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BIO 424

Climate Change and its Impact on Human Health in the Arctic

Modern climate change represents one of the biggest challenges of our times, with extensive impacts on ecosystems, economies, and societies worldwide (Grigorieva, 2024). Climate change can be defined as the significant variation in weather conditions over an extended period of time. It is the change in the climatic variables on a decadal scale (Ahmed et al., 2023). This is different from the natural weather variability that occurs seasonally. Climate change affects all living beings and manifests in numerous ways. It can be seen around the world through extreme storms, severe floods, and deadly heat (Ahmed et al., 2023). Over the most recent decades, the Arctic has been particularly affected by environmental shifts. This area has begun facing a wide range of climate-related challenges, from rising temperatures to ice melting and permafrost thaw, which have had significant implications for not only the ecosystems but also human well-being (Grigorieva, 2024). What's more, many instrumental observations and climate models have reported that the Arctic is warming faster than the rest of the globe (Rantanen et al., 2022), experiencing a rate of warming nearly two to four times faster (Grigorieva, 2024). This phenomenon is known as Arctic amplification (AA). The Arctic's unique geography, including its extensive ice cover, ocean currents, and atmospheric circulation, plays a crucial role in the impact of these changes. Scientists have suggested that factors like ice-albedo feedback, ocean heat transport, and atmospheric moisture movement can influence AA (Rantanen et al., 2022). Native Arctic populations have been the most affected by these impacts, especially regarding food insecurity. Therefore, this case study aims to analyse and discuss climate change impacts on human health in Arctic communities. These changes raise human health concerns and threaten cultural traditions. Understanding these effects is crucial, not only to protect vulnerable populations, but also to recognize the global implications that this issue presents.

Climate change is not only altering the physical landscape but also impacts the health and well-being of Arctic inhabitants in various ways. For instance, infections are a common challenge in all Arctic communities, and environmental shifts can influence their prevalence, distribution, and transmission dynamics. Rising temperatures are expanding the geographical range and spread of common food-borne pathogens, water-borne illnesses, zoonotic infections, and even the introduction of new viral germs that can be liberated after being trapped for ages within frozen layers, as permafrost and glaciers thaw (Grigorieva, 2024). Additionally, researchers demonstrated that changes in weather patterns, snow, and ice stability, as well as shifts in wildfire and vegetation distribution, have negative effects on mental health and well-being. These abrupt changes often lead to family tensions, a higher incidence of substance abuse, exacerbation of existing injuries and mental health issues, and an elevated risk of suicidal thoughts (Grigorieva, 2024). Moreover, and mostly concerning, shifts in environmental conditions caused by climate change can have serious implications in food security and nutrition of these communities. Without a proper diet, all the previously mentioned health impacts and many more, can be seriously aggravated. Changes in ice cover and sea surface temperatures are having a huge impact on marine ecosystems and the availability of traditional food sources, as

well as access to good-quality drinking water, affecting the nutritional status and susceptibility to diseases among indigenous populations (Grigorieva, 2024). Figure 1 presents a visual of these health effects.

