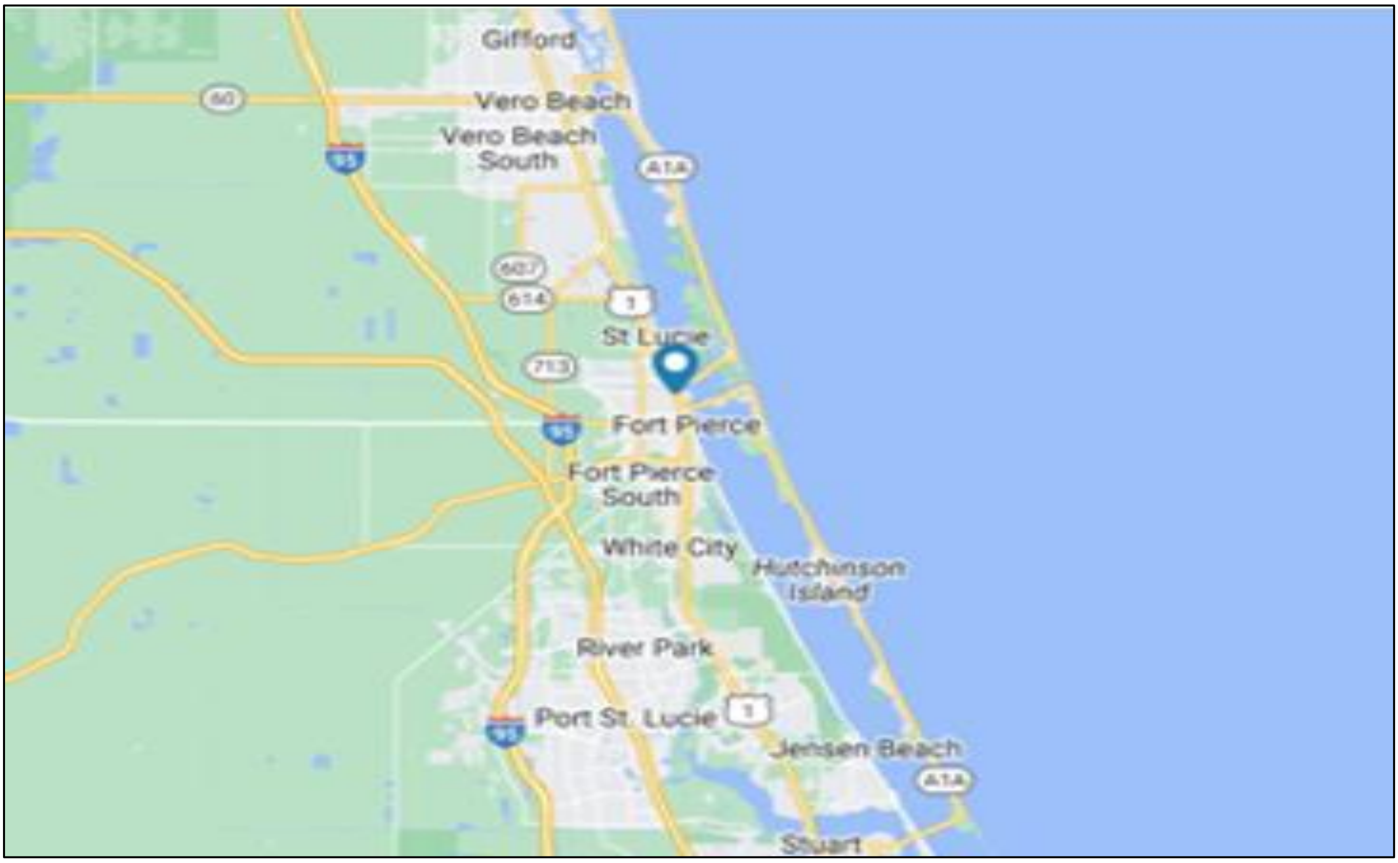

Fig 16: Fort Pierce Site (Observational Variable)

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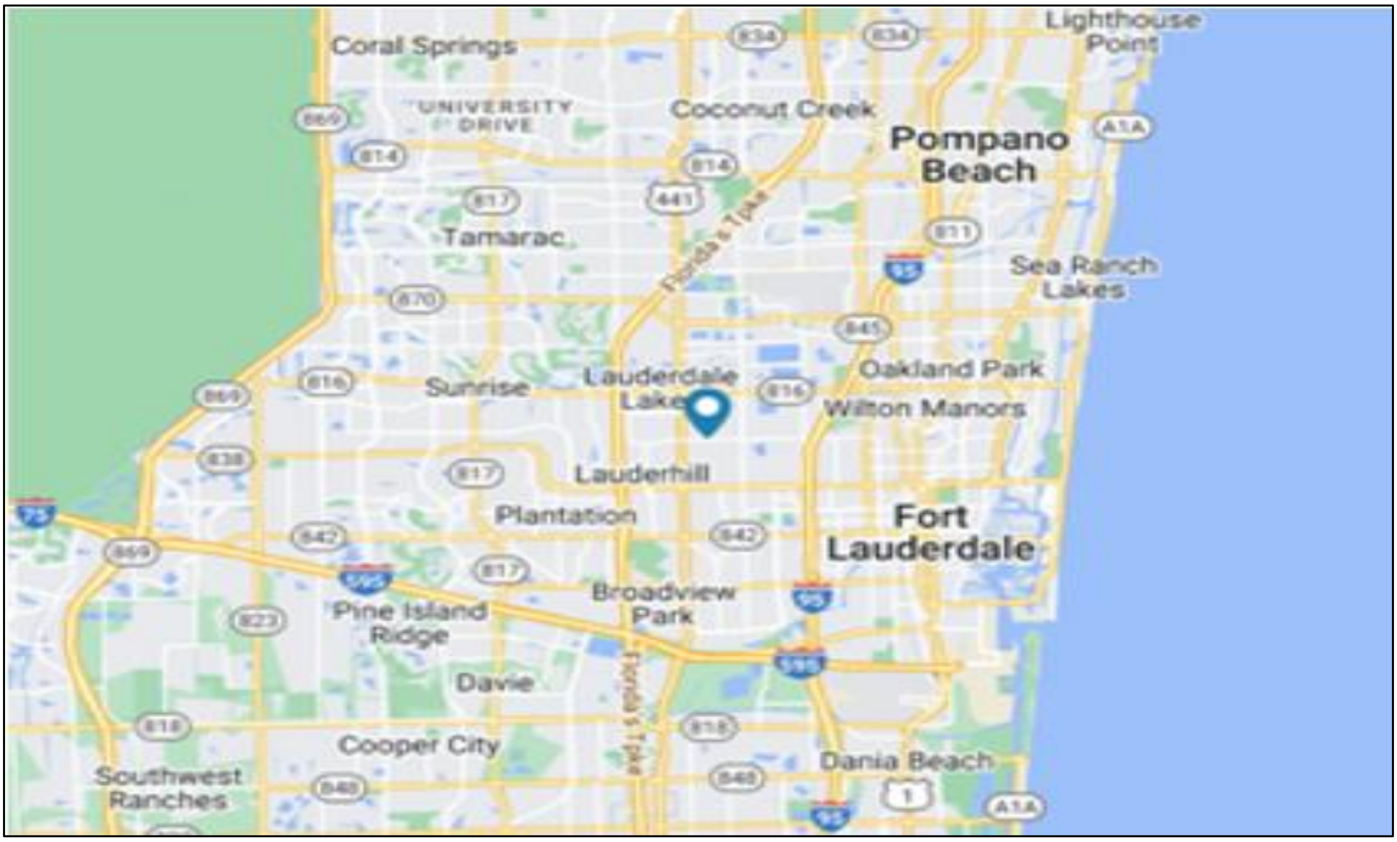

Fig 17: Fort Lauderdale Site (Observational Variable)

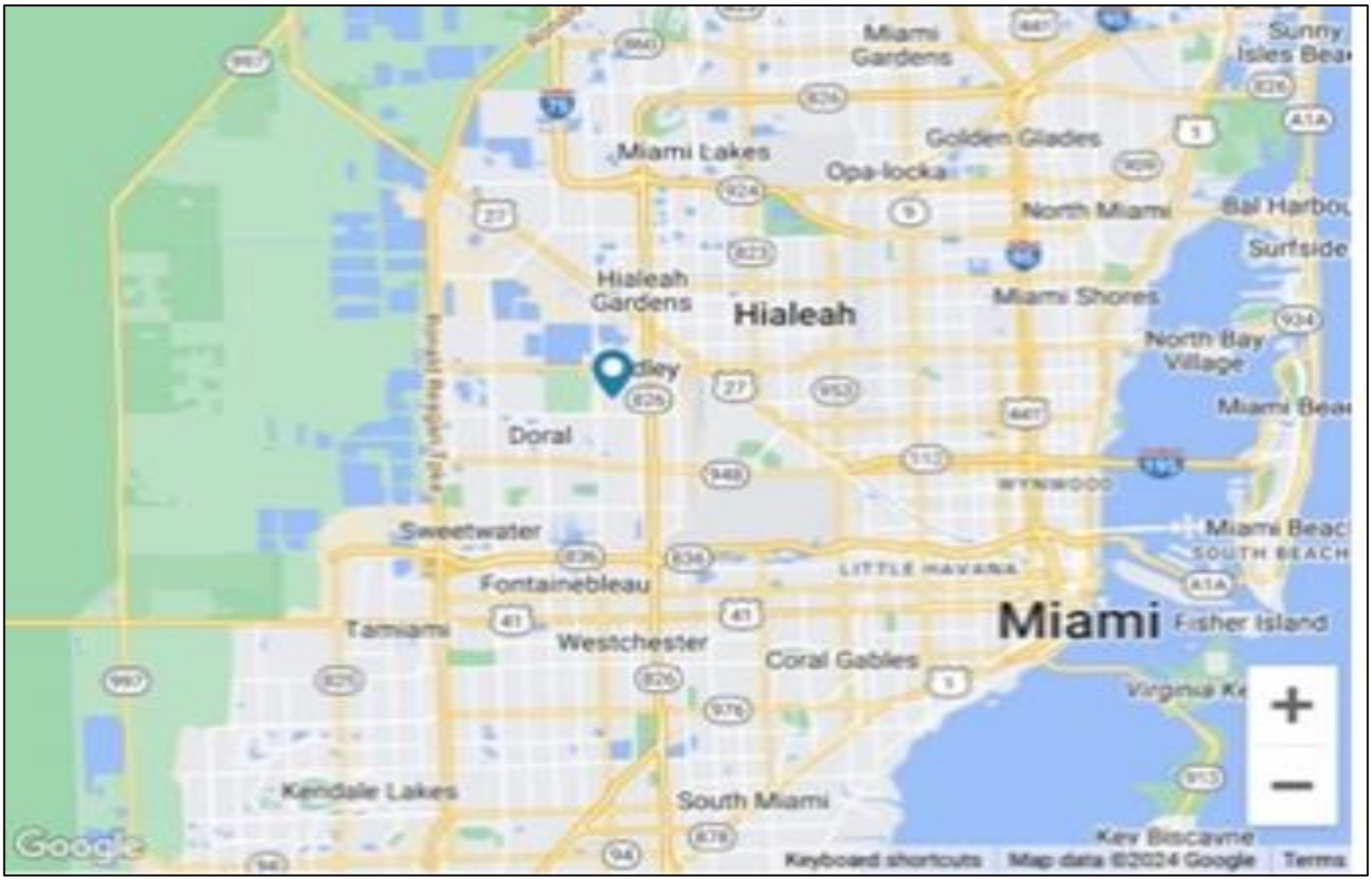

Fig 18: Miami Site (Observational Variable).