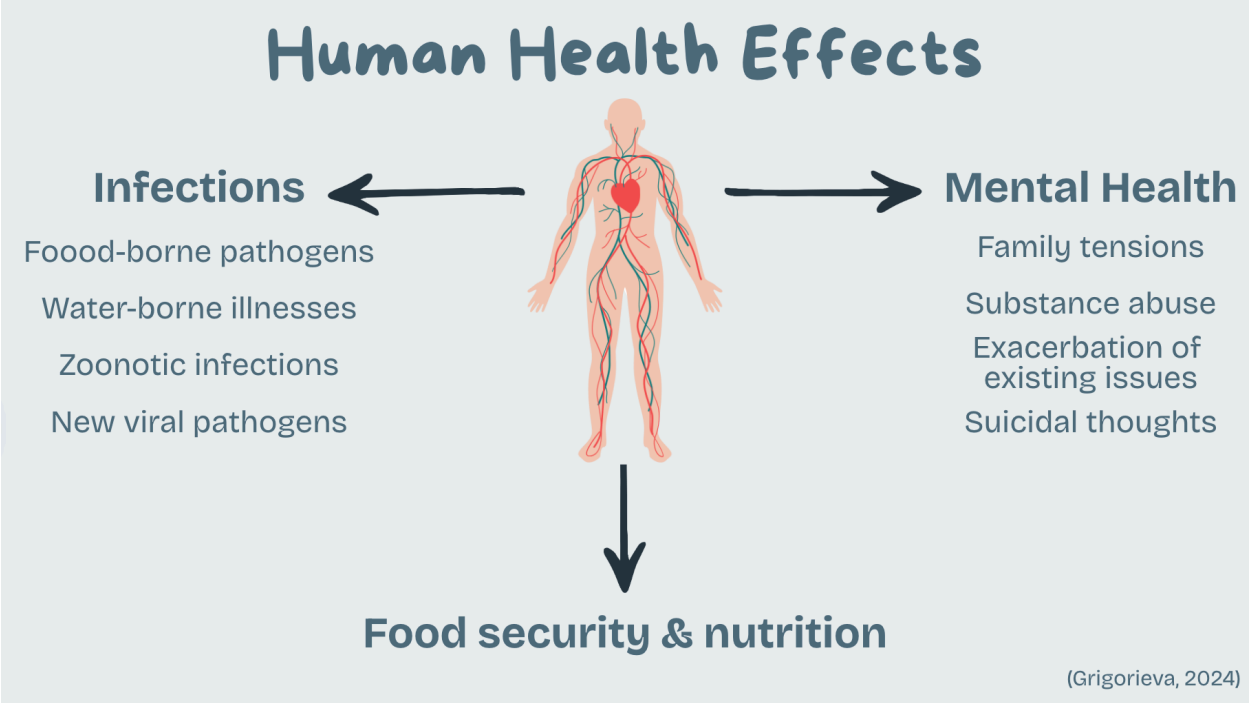

Figure 1. Human health effects on Arctic communities due to climate change.

Inuit communities are indigenous communities that live in the Arctic regions of North America, including areas of Canada, Greenland, and Alaska, known for their deep connections with the environment, traditional fishing and hunting practices, and strong cultural values. Canada's Inuit population experiences unique patterns of food insecurity, with studies indicating that between 50 and 80% of their people suffer from it, including a high prevalence in children (Ford and Beaumier, 2011). Igloolik is a coastal Inuit community of 1538 people located on Igloolik Island in the Canadian High Arctic territory of Nunavut. They rely on both traditional foods, which are obtained by fishing and hunting, as well as store bought foods. In 2008 a study by Ford and Beaumier was conducted to analyze food insecurity among this population where it was found that food insecurity is common and transitory, with multiple families experiencing periods of food scarcity throughout the year. Members of the community in this study, along with other research studies, mentioned that there has been a big decrease in the number of people that hunt full time, which has caused serious implications for the availability of native foods. Changing climatic conditions had made hunting more dangerous most times of the year as ice freezes and breaks more often. Only a few hunters have the skill and time to safely and successfully harvest. Moreover, all participants in this study indicated that the alternative store bought foods they can find are often expensive, have a low nutritional value, and are sometimes even close to the expiration date. They also have no education regarding how to prepare many of these foods, as well as their bodies are not used to them and often reject them. The decline in

traditional food consumption in Igloolik residents has led to deficiencies in essential nutrients leading to weak immune systems and susceptibility to infections, higher intake of processed foods with high fats and sugar which can lead to obesity and cardiovascular diseases, and mental health issues of stress, anxiety, and substance abuse (Ford and Beaumier, 2011). Figure 2 presents a conceptual map that links all the topics discussed (Ford and Beaumier, 2011). Figure 3 presents a visual of health effects identified in the study by Ford and Beaumier.

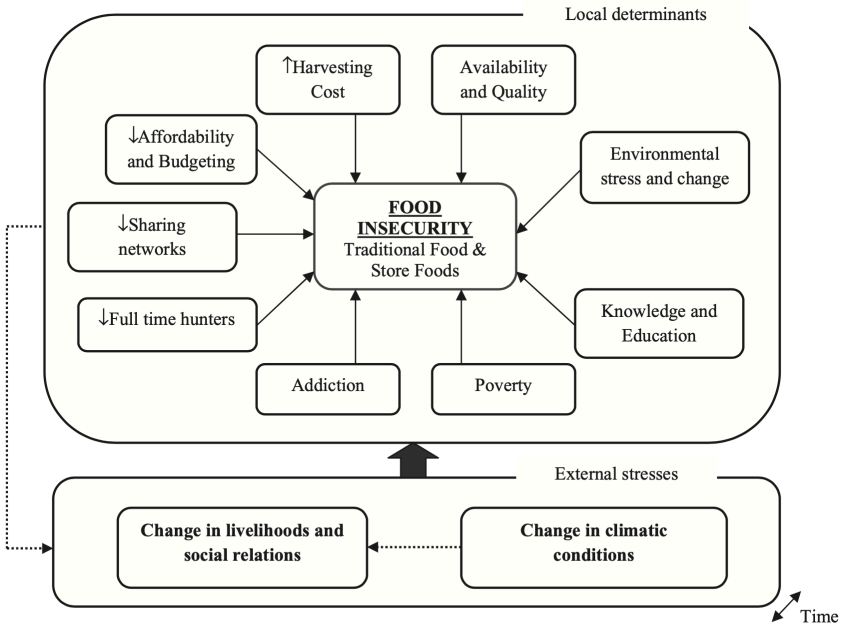

Figure 2 Conceptual map of local and broader determinants of food insecurity in Igloolik
Source: modified from Beaumier and Ford (2010)

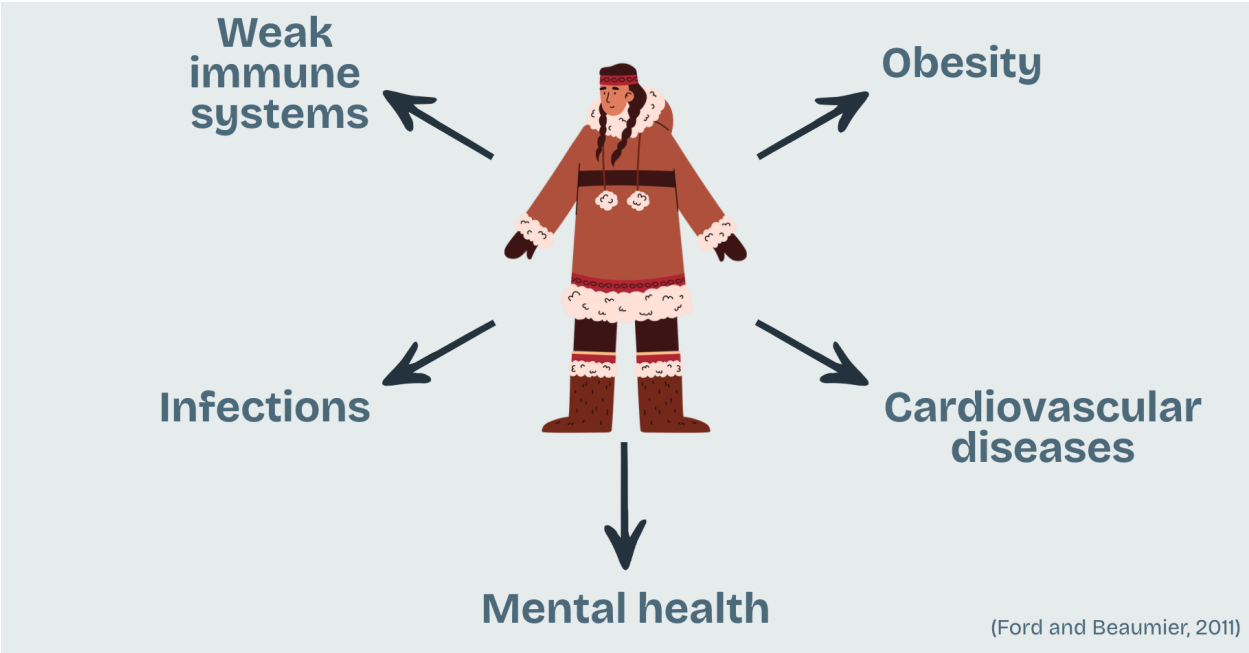

Figure 3. Health effects identified in Igloolik community members in the study by Ford and Beaumier (2011).