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Table 1: I Made a Table of Whether the Heavy Metals were Carcinogenic or not and What the Heavy Metal Targets in the Body if Exposure to it is Sustained

Element	Carcinogenic	Target Organ/Systems or Effects
Arsenic (mg/kg)	Yes	Cardiovascular, Skin
Cadmium (mg/kg)	Yes	Kidney
Chromium (mg/kg)	Yes	Respiratory
Copper (mg/kg)	No	Gastrointestinal
Lead (mg/kg)	No	Neurological
Mercury (mg/kg)	No	Nervous system, lungs, kidneys

III. METHOD AND PROCEDURE

I conducted an observational comparison study for my methodology. Through the observational study, I will be testing three hypotheses. The first hypothesis is that due to the prevalence of HMs Chromium, Cadmium, Arsenic, and Copper, the soil samples will exhibit higher levels of pH acidity. The second is that due to the prevalence of heavy metal Lead, the soil samples will exhibit higher alkaline pH levels. Finally, the third hypothesis is that the soil samples containing sharps and incinerator ash will demonstrate higher levels than the Soil Clean Up Target Levels (SCLT), indicating elevated concentrations of HMs.

I collected three samples from around each building or area, starting with the state park (control) and finishing with the last observational variable (Miami). For one location, initially the State Park (control), I chose three locations around the building or area. I then put each sample into its four-ounce jars (three times, three different places, in one site). When done collecting, I emptied the contents of the jars in a bowl and thoroughly mixed the three samples in one location. I emptied the sample into a new four-ounce jar, creating the 'perfect sample.' I repeated this procedure for the three observational sites: Fort Pierce, Fort Lauderdale, and Miami.

Fig 19: Photo of Collecting Samples (I am behind the Censor).

Fig 20: Photograph of the 4 Four-Ounce Soil Samples that were Sent to Eurofins Laboratory. The State Park (Control Variable), and the Observational Variables: Sites Fort Pierce, Fort Lauderdale, and Miami

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Fig 21: Photograph of the 4 Four-Ounce Soil Samples that were Sent to Eurofins Laboratory. The State Park (Control Variable), and the Observational Variables: Sites Fort Pierce, Fort Lauderdale, and Miami

Fig 22: Photograph of the 4 Four-Ounce Soil Samples that were Sent to Eurofins Laboratory. The State Park (Control Variable), and the Observational Variables: Sites Fort Pierce, Fort Lauderdale, and Miami.

Fig 23: Photograph of the 4 Four-Ounce Soil Samples that were Sent to Eurofins laboratory. The State Park (Control Variable), and the Observational Variables: Sites Fort Pierce, Fort Lauderdale, and Miami.

Fig 24: Photograph of the 4 Four-Ounce Soil Samples that were Sent to Eurofins Laboratory. The State Park (Control Variable), and the Observational Variables: Sites Fort Pierce, Fort Lauderdale, and Miami

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After all the sites had a 'perfect sample,' I sent them to Eurofins laboratory, a global scientific laboratory, to test the samples for milligrams per kilogram (mg/kg) of soil of Arsenic, Cadmium, Copper, Lead, Mercury, and Chromium. Chromium is being tested in particular because of Koros' paper, explaining Chromium being highly prevalent and having the largest concentration in bottom ash because of stainless steel needles. The laboratory also tested the pH of the samples in su (standard unit).

Eurofins laboratory tested the samples through five processes, each respectively called Inductively coupled plasma atomic emission spectroscopy, inductively coupled plasma mass spectrometry, Large Volume Injection modern gas chromatographic-mass spectrometry, High-performance liquid chromatography, and Liquid chromatography-mass spectrometry. These processes separate and quantify the various components present in the soil through precise chemical analysis, each method offering specific advantages in terms of sensitivity, selectivity, and detection capabilities to ensure comprehensive soil analysis.

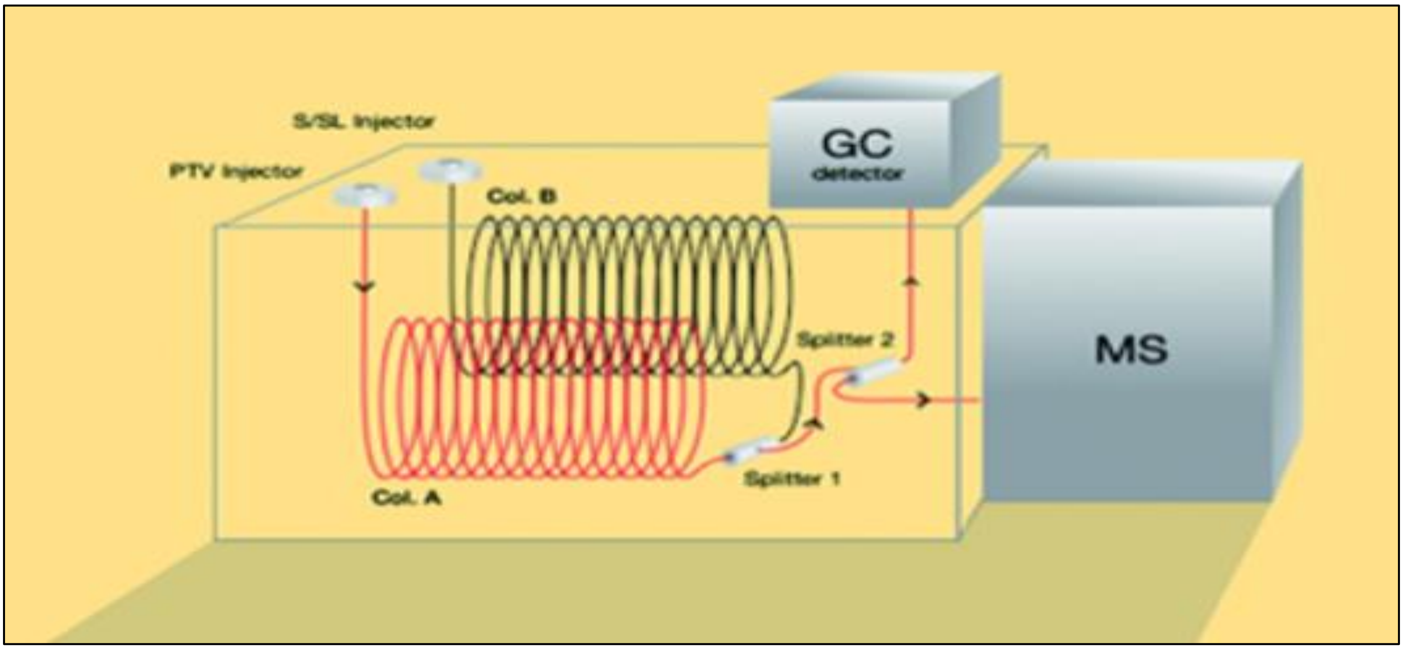

Fig 25: A Method used by Eurofins Lab to Collect the Data Needed, Large Volume Injection Gas Chromatography-Mass Spectrometry (LVI-GC-MS) Method. (ICP-MS? | Quadrupole ICP-MS Lab, n.d.).