The Igloolik along with many other Arctic communities need global collaboration to address this problem. Being able to adapt to climate change in the Arctic requires a coordinated effort across multiple levels of governance, from local communities to regional and national governments, as well as international cooperation (Grigorieva, 2024). For example, populations need to be teached and given the tools to be able to adapt to these shifting environmental conditions. Traditional and more scientific and technological knowledge should be integrated, actively involving community members in decision making, and recognizing their unique needs and circumstances (Grigorieva, 2024). Additionally, adaptation efforts should incorporate both EcoHealth principles, such as systems thinking and interdisciplinary collaboration, as well as the One Health strategy, addressing impacts along ecosystems, landscapes, and communities (Grigorieva, 2024). Finally, each individual around the world should make an effort on their power level to reduce the impacts of climate change. Addressing human health impact in the Arctic requires immediate and sustained efforts to protect vulnerable communities.

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BIO 424- Environmental Health (Spring 25)

Final Case Study

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Dr. Elias

Lichens and Climate Change: Indicators of Environmental Health

The average global temperature on Earth has increased by at least 1.1° Celsius (1.9° Fahrenheit) since 1880. (NASA, 2023). The Arctic is warming nearly four times faster than the global average as a result of human-caused climate change, driven primarily by burning fossil fuels. (Moran, 2023). Lichens, due to their unique biology and sensitivity to contaminants, have emerged as valuable tools for biomonitoring. Their ability to respond to climatic and air quality variations makes them reliable indicators of environmental shifts. (Thakur et al., 2024). This case study explores the relationships between climate change, lichen communities, and shrub expansion in Arctic ecosystems. By analyzing changes in lichen abundance and the ongoing shrub expansion, we can assess the potential impacts of these shifts on biodiversity, nutrient cycling, and ecosystem stability. The findings highlight the utility of lichens as early-warning indicators of Arctic ecosystem change and emphasize the need for long-term monitoring to better understand the consequences of ongoing climate trends.

A lichen is a symbiotic relationship between a fungal partner (the mycobiont) and a photosynthetic partner (the photobiont). Lichens cover about 7% of the Earth's surface. They survive in extreme environments, including tundra, deserts, on rocks, and even inside rocks between the grains. (Helmenstine, 2023). The green algae or cyanobacteria photosynthesize and produce food in the form of sugar for the fungus and in return the fungus provides a home for the microbes as well as water, minerals, and other nutrients. Lichens are also sensitive to changes in climate, as most species require specific temperature and moisture conditions in order to thrive. Even a 1℃ shift in average annual temperature can drastically increase or decrease the probability of finding certain lichens. (Blett, 2020). With the distribution of lichen species being highly correlated with environmental conditions such as air pollution and climate, the study of distribution maps of lichen bioindicators can provide information on trends in environmental factors contributing to predictions of future ecosystem changes. (Morillas, 2024)