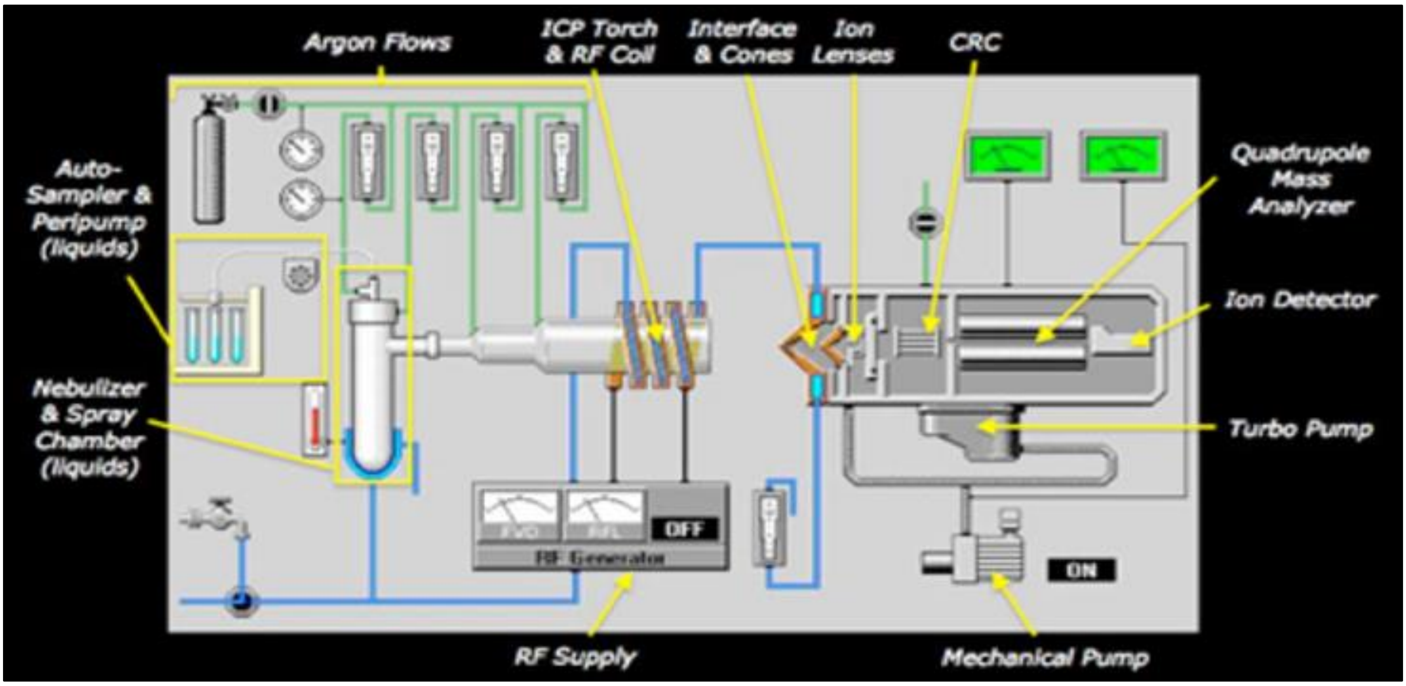

Fig 26: A Method used by Eurofins Lab to Collect the Data Needed, Inductively Coupled Plasma Mass Spectrometry (ICP-MS). (Agilent 1100 Analytical HPLC System VWD | Yalist Labs | Used Agilent 1100 HPLC, n.d.).

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Fig 27: A method used by Eurofins Lab to Collect the Data Needed, High-Performance Liquid Chromatography, and Liquid Chromatography-Mass Spectrometry. Inductively Coupled Plasma Atomic Emission Spectroscopy was also Used

RESULTS AND DISCUSSION

Table 2: Image of the Eurofins Laboratory Results When Sent to Me

Detection Summary

Job ID: 670-34856-1

Project/Site: High School AP Research Project

Client Sample ID: Fort pierce **Lab Sample ID: 670-34856-1**

Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Arsenic	3.2		1.1	0.19	mg/Kg	5	☼	6020B	Total/NA
Cadmium	1.3		1.1	0.60	mg/Kg	5	☼	6020B	Total/NA
Chromium	16		1.1	0.52	mg/Kg	5	☼	6020B	Total/NA
Copper	55		1.1	0.33	mg/Kg	5	☼	6020B	Total/NA
Lead	38		1.1	0.088	mg/Kg	5	☼	6020B	Total/NA
pH	7.1	Q	1.0	1.0	SU	1		9045D	Total/NA
Temperature	18.9	Q	0.1	0.1	Deg. C	1		9045D	Total/NA

Client Sample ID: State Park **Lab Sample ID: 670-34856-2**

Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Arsenic	1.2		1.1	0.20	mg/Kg	5	☼	6020B	Total/NA
Chromium	4.2		1.1	0.53	mg/Kg	5	☼	6020B	Total/NA
Copper	2.7		1.1	0.34	mg/Kg	5	☼	6020B	Total/NA
Lead	3.8		1.1	0.090	mg/Kg	5	☼	6020B	Total/NA
pH	7.2	Q	1.0	1.0	SU	1		9045D	Total/NA
Temperature	18.9	Q	0.1	0.1	Deg. C	1		9045D	Total/NA

Client Sample ID: Fort Lauderdale **Lab Sample ID: 670-34856-3**

Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Arsenic	4.4		1.1	0.19	mg/Kg	5	☼	6020B	Total/NA
Chromium	25		1.1	0.52	mg/Kg	5	☼	6020B	Total/NA
Copper	30		1.1	0.33	mg/Kg	5	☼	6020B	Total/NA
Lead	57		1.1	0.087	mg/Kg	5	☼	6020B	Total/NA
Mercury	0.073		0.047	0.023	mg/Kg	1	☼	7471B	Total/NA
pH	7.3	Q	1.0	1.0	SU	1		9045D	Total/NA
Temperature	18.9	Q	0.1	0.1	Deg. C	1		9045D	Total/NA

Client Sample ID: Miami **Lab Sample ID: 670-34856-4**

Analyte	Result	Qualifier	PQL	MDL	Unit	Dil Fac	D	Method	Prep Type
Arsenic	6.7		1.5	0.26	mg/Kg	5	☼	6020B	Total/NA
Cadmium	17		1.5	0.81	mg/Kg	5	☼	6020B	Total/NA
Chromium	29		1.5	0.71	mg/Kg	5	☼	6020B	Total/NA
Copper	320		1.5	0.45	mg/Kg	5	☼	6020B	Total/NA
Lead	410		1.5	0.12	mg/Kg	5	☼	6020B	Total/NA
Mercury	0.28		0.058	0.029	mg/Kg	1	☼	7471B	Total/NA
pH	7.0	Q	1.0	1.0	SU	1		9045D	Total/NA
Temperature	18.9	Q	0.1	0.1	Deg. C	1		9045D	Total/NA

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A. Samples

When the original table was sent, I analyzed each section to produce an easier way of seeing the makeup of each sample.

Fig 28: State Park (Control Variable) Data Collected in a Pie Chart

Table 3: State Park (Control Variable) Data Collected in a Table

Element (HM):	State Park (Control Variable)
Arsenic (mg/kg)	1.2
Cadmium (mg/kg)	0.61 U
Chromium (mg/kg)	4.2
Copper (mg/kg)	2.7
Lead (mg/kg)	3.8
Mercury (mg/kg)	0.022 U

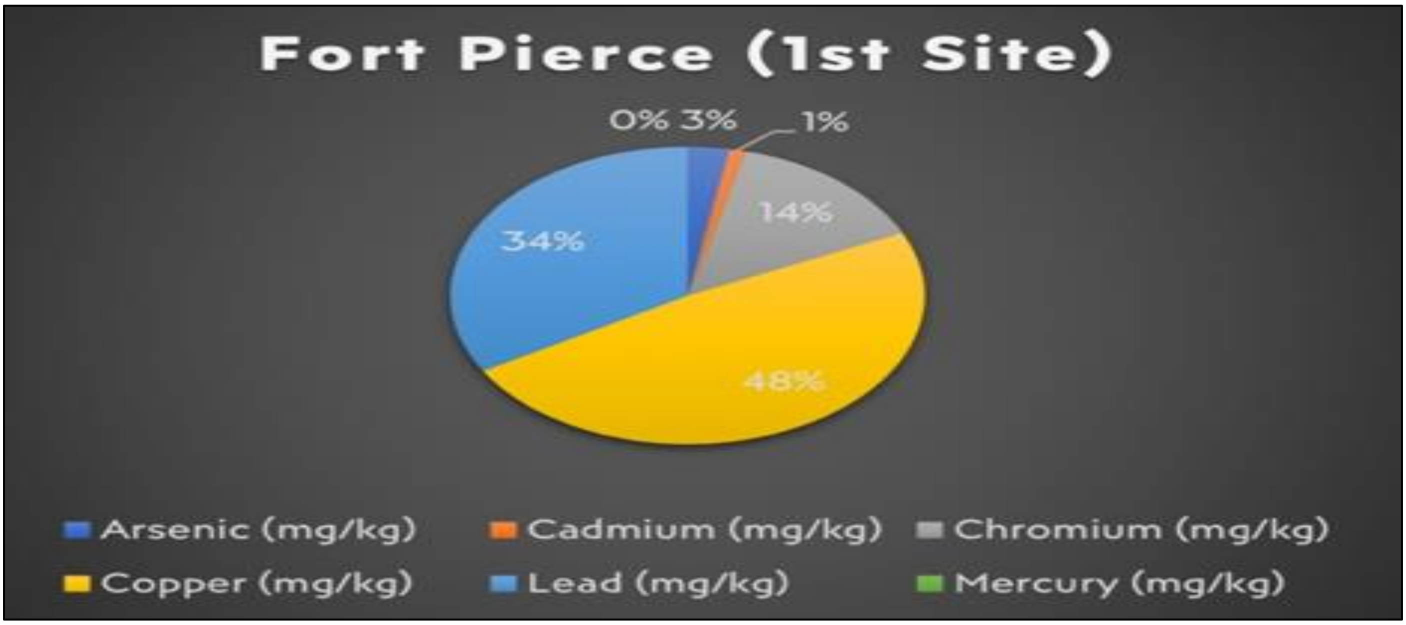

Fig 29: Fort Pierce (1st Site) data collected in a pie chart.

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Table 4: Fort Pierce (1st Site) Data Collected in a table.

Element (HM):	Fort Pierce (1st Site)
Arsenic (mg/kg)	3.2
Cadmium (mg/kg)	1.3
Chromium (mg/kg)	16
Copper (mg/kg)	55
Lead (mg/kg)	38
Mercury (mg/kg)	0.022 U

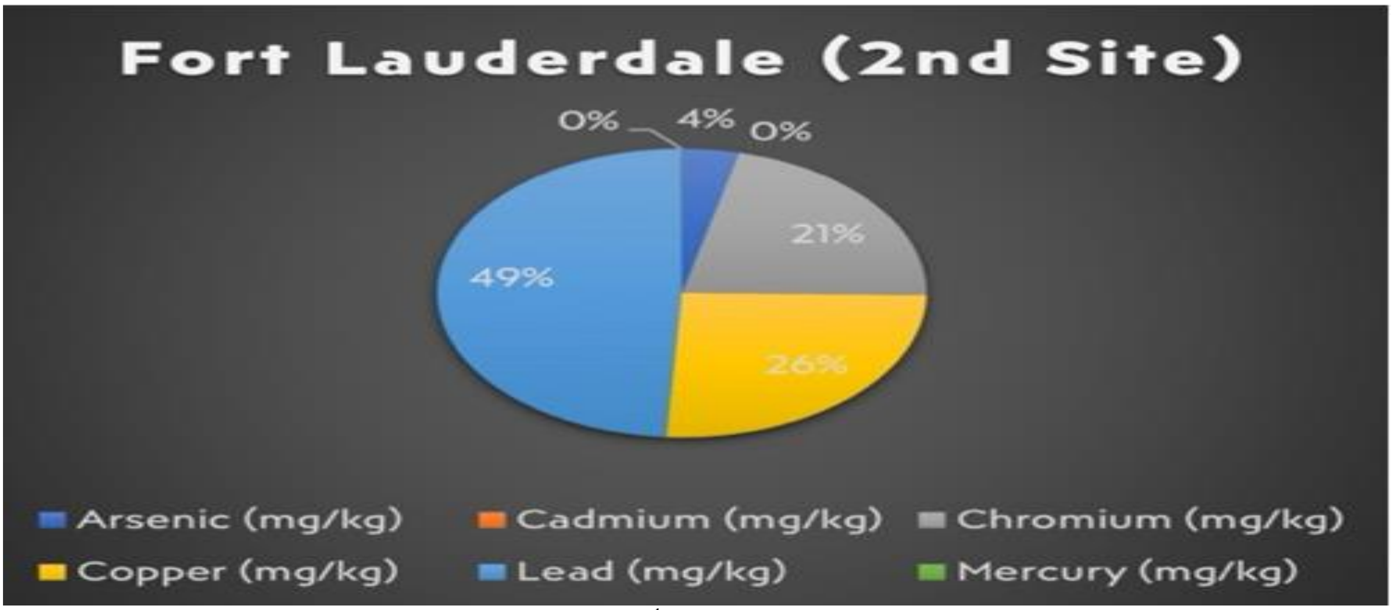

Fig 30: Fort Lauderdale (2nd Site) Data Collected in a Pie Chart

Table 5: Fort Lauderdale (2nd Site) Data Collected in a Table

Element (HM):	Fort Lauderdale (2nd Site)
Arsenic (mg/kg)	4.4
Cadmium (mg/kg)	0.59 U
Chromium (mg/kg)	25
Copper (mg/kg)	30
Lead (mg/kg)	57
Mercury (mg/kg)	0.073

Starting with the state park (control), the highest concentration found of the HMs was Chromium at 4.2mg/kg, and Lead with 3.8mg/kg of the soil sample.

The first observational site, Fort Pierce, showed a high concentration of Copper, 55mg/kg, and Lead, 38mg/kg of the sample.

Fort Lauderdale showed a high Lead concentration, 57mg/kg, compared to its second-highest concentration of 30mg/kg of Copper.

Miami, showed again a high Lead concentration at 410mg/kg and a high Copper concentration at 320mg/kg.

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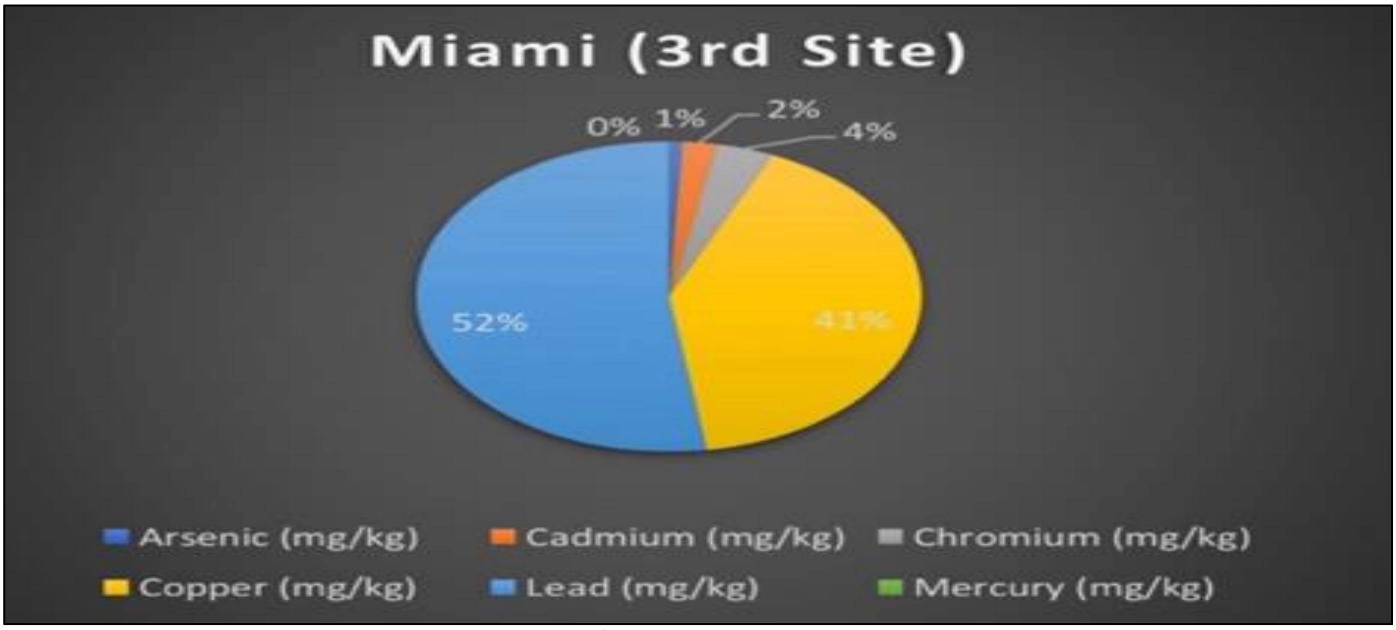

Fig 31: Miami (3rd Site) Data Collected in a Pie Chart.

Table 6: Miami (3rd Site) Data Collected in a Table

Element (HM):	Miami (3rd Site)
Arsenic (mg/kg)	6.7
Cadmium (mg/kg)	17
Chromium (mg/kg)	29
Copper (mg/kg)	320
Lead (mg/kg)	410
Mercury (mg/kg)	0.28

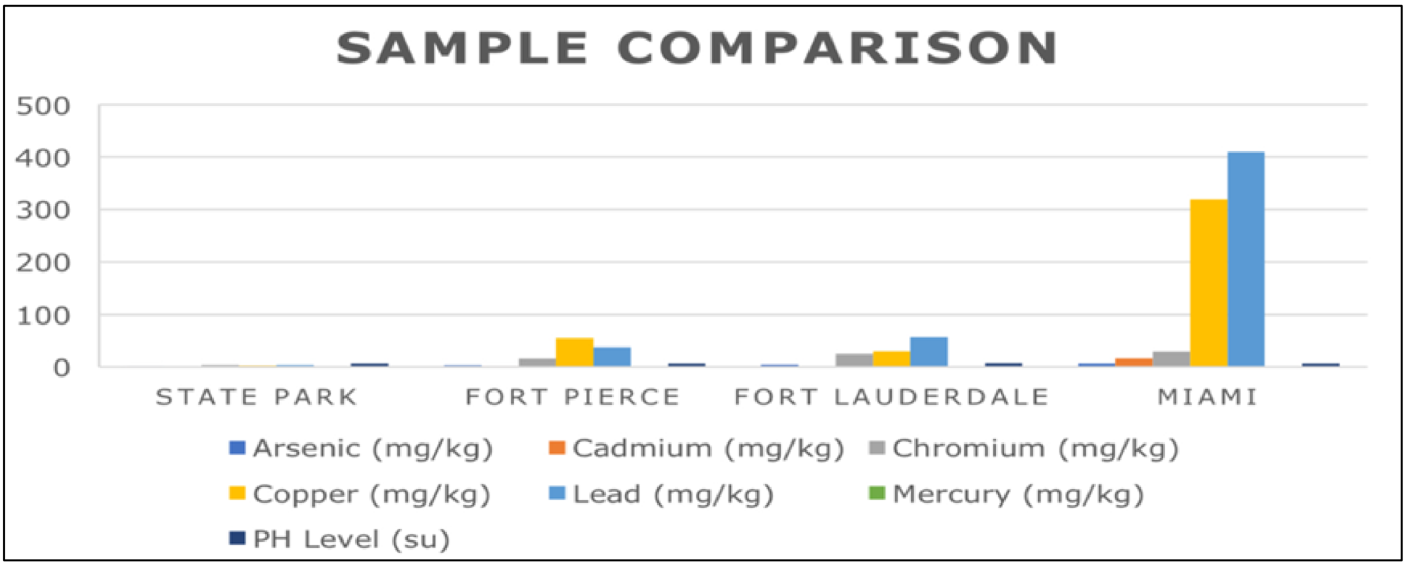

Fig 32: A Comparison of all the Samples

All the samples had similar results regarding the HMs with higher concentrations, such as those with Lead concentrations of over 31%, Copper concentrations of over 22% in all sites, and Chromium concentrations of over 13% in all sites but Miami. All samples also had low Cadmium, Mercury, and Arsenic concentrations of 0% to 4% of the samples.

The Miami site had the highest concentrations of all HMs compared to other sites, showing a clear difference in the samples, but also pointing out that other variables at the SW facilities could have altered the results, skewing the data for Miami in comparison with other observational sites.

The state park had the lowest concentrations of all HMs in the soil, which shows a stark difference in comparison with the observational sites. This shows that there are, in fact, more HMs in the soil at the SW facilities.