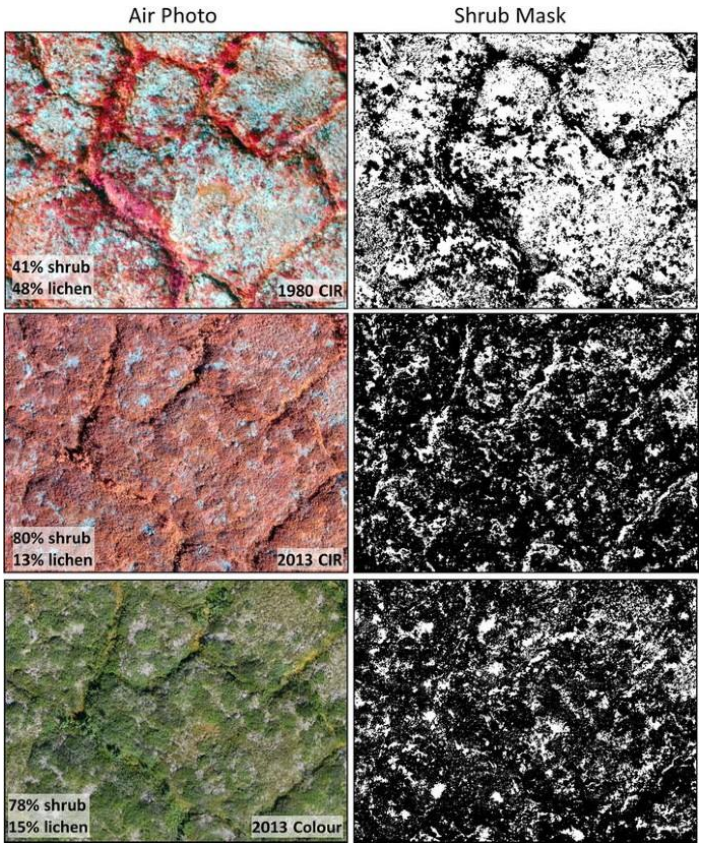
The Arctic is an extreme environment with frigid temperatures, powerful winds, and dramatic seasonal changes in daylight, where winter brings darkness for months and summer features continuous sunlight. Despite its harsh conditions, the region is home to diverse wildlife, including polar bears, walruses, birds, fish, and tiny plankton, as well as small plants that survive in the tundra and permafrost. Covering much of Earth's northern pole, the Arctic consists of glaciers, sea ice, and treeless plains, with temperatures ranging from -40°F in winter to 50°F in

summer. (The National Wildlife Federation, 2019). The Arctic is undergoing rapid transformation due to climate change, with rising temperatures intensifying wildfires, thawing permafrost, and accelerating coastal erosion. Wildfires release greenhouse gases, threatening ecosystems and local communities, while permafrost degradation endangers infrastructure and disrupts wildlife habitats. Shrinking summer sea ice is putting species like polar bears and narwhals at risk and weakening the Arctic's role in regulating global temperatures. Meanwhile, melting glaciers and the Greenland Ice Sheet are significantly contributing to sea level rise, posing a growing threat to coastal regions worldwide. (WWF, 2023). Lichens play a crucial role in Arctic ecosystems by providing food, shelter, and nesting material for wildlife, as well as supporting hydrological and mineral cycles, including nitrogen fixation. (Walton, 2021).

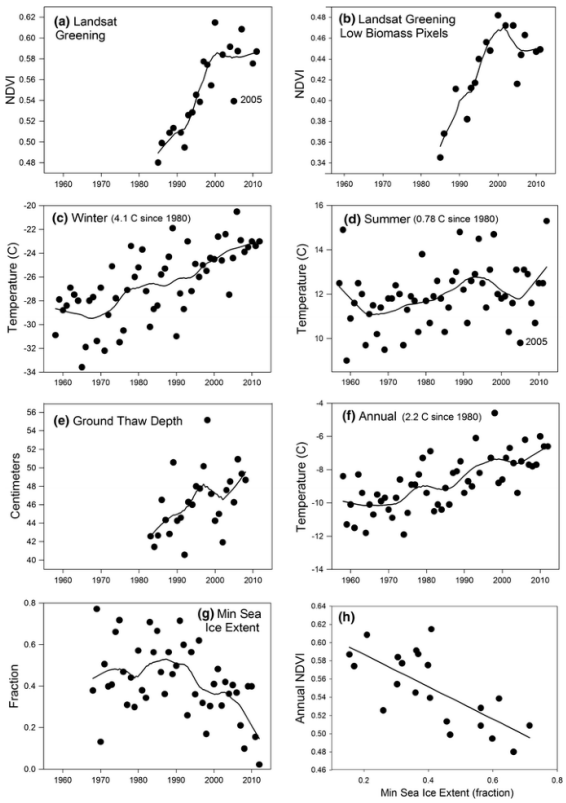
Shrub expansion is the increasing spread of shrubs in ecosystems, especially in high-latitude regions like the Arctic tundra. Shrubs are woody plants with diverse growth forms including tall multi-stemmed shrubs (0.4–4.0 m), erect dwarf shrubs (0.1–0.4 m) and prostrate dwarf shrubs (<0.1 m) that grow laterally along the ground surface (Myers-Smith et al., 2011). Driven by rapid climate warming, this shift alters ecosystem processes and affects the carbon balance, potentially influencing Arctic biodiversity and climate dynamics. (Mekonnen et al., 2021). Recent changes in Arctic lichen communities have drawn attention as expanding shrub cover and rising fire frequency contribute to lichen decline. Since lichens are a key food source for caribou, such as the Western Arctic Caribou Herd which is one of North America's largest free-roaming herds with an estimated 234,000 individuals, their loss could have significant ecological impacts. This decline may also affect local subsistence communities that rely on caribou for food and cultural traditions. (Walton, 2021).

A case study by Fraser et al. (2014) highlights a critical ecological shift in the western Canadian Arctic due to climate change, where warming temperatures have led to significant shrub expansion and a concurrent decline in lichen populations. Over a 26-year period, researchers used satellite and aerial imagery to reveal that 85% of the 15,000 km² study area exhibited increased vegetation greenness, indicating rapid shrub growth (Fraser et al., 2014). This shift not only alters the biodiversity of the region but also threatens traditional food sources for wildlife such as caribou, which rely heavily on lichens. The findings underscore the urgent need for sustainable environmental policies that consider the cascading effects of climate change on fragile Arctic ecosystems and indigenous livelihoods.

This section presents data visualizations and analysis from Fraser et al. (2014), which document significant ecological changes in the western Canadian Arctic over a 26-year period.

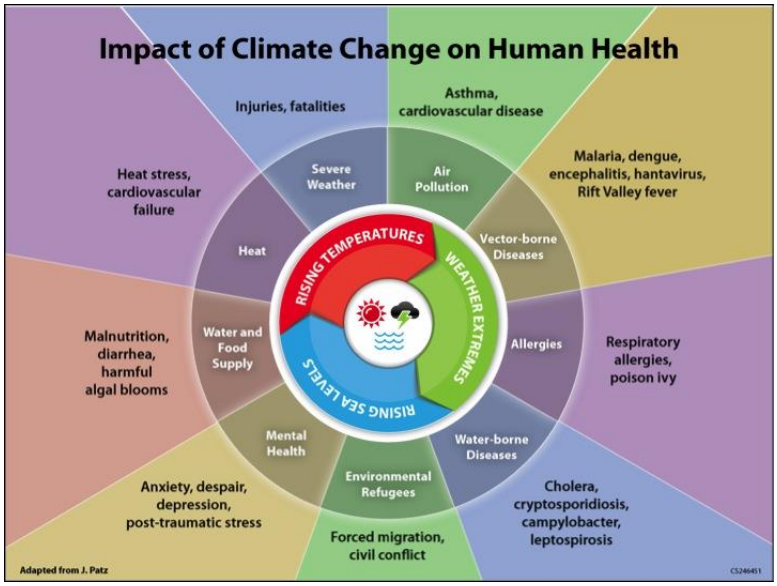


The image above is side-by-side high-resolution aerial photos that demonstrate visual changes in vegetation over time. The 2013 images show more dark tones, indicating increased shrub cover, while 1980 photos show more open, lichen-dominated ground (Fraser et al., 2014).



This next figure is a graph illustrating the correlation between winter temperature increases (around +4°C over 30 years) and NDVI gains. It supports the idea that warming is a key driver of these ecological shifts (Fraser et al., 2014).