B. PH

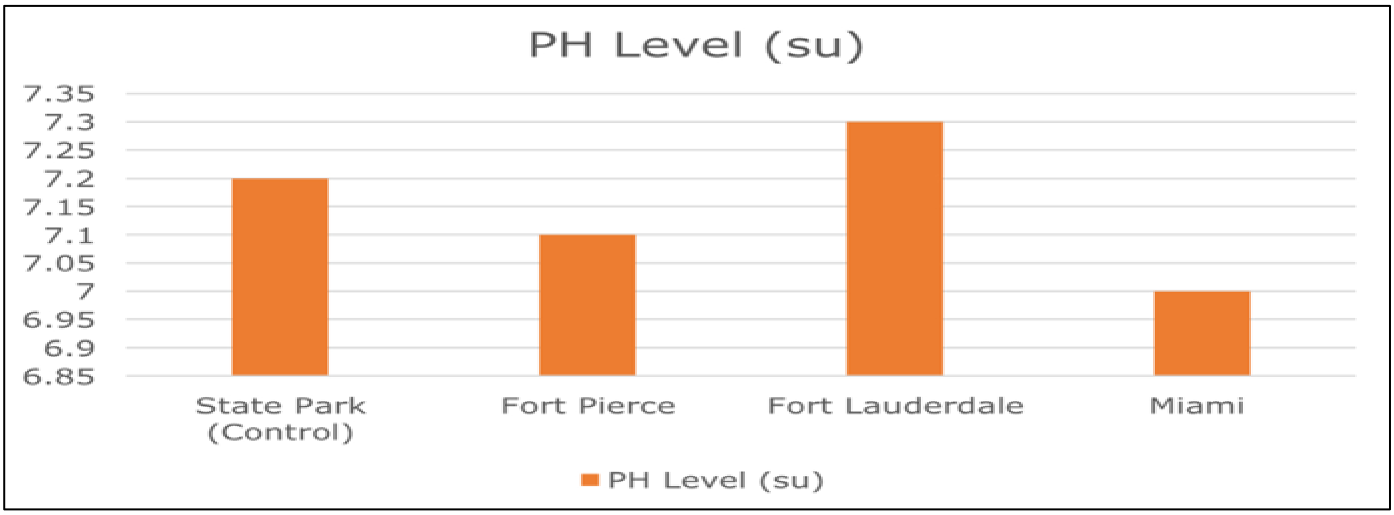

Fig 33: A Chart Showing How the pH Levels Compared in Each Sample

Next, as seen in Figure 33, all samples are around the same pH level (7), which is considered neutral and normal for the standards of regular soil pH. The differences may be minor but can be enumerated, nonetheless.

The Fort Lauderdale sample had the highest alkaline pH, 7.3su, while the Miami sample had the most acidic pH, 7su. The state park (control) had more Chromium (35%) and Lead (32%) than other HMs. Because it has the most Chromium, it should be more acidic, but it is instead more alkaline, with a pH of 7.2su. It is also more alkaline than the Fort Pierce and Miami samples.

For the observational sites, Fort Pierce had more Copper (48%) and Lead (34%) than other HMs, and because it has the most Copper, it should be more acidic. The results show that it is more acidic than the state park, with a pH of 7.1su due to the higher prevalence of the more acidic heavy metal, Copper.

Fort Lauderdale had more Lead (49%) and Copper (26%) than other HMs, and because it has the most Lead, it should be more alkaline. The results show that it is more alkaline than the state park, with a pH of 7.3su due to the higher prevalence of the more alkaline HM Lead.

Miami had more Lead (52%) and Copper (41%) than other HMs. Because it has the most Lead, it should be more alkaline, but instead is more acidic, with a pH of 7su.

The first hypothesis that the samples would exhibit higher pH acidity due to HMs Chromium, Cadmium, Arsenic, and Copper was incorrect. The state park showed a more alkaline sample when it should have exhibited more acidic results because of the higher prevalence of Chromium. However, Fort Pierce's results also proved the first hypothesis, which showed that the higher concentration of Copper made the sample more acidic, potentially facilitating their dissolution and release into the environment, potentially affecting the surrounding animal and plant life.

The second hypothesis, that due to the prevalence of heavy metal Lead, the soil samples will exhibit higher pH alkaline, was also incorrect. The Miami sample showed a more acidic sample when it should've exhibited a more alkaline sample because of the higher prevalence of Lead. However, Fort Lauderdale's results of the higher concentration of Lead also proved the second hypothesis correct, making the sample more alkaline, again, promoting dissolution that can seep into groundwater and pollute.

C. SCLTs

My data was compared to the Florida Department of Environmental Protection's Soil Clean-Up Target Levels. These levels serve as crucial indicators of public safety. If the heavy metal composition in the sample tested exceeds the recommended target level for human exposure, it is deemed too dangerous for sustained exposure. For instance, Arsenic's target level for Direct Exposure Commercial / Industrial (DECI) is 12mg/kg. The sample for Fort Pierce contained 3.2mg/kg of Arsenic, making the Arsenic level in the sample safe for prolonged human exposure.

First, I compared her samples to the DECI because all samples were obtained from commercial sharps incineration sites. When the samples were compared to the DECI levels, no heavy metal (mg/kg) surpassed the DECI levels.

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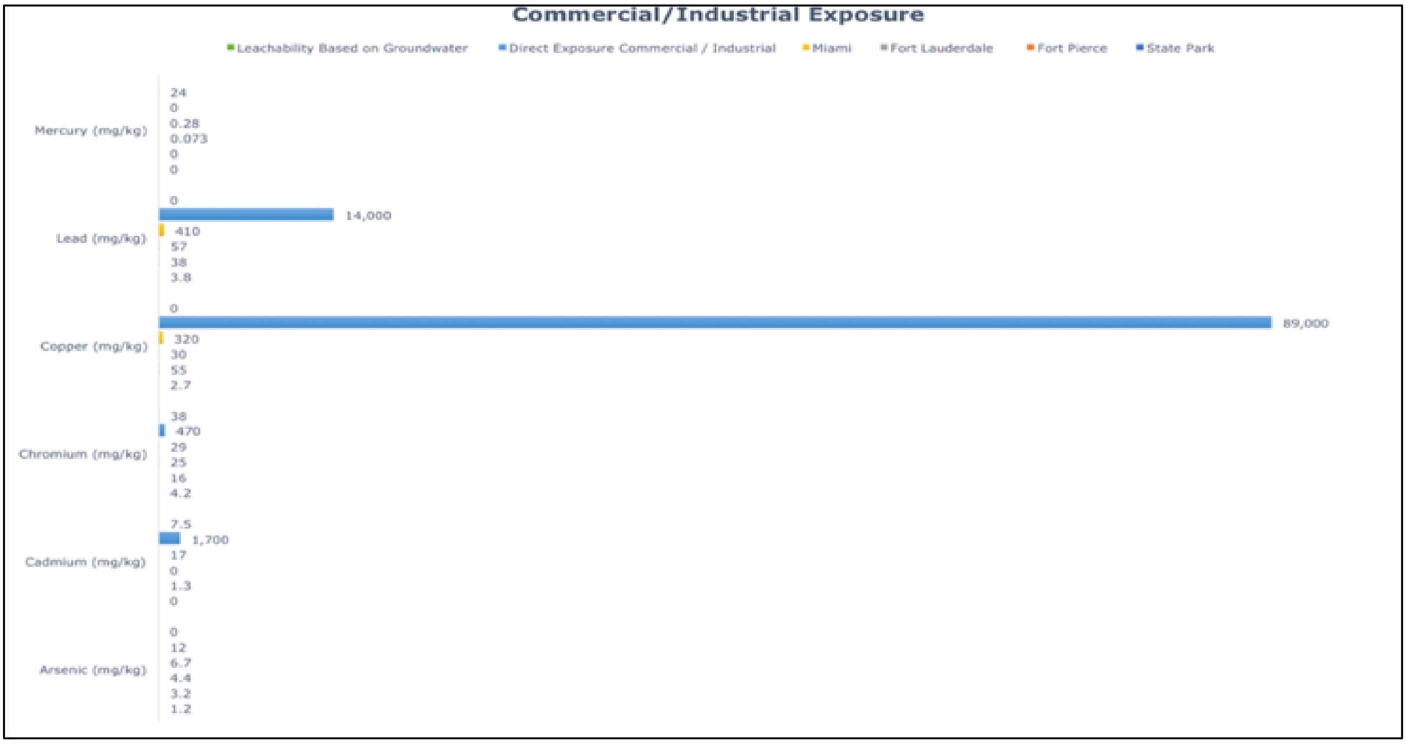

Fig 34: A Bar Graph of the DECI Levels Compared to the Samples Levels

Next, I compared the samples to the Leachability Based on Groundwater (LBG) levels because if the HMs in the soil samples exceeded the levels, that would mean that the fly ash from the incineration sites could be contaminating the soil around the site and, therefore, leaching into the groundwater underneath the soil.

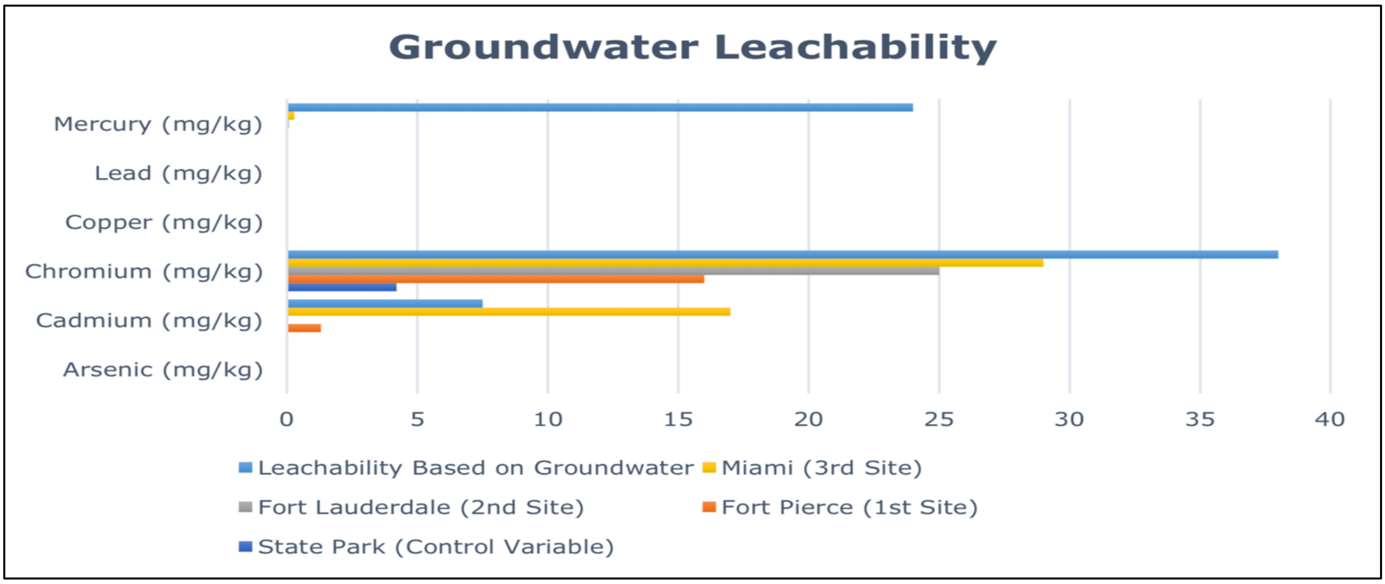

Fig 35: A Bar Graph of the LBG Levels Compared to the Samples Levels

The results, as depicted in Figure 34, reveal a deeply concerning situation. In the Miami site, the 17mg/kg Cadmium level exceeded the 7.5mg/kg target limit. This indicates that the Cadmium in the soil from Miami has been seeping into the groundwater near the site, potentially contaminating the drinking water. As shown previously in Table 1, this could lead to kidney diseases among the residents, underlining the severity of the situation and the immediate threat to public health.