The data from Fraser et al. (2014) shows that the western Canadian Arctic is experiencing rapid shrub expansion and lichen decline, driven primarily by warming temperatures. Over 85% of the studied area showed increased vegetation greenness, indicating significant ecological transformation. This shift alters habitat structure, reduces food availability for animals like caribou, and contributes to global climate feedback loops through reduced reflectivity and increased carbon emissions.



This image shows how climate change creates rising temperatures, extreme weather, and rising sea levels that in return have effects on human health in multiple ways, including increased respiratory and cardiovascular issues, more frequent and intense natural disasters that can lead to injuries and fatalities, the spread of infectious diseases, and mental health issues.

Solutions to address climate change in the Arctic include reducing global carbon emissions, protecting and restoring Arctic ecosystems, and strengthening international cooperation on climate policies. Reducing worldwide emissions of greenhouse gases and other short-lived climate forcers like black carbon is necessary to limit climate change impacts in the Arctic region. Wetlands and thawing permafrost, as well as fossil fuel production and transport, agriculture, and waste contribute a lot to methane emissions in the Arctic. Black carbon in the Arctic primarily comes from wildfires that release carbon stores directly from trees and soils, as well as surface transportation, energy production, and homes and businesses (*Addressing Climate Change in the Arctic | US EPA*, 2024). It is also essential to develop sustainable practices for land and resource management and invest in climate adaptation strategies for vulnerable Arctic communities and wildlife. These efforts, combined with the transition to renewable energy sources, can help slow the region's warming and minimize the global impact (Fraser et al., 2014).

In the Arctic, climate change is already impacting local communities, which have observed profound changes in their local environments, and are leading to significant economic and cultural upheaval particularly for the indigenous peoples of the Arctic. Because climate change is more advanced in the Arctic than other regions of the world, the Arctic can play a vital role in preparing the world for what is to come. (Parkinson & Evengård, 2009). Arctic warming, amplifying the effects of climate change and altering regional weather patterns, additionally leading to degraded air quality and respiratory health hazards for nearby communities. (Grigorieva, 2024). Over half of known human pathogenic diseases can be aggravated by climate change. The Arctic's rising temperatures may lead to the liberation of pathogenic

microorganisms trapped for ages within frozen layers, as permafrost and glaciers thaw. Global pollution and communicable diseases are shown to pose threats to Indigenous peoples living in the Arctic and sub-Arctic regions. (Grigorieva, 2024).

In conclusion, the Arctic functions like Earth's air conditioner, helping regulate global temperatures by reflecting sunlight with its ice and snow. As climate change accelerates warming in the region, ice melts, reflectivity is lost, and the planet warms even faster. In the western Canadian Arctic, this has led to significant shrub expansion and a steep decline in lichen, which affects the caribou population and the Indigenous communities that rely on them. These environmental changes also contribute to the release of greenhouse gases, which intensify global health risks such as heat-related illnesses, respiratory issues from poor air quality, food and water insecurity, and the spread of disease. Protecting the Arctic is not just an environmental necessity, it is a critical step in safeguarding global human health and well-being.

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Forest fires and their impact on human and environmental health

Introduction

Forest fires can occur naturally or artificially, and need many different factors and conditions to occur at the same time for them to grow out of control. There are several negative effects that forest fires have on the environment relating to pollution, soil health, and the health of living organisms that inhabit the particular affected ecosystem. In addition to the destructive impact that forest fires have on the environment, they also have a large effect on human health, including short- and long-term adverse health effects. There are many policies and regulations currently in place to mitigate the impact of forest fires, however there could be future alterations and additions made, especially in areas that see consistent forest fires. A study was conducted by Gao et al. looking at the Palisades and Eaton fires that burned the first month of 2025; they looked at particulate matter levels of 2.5 and 10 micrometers and compared the Los Angeles levels with two other locations, one with typically high PM exposure and one with typically low exposure year-round (2025). The aim of this paper was to identify the various human and environmental impacts, as well as identify ways to better fight and/or control forest fires in the future.