Because fly ash from sharps incinerators disperses particles into the air, and because all the commercial sites from which I collected the samples were directly next to residential areas and neighborhoods, I also decided it would be necessary to compare the soil samples to the Residential Exposure (RE) levels.

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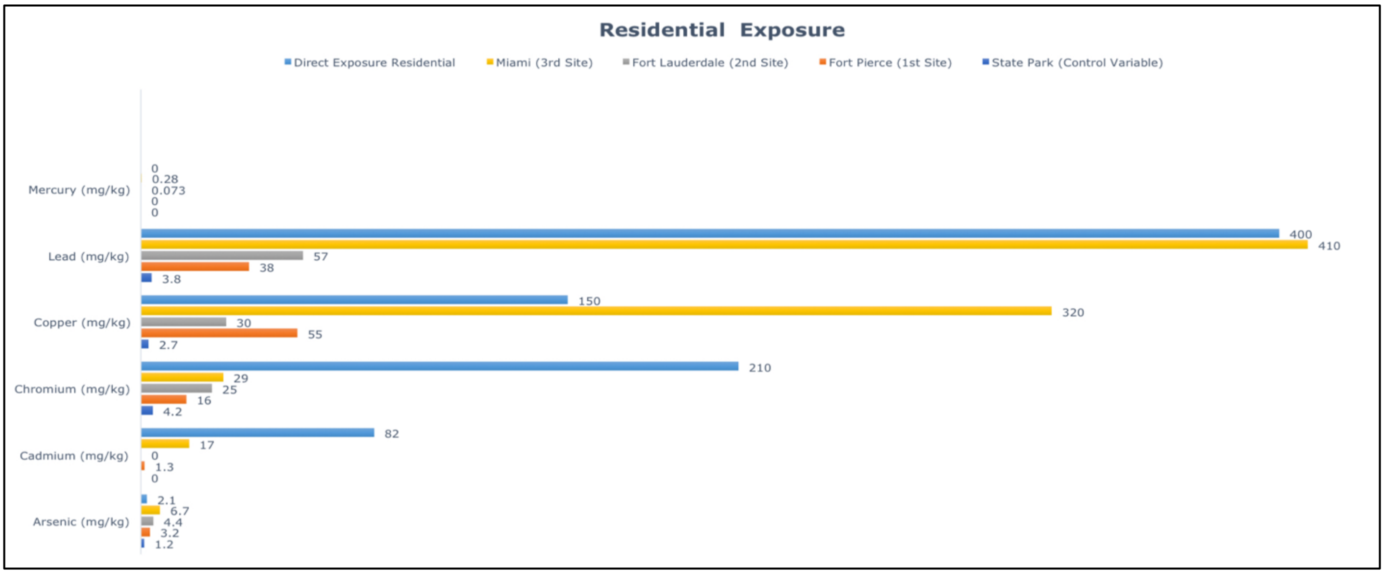

Fig 36: A Bar Graph of the RE Levels Compared to the Samples Levels

After comparison, I found that the Arsenic levels for all observational sites were higher than the recommended amount of Arsenic in the soil for residential prolonged exposure: Miami Arsenic, 6.7mg/kg, almost tripling the recommended amount, 2.1mg/kg.

I also found that the Miami site had higher levels than the recommended RE amount for both HMs, Copper and Lead, at 320mg/kg and 410mg/kg, respectively. The recommended amounts are 150mg/kg and 400mg/kg.

These alarming findings highlight the pressing need for immediate action. The individuals living in close proximity to the sharps incineration sites and the workers are being exposed to hazardous levels of Arsenic, Copper, and Lead. As previously indicated in Table 1, and as Koros mentioned, this exposure could lead to a variety of serious health conditions, including cardiovascular, skin, gastrointestinal, and neurological diseases, posing a significant threat to public health and safety.

Table 7: Severity of Results

Measuring	State Park (Control Variable)	Fort Pierce (Site 1)	Fort Lauderdale (Site 2)	Miami (Site 3)
Soil pH Safety (6.0-7.5)	Safe	Safe	Safe	Safe
Direct Exposure Safety Commercial / Industrial	Safe	Safe	Safe	Safe
Leachability Safety	Safe	Safe	Safe	Unsafe for Cadmium
Direct Exposure Safety Residential	Safe	Unsafe for Arsenic	Unsafe for Arsenic	Unsafe for Arsenic, Copper, Lead

After the comparisons were made, I compiled all the data to easily see the severity of my results, indicated in Table 7. I concluded that the Fort Piece site RE was unsafe for Arsenic, the Fort Lauderdale site RE was unsafe for Arsenic, and the Miami site was unsafe for LBG for Cadmium and RE for Arsenic, Copper, and Lead.

D. Statistics

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

Equation 1: (How to Calculate Statistical Significance, n.d.)

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I wanted to know if my data was reliable for these conclusions, so I took the statistical significance (SS) of each variable compared to the state parks information, using the equation in Equation 1. SS indicates whether a study's observed effect or result is likely genuine rather than occurring by chance. The p-value is a measure of evidence against a null hypothesis in SS, and a lower p-value suggests more substantial evidence against the null hypothesis, implying the observed effect is unlikely due to random chance. I created Tables 8, 9, and 10 to see if my data was SS, including their p-values for reference.

Table 8: Statistical Significance and P-Values of Direct Exposure for Commercial/Industrial sites

Statistical Significance:

Element	State Park	Fort Pierce	Fort Lauderdale	Miami	Leachability Based on Groundwater
Cadmium (mg/kg)	0.61 U	No	No	No	7.5
Chromium (mg/kg)	4.2	Yes	Yes	Yes	38
Mercury (mg/kg)	0.022 U	No	No	No	24

P- Value's:

Element	Fort Pierce	Fort Lauderdale	Miami
Cadmium (mg/kg)	0.5	0.5	NaN
Chromium (mg/kg)	0.004	0	0
Mercury (mg/kg)	NaN	NaN	0.1535

Table 9: Statistical Significance and P-Values of Leachability Based on Groundwater

Statistical Significance:

Column1	State Park	Fort Pierce	Fort Lauderdale	Miami	Direct Exposure Commercial / Industrial
Arsenic (mg/kg)	1.2	Yes	Yes	Yes	12
Cadmium (mg/kg)	0.61 U	No	No	Yes	1,700
Chromium (mg/kg)	4.2	Yes	Yes	Yes	470
Copper (mg/kg)	2.7	Yes	Yes	Yes	89,000
Lead (mg/kg)	3.8	Yes	Yes	Yes	14,000

P- Value's:

Element	Fort Pierce	Fort Lauderdale	Miami
Arsenic (mg/kg)	0.135	0.0565	0.0011
Cadmium (mg/kg)	0.5	0.5	0.0001
Chromium (mg/kg)	0.0032	0	0
Copper (mg/kg)	0	0	0
Lead (mg/kg)	0	0	0

Table 10: Statistical Significance and P-Values of Direct Exposure sites

Statistical Significance:

Element	State Park	Fort Pierce	Fort Lauderdale	Miami	Direct Exposure Residential
Arsenic (mg/kg)	1.2	No	No	No	2.1
Cadmium (mg/kg)	0.61 U	No	No	Yes	82
Chromium (mg/kg)	4.2	Yes	Yes	Yes	210
Copper (mg/kg)	2.7	Yes	Yes	No	150
Lead (mg/kg)	3.8	Yes	Yes	No	400

P- Value's:

Element	Fort Pierce	Fort Lauderdale	Miami
Arsenic (mg/kg)	NaN	NaN	NaN
Cadmium (mg/kg)	0.5	0.8428	0.0028
Chromium (mg/kg)	0	0	0
Copper (mg/kg)	0	0	NaN
Lead (mg/kg)	0	0	NaN

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The results are as follows: Only Chromium has SS for LBG, and only Cadmium's data isn't SS for Fort Pierce and Fort Lauderdale. Cadmium for Miami, all Chromium data, and Copper and Lead for Fort Pierce and Fort Lauderdale are significant. Arsenic only has SS for DECI, while Mercury is not SS in any data points.

While the number of variables showing SS is limited, this does not diminish the importance of my findings. As detailed in Table 7, my research indicates potential harm at all three observational sites. This underscores the risks faced by people working in or living near near incineration sites, making the findings crucial for environmental researchers, public health professionals, and policymakers.

Because Chromium's data is SS, Chromium emerged as a significant element, consistently associated with respiratory issues, highlighting potential health risks linked to SW incineration. Because I found these results, I wanted to test Chromium's SS further to determine if my initial SS was correct and could be applied to the larger population. This was done using Equation 2.

E. Equation 2

As shown above, I conducted a significance test for a difference between mean Chromium levels (mg/kg) at a protected land area and the land at SW facilities. Using a sample of size 3 (although, as acknowledged below in "Limitations," this violates the required condition of a minimum sample of size 30), the probability of obtaining a test statistic at least as extreme as 4.977, if, in fact, the null hypothesis is true, is 0.019. Because this p-value is less than alpha = 0.05, this serves as sufficient evidence for me to reject the null and conclude that there is a significant difference between the mean Chromium levels (mg/kg) at the three facilities (incineration sites) and the control location (state park).

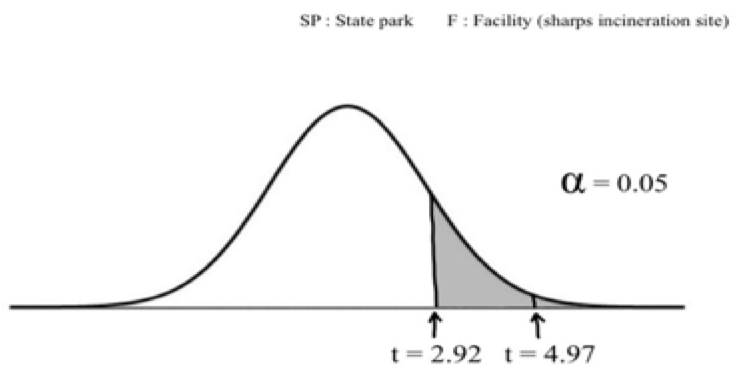
$H_o : \mu_F - \mu_{SP} = 0$

$H_a : \mu_F - \mu_{SP} > 0$

$\bar{x} = 23.3333$

$S = 6.658$

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}} = \frac{23.333 - 4.2}{\frac{6.658}{\sqrt{3}}} = 4.977$$



$\text{P-value} = 0.019 < \alpha = 0.05$

We can reject null hypothesis and determine a statistically significant change.

Conditions:

- Randomly selected locations in and around sites for samples
- There are more than 30 incineration sites
- There is a sample size of 30

F. Limitations

Multiple limitations surfaced throughout this research process. I initially encountered my first limitation due to the hazards of physically handling bottom ash from sharps incinerators. Therefore, I pivoted to focus on obtaining fly ash from sharps incinerators that had collected in the soil around the incinerator sites. This allowed me to safely collect on-site samples.

I coordinated with a scientific testing laboratory and was graciously offered the use of their analysis services for up to four samples. However, this meant limited samples of limited size, minimized locations of samples, and limited testing for HMs and contaminants. I could only acquire a soil sample size of four ounces for each sample, and only four samples could be analyzed in the laboratory. This means I was limited to choosing only three SW sites and one uncontaminated site (state park).

If I could do further and future research, it would benefit from a more extensive and diverse sample pool with different locations, meaning that I could select multiple locations of SW facilities and control variables to have more accurate data to test my hypotheses.

Additionally, I would also consider collecting different samples from the same location over multiple days or weeks to see if all days yielded the same result and would take the mean of all the data points to see the validity of their obtained data.

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The research would also benefit from the testing of multiple different HMs, harmful elements, and soil contaminates that were detailed in the Florida Department of Environmental Protection's Soil Clean Up Target Levels list, such as Nickel, Aluminum, and Thallium, and Beryllium. This would show if more harm were being done to the ecosystem and public health.

I also acknowledge that there was a limitation presented in the choice of the company that disposes of SW. If I continued this research, I would seek out other SW companies in SF, or even statewide, and eventually reach the national level to see significant effects in broader areas of the United States.

The most significant limitation that I faced was the small sample size. Because tests of SS rely on sample data to infer about populations, it is important to meet appropriate sample size requirements, 30 samples (not met). Small sample sizes may result in inflated standard deviations, compared with larger sample sizes that are more likely to yield accurate results and a definitive conclusion.

IV. CONCLUSION

As previously detailed, the first and second hypotheses were proven both incorrect and correct. Third hypothesis was proven correct such that, as shown in Table 7, the observational soil samples did surpass SCLT levels, indicating elevated concentrations of HMs, highlighting the environmental effects and harmful effects on humans that are being caused by the traditional methods of disposal from SW through incineration that creates fly and bottom ash that spread harmful HMs into the air and groundwater surrounding facilities.

The research finds that the HMs in traditional vaccines for T1D patients shows a noticeable, but not extensive impact on SF's environment. However, because there is potential for groundwater leachability and contamination, there is a possibility for pollution of SF's drinking water and air that cause severe respiratory infections and illnesses like "Asthma, chronic obstructive pulmonary disease, pulmonary fibrosis, pneumonia, and lung cancer," this research highlights the need for safer, more effective, and sustainable alternatives (cancer.gov, 2011).

In conclusion, both correct and incorrect disposal of diabetic SW negatively impacts the environment. The current disposal methods, autoclaves, and incinerators are no longer sustainable solutions in the era of advanced technology, where the world could be utilizing better and more environmentally sustainable methods instead. With minimal waste production, MNs offer a promising solution for T1Ds; transitioning from traditional needles to MNs will reduce medical industry waste significantly and positively benefit the environment and public health without contaminating HMs in the air and groundwater. Addressing environmental concerns and improving healthcare, MNs represent a crucial step towards a sustainable future. The research underscores the importance of exploring and adopting innovative solutions like MNs to address healthcare and environmental challenges.

REFERENCES

[1]. %22Type 1 Diabetes%22 Images – Browse 2,114 Stock Photos, Vectors, and Video. (n.d.). Adobe Stock. https://stock.adobe.com/search?k=%22type+1+diabetes%22
[2]. Agilent 1100 Analytical HPLC System VWD | Yalist Labs | Used Agilent 1100 HPLC. (n.d.). Yalist Labs. Retrieved April 12, 2024, from https://www.yalistlabs.com/product-page/agilent-1100-analytical-hplc-system-vwd
[3]. Ali, H., Khan, E., & Ilahi, I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. Journal of Chemistry, 2019, 1–14. https://doi.org/10.1155/2019/6730305
[4]. Basazn Mekuria, A., Melaku Gebresillassie, B., Asfaw Erku, D., Taye Haile, K., & Melese Birru, E. (2016). Knowledge and Self-Reported Practice of Insulin Injection Device Disposal among Diabetes Patients in Gondar Town, Ethiopia: A Cross-Sectional Study. Journal of Diabetes Research, 2016, 1–7. https://doi.org/10.1155/2016/1897517
[5]. BD Ultra Fine 0.3 ml 31 G x 15/64 in. (6 mm) Insulin Syringe with Needle. (n.d.). Delasco. Retrieved December 8, 2023, from https://www.delasco.com/bd-0-3-ml-insulin-syringe-with-needle-31-g-x-15-64-in-ultra-thin-wall/
[6]. Benard Koros, K. (2009, August 28). ASSESSMENT OF HEAVY METALS CONCENTRATION IN ASH FROM INCINERATORS AND ITS ENVIRONMENTAL IMPLICATION IN NAIROBI, KENYA (Dr. J. M. Mbaria & Dr. L. Kanja, Eds.) [Review of ASSESSMENT OF HEAVY METALS CONCENTRATION IN ASH FROM INCINERATORS AND ITS ENVIRONMENTAL IMPLICATION IN NAIROBI, KENYA]. International Atomic Energy Agency; University of Nairobi. https://inis.iaea.org/collection/NCLCollectionStore/_Public/54/010/54010148.pdf
[7]. Centers for Disease Control and Prevention. (2022, July 7). What is Diabetes? Centers for Disease Control and Prevention. https://www.cdc.gov/diabetes/basics/diabetes.html#:~:text=With%20diabetes%2C%20your%20body%20doesn
[8]. Chen, C.-H., Shyu, V., & Chen, C.-T. (2018). Dissolving Microneedle Patches for Transdermal Insulin Delivery in Diabetic Mice: Potential for Clinical Applications. Materials, 11(9), 1625. https://doi.org/10.3390/ma11091625
[9]. Contaminants Leachability Based on Groundwater Criteria Residential Target Organs/Systems or Effects † Direct Exposure. (n.d.). https://www.miamidade.gov/environment/library/reports/soil-cleanup-target-levels.pdf

[10]. Crossen, S., Xing, G., & Hoch, J. S. (2020). Changing costs of type 1 diabetes care among US children and adolescents. Pediatric Diabetes, 21(4), 644–648. https://doi.org/10.1111/pedi.12996
[11]. Davis, S. P., Martanto, W., Allen, M. G., & Prausnitz, M. R. (2005). Hollow Metal Microneedles for Insulin Delivery to Diabetic Rats. IEEE Transactions on Biomedical Engineering, 52(5), 909–915. https://doi.org/10.1109/tbme.2005.845240
[12]. Ding, C., Chen, J., Zhu, F., & Chai, L. (2022, May). Biological Toxicity of Heavy Metal(loid)s in Natural Environments: From Microbes to Humans [Review of Biological Toxicity of Heavy Metal(loid)s in Natural Environments: From Microbes to Humans]. ResearchGate; Frontiers . https://www.researchgate.net/publication/360862687_Biological_Toxicity_of_Heavy_Metalloids_in_Natural_Environments_From_Microbes_to_Humans
[13]. Does pH has correlation with heavy metals? | 3 Answers from Research papers. (n.d.). SciSpace - Question. Retrieved December 9, 2023, from https://typeset.io/questions/does-ph-has-correlation-with-heavy-metals-2o7v4373ej
[14]. Elbana, T. A., & Selim, H. M. (2011). Copper Mobility in Acidic and Alkaline Soils: Miscible Displacement Experiments. Soil Science Society of America Journal, 75(6), 2101–2110. https://doi.org/10.2136/sssaj2011.0185
[15]. Financial Help for Diabetes Care | NIDDK. (n.d.). National Institute of Diabetes and Digestive and Kidney Diseases. https://www.niddk.nih.gov/health-information/diabetes/financial-help-diabetes-care#:~:text=Many%20people%20who%20have%20diabetes
[16]. Florida Department of Health. (2019, January 12). Florida Diabetes Report[Review of Florida Diabetes Report]. Florida Department of Health. https://www.floridahealth.gov/diseases-and-conditions/diabetes/diabetes-resources/_documents/2019-dac-report.pdf
[17]. Fly ash - Energy Education. (n.d.). Energyeducation.ca. https://energyeducation.ca/encyclopedia/Fly_ash
[18]. Government of Canada, Canadian Centre for Occupational Health and Safety. (2018, July 26). Needlestick and Sharps Injuries. Ccohs.ca. https://www.ccohs.ca/oshanswers/diseases/needlestick_injuries.html
[19]. Gregory, G. A., Robinson, T. I. G., Linklater, S. E., Wang, F., Colagiuri, S., Beaufort, C. de, Donaghue, K. C., Magliano, D. J., Maniam, J., Orchard, T. J., Rai, P., & Ogle, G. D. (2022). Global incidence, prevalence, and mortality of type 1 diabetes in 2021 with projection to 2040: a modelling study. The Lancet Diabetes & Endocrinology, 10(10), 741–760. https://doi.org/10.1016/S2213-8587(22)00218-2
[20]. Gupta, J., Felner, E. I., & Prausnitz, M. R. (2009). Minimally Invasive Insulin Delivery in Subjects with Type 1 Diabetes Using Hollow Microneedles. Diabetes Technology & Therapeutics, 11(6), 329–337. https://doi.org/10.1089/dia.2008.0103
[21]. Helping Diabetic Patients with Safe Needle Disposal. (n.d.). Www.stericycle.com. https://www.stericycle.com/en-us/resource-center/blog/diabetic-sharps-disposal
[22]. Home Page | Environmental Law Institute. (2012, March 19). Eli.org. https://www.eli.org/
[23]. Hospital Incinerator #1 by Robert Brook/science Photo Library. (n.d.). Fine Art America. Retrieved April 12, 2024, from https://fineartamerica.com/featured/1-hospital-incinerator-robert-brookscience-photo-library.html
[24]. House, L. K. (n.d.). Microneedle Patches: Definition, Function, and How They're Manufactured. Www.strouse.com. https://www.strouse.com/blog/microneedle-patches#:~:text=Microneedle%20patches%20are%20a%20type
[25]. https://www.cancer.gov/publications/dictionaries/cancer-terms/def/respiratory-disease#. (2011, February 2). Www.cancer.gov. https://www.cancer.gov/publications/dictionaries/cancer-terms/def/respiratory-disease#
[26]. How to Calculate Statistical Significance. (n.d.). CloudResearch. https://www.cloudresearch.com/resources/guides/statistical-significance/calculate-statistical-significance/
[27]. ICP-MS? | Quadrupole ICP-MS Lab. (n.d.). Www.jsg.utexas.edu. https://www.jsg.utexas.edu/icp-ms/icp-ms/
[28]. Insulin Pen Needles for Diabetes | Diabetic Pen Needles for Sale. (n.d.). Total Diabetes Supply. https://www.totaldiabetessupply.com/collections/pen-needles
[29]. International Diabetes Federation. (2022). IDF Diabetes Atlas | Tenth Edition. IDF Diabetes Atlas. https://diabetesatlas.org/#:~:text=Diabetes%20around%20the%20world%20in%202021%3A
[30]. Kalra, S., Girdhar, R., & Sahay, R. (2015). Green diabetology. Indian Journal of Endocrinology and Metabolism, 19(6), 698. https://doi.org/10.4103/2230-8210.164030
[31]. Kim, Y.-C., Park, J.-H., & Prausnitz, M. R. (2012). Microneedles for drug and vaccine delivery. Advanced Drug Delivery Reviews, 64(14), 1547–1568. https://doi.org/10.1016/j.addr.2012.04.005
[32]. Li, R., Liu, X., Yuan, X., Wu, S., Li, L., Jiang, X., Li, B., Jiang, X., & Gou, M. (2022). Fast Customization of Hollow Microneedle Patches for Insulin Delivery. International Journal of Bioprinting, 8(2). https://doi.org/10.18063/ijb.v8i2.553
[33]. Lin, H., Li, G., Dong, Y., & Li, J. (2017). Effect of pH on the release of heavy metals from stone coal waste rocks. International Journal of Mineral Processing, 165, 1–7. https://doi.org/10.1016/j.minpro.2017.05.001
[34]. Lin, J., Thompson, T. J., Cheng, Y. J., Zhuo, X., Zhang, P., Gregg, E., & Rolka, D. B. (2018). Projection of the future diabetes burden in the United States through 2060. Population Health Metrics, 16(1). https://doi.org/10.1186/s12963-018-0166-4

[35]. Majumdar, A., Sahoo, J., Roy, G., & Kamalanathan, S. (2015). Improper sharp disposal practices among diabetes patients in home care settings: Need for concern? Indian Journal of Endocrinology and Metabolism, 19(3), 420. https://doi.org/10.4103/2230-8210.152792
[36]. Marder, D., Tzanani, N., Prihed, H., & Gura, S. (2018). Trace detection of explosives with a unique large volume injection gas chromatography-mass spectrometry (LVI-GC-MS) method. Analytical Methods, 10(23), 2712–2721. https://doi.org/10.1039/c8ay00480c
[37]. Merriam-Webster Dictionary. (2020). Merriam-Webster.com. https://www.merriam-webster.com/dictionary/hypodermic%20syringe
[38]. Needle length. (n.d.). Livingwithdiabetes.bd.com. https://livingwithdiabetes.bd.com/successful-injections/needle-length#:~:text=This%20approach%20can%20help%20keep
[39]. Oyem, H. H., & Oyem, I. M. (2022). Heavy Metals pH-Mediated Microbial-Remediation in Septic Tank Effluents. International Journal of Environmental Chemistry and Ecotoxicology Research, 4(1), 15–32. https://doi.org/10.37745/10.37745/ijecer.16/vol4n11532
[40]. Periodic Table of Heavy Metal by SteveHNo96 on DeviantArt. (2012, June 27). Www.deviantart.com. https://www.deviantart.com/stevehno96/art/Periodic-Table-of-Heavy-Metal-310972769
[41]. Rijal, N. (2019, October 3). Autoclave: Principle, Procedure, Types and Uses. Learn Microbiology Online. https://microbeonline.com/autoclave-principle-procedure-types-and-uses/
[42]. Rzhevskiy, A. S., Singh, T. R. R., Donnelly, R. F., & Anissimov, Y. G. (2018). Microneedles as the technique of drug delivery enhancement in diverse organs and tissues. Journal of Controlled Release, 270, 184–202. https://doi.org/10.1016/j.jconrel.2017.11.048
[43]. Sabiha-Javied, Tufail, M., & Khalid, S. (2008). Heavy metal pollution from medical waste incineration at Islamabad and Rawalpindi, Pakistan. Microchemical Journal, 90(1), 77–81. https://doi.org/10.1016/j.microc.2008.03.010
[44]. Sartawi, Z., Blackshields, C., & Faisal, W. (2022). Dissolving microneedles: Applications and growing therapeutic potential. Journal of Controlled Release, 348, 186–205. https://doi.org/10.1016/j.jconrel.2022.05.045
[45]. Services, D. of H. & H. (n.d.). Diabetes and insulin. Www.betterhealth.vic.gov.au. Retrieved December 8, 2023, from https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/diabetes-and-insulin#:~:text=Summary&text=People%20with%20type%201%20diabetes
[46]. Smith, F., Sabri, A. H., Heppel, M., Fonseca, I., Chowdhury, F., Cheung, K., Willmor, S., Rawson, F., & Marlow, M. (2022). The clinical and translational prospects of microneedle devices, with a focus on insulin therapy for diabetes mellitus as a case study. International Journal of Pharmaceutics, 628, 122234. https://doi.org/10.1016/j.ijpharm.2022.122234
[47]. staff, S. X. (2016, June 10). Coal ash ponds found to leak toxic materials. Phys.org; Phys.org. https://phys.org/news/2016-06-coal-ash-ponds-leak-toxic.html
[48]. StoryMD. (n.d.). Insulin Devices. StoryMD.com. https://storymd.com/journal/j3ybpdq0aw-insulin/page/vbdo4kidxrp4-insulin-devices
[49]. Thompson, B. M., & Cook, C. B. (2021). Unsafe Sharps Disposal Among Insulin-Using Patients With Diabetes Mellitus: An Emerging Global Crisis. Journal of Diabetes Science and Technology, 193229682110598. https://doi.org/10.1177/19322968211059851
[50]. US EPA. (2019, March 14). Clean Air Act Overview | US EPA. United States Environmental Protection Agency. https://www.epa.gov/clean-air-act-overview
[51]. USGS Mineral Resources Program. (2010). https://pubs.usgs.gov/fs/2010/3089/pdf/fs2010-3089.pdf
[52]. Vanstone, E. (2023, September 27). What is the pH Scale? Science Experiments for Kids. https://www.science-sparks.com/what-is-the-ph-scale/
[53]. Waghule, T., Singhvi, G., Dubey, S. K., Pandey, M. M., Gupta, G., Singh, M., & Dua, K. (2019). Microneedles: a Smart Approach and Increasing Potential for Transdermal Drug Delivery System. Biomedicine & Pharmacotherapy, 109, 1249–1258. https://doi.org/10.1016/j.biopha.2018.10.078
[54]. Walker, A. F., Schatz, D. A., Johnson, C., Silverstein, J. H., & Rohrs, H. J. (2015). Disparities in Social Support Systems for Youths With Type 1 Diabetes. Clinical Diabetes, 33(2), 62–69. https://doi.org/10.2337/diaclin.33.2.62
[55]. What is Ashcrete? (2022, July 18). The Constructor. https://theconstructor.org/building/ashcrete/565323/
[56]. Xenikakis, I., Tsongas, K., Tzimtzimis, E. K., Katsamenis, O. L., Demiri, E., Zacharis, C. K., Georgiou, D., Kalogianni, E. P., Tzetzis, D., & Fatouros, D. G. (2022). Transdermal delivery of insulin across human skin in vitro with 3D printed hollow microneedles. Journal of Drug Delivery Science and Technology, 67, 102891. https://doi.org/10.1016/j.jddst.2021.102891
[57]. yasminlp. (2024, January 3). Steam's Crucial Role in Autoclave Sterilization. TOMY. https://tomy.amuzainc.com/blog/importance-steam-lab-autoclaves/
[58]. Yones Khaledian, Valle, R., Brevik, E. C., N. Pundyte, & Dainius Paliulis. (2017). The Influence of Organic Carbon and pH on Heavy Metals, Potassium, and Magnesium Levels in Lithuanian Podzols. 28(1), 345–354. https://doi.org/10.1002/ldr.2638

[59]. Zhang, N., Zhao, X., Liu , L., Zhao, L., Xie, H., & Yang, Z. (2021). Dissolving Polymer Microneedles for Transdermal Delivery of Insulin [Review of Dissolving Polymer Microneedles for Transdermal Delivery of Insulin]. Frontiersin.org; Frontiersin.org. https://www.frontiersin.org/articles/10.3389/fphar.2021.719905/ful
[60]. Zhao, J., Xu, G., Yao, X., Zhou, H., Lyu, B., Pei, S., & Wen, P. (2021). Microneedle-based insulin transdermal delivery system: current status and translation challenges. Drug Delivery and Translational Research. https://doi.org/10.1007/s13346-021-01077-3
[61]. Zhao, L., Zhang, F.-S., Wang, K., & Zhu, J. (2009). Chemical properties of heavy metals in typical hospital waste incinerator ashes in China. Waste Management, 29(3), 1114–1121. https://doi.org/10.1016/j.wasman.2008.09.003