Background

Firstly, it is important to note the distinction between "forest fires" and "fire regimes." A forest fire is an uncontrolled fire that engulfs wooded areas, and is typically an isolated event. In comparison, fire regimes are a type of forest fire that convey a pattern, whether it be temporal or regional (Aponte et al. 2016). When looking at the causative factors of forest fires and fire regimes, there is a combination of both environmental and human elements that contribute.

Environmental Factors

Some environmental factors that can cause forest fires to spark include dry conditions, high winds, the amount of sunlight, the amount of fallen organic matter, and climate change (Földi and Kuti 2016). Dry conditions can come from temporary or prolonged droughts (Merzdorf 2019). This lack of moisture and humidity, along with the combined factors of high winds and direct sunlight, act as fuel for incoming fires. High winds play a large part in the rapid spread of the fires, making it harder for them to be stopped. Additionally, fallen organic matter—such as leaves, twigs, pine needles, etc.—can serve as great conductors when these other factors take place. Finally, the recent change in climate has also led to an increased risk of forest fires and fire regimes (Aponte et al. 2016). Climate change is most commonly known to cause rising water levels due to melting ice, but this phenomenon leads to extreme precipitation on both ends of the spectrum. Not only are "wet areas" getting wetter, but "dry areas" are growing increasingly dry (Merzdorf 2019).

Human Factors

Not all forest fires are started through natural means; many forest fires have started and grown because of human activity. One example of this is illegal or unregulated fires, such as burning trash or agricultural waste, especially when "burn bans" are in place (Földi and Kuti 2016). Burn bans are regulations, imposed either by fire departments or local governments, that restrict outdoor burnings for a certain period of time, more specifically when environmental conditions exhibit a higher risk for forest fires (Suri 2023). In addition to this, people smoking near forested areas has as well proven to be a significant factor in the igniting of forest fires (Földi and Kuti 2016). This is more so true for cigarette smokers who throw their used butts on the ground, where there is typically a high concentration of organic matter littered about. These human-related factors can also be perpetuated when unfavorable environmental conditions— such as the ones listed above—are also occurring.

Data and Analysis

Fire regimes have a heightened impact on human and environmental health due to their persistent recurrences. Because they are not isolated incidents, and rather fires that are essentially guaranteed to return, their health effects are prolonged, resulting in short-term, as well as potentially long-term effects on humans and the environment.

Short-term Effects on Humans

The short-term effects of forest fires on human health tend to also be more direct. The first—and perhaps the most obvious—short-term effect on human health would be receiving minor to severe burns, or death. Not only can the burns you receive be fatal, but also inhaling enough smoke from a fire can significantly limit your oxygen intake, suffocating you. Additionally, there could be significant, if not complete, damage to residential property, such as homes, front and/or backyards, and landscaping, as well as personal, valuable, and/or irreplaceable items that may be within the property. This can result in businesses having to close down (either temporarily or permanently), which would affect both the workers and the consumers. Roadways can also become blocked or destroyed, limiting or completely ceasing the possibility of travel and transportation. Along with this, exposure to air pollution can lead to a variety of short-term health complications. Air pollutants from forest fires—such as biomass smoke, particulate matter, carbon monoxide, and other irritants—have proven to cause adverse health effects (Fowler 2003). Some common respiratory symptoms of air pollutant exposure include shortness of breath, coughing and wheezing, inflammation in the lungs, and an excessive production of mucus (Fowler 2003). Other related conditions include the development of allergies, asthma, bronchitis, or pneumonia (Fowler 2003). Individuals who are more vulnerable to air pollution effects are elders, young children, people with pre-existing conditions, and smokers (Fowler 2003).

Long-term Effects on Humans

Long-term exposure to forest fires heightens the probability of long-term human health problems, mainly resulting from air pollution. Along with the previously stated short-term impacts of air pollution on human health, it can also lead to various cancers, respiratory and cardiovascular diseases, and other chronic illnesses; the most notable cancer related to forest fire pollution is lung cancer (Fowler 2003). In addition to these, exposure to air pollutants can lead to a suppressed immune system, negatively affecting the body's ability to fight off infections (Fowler 2003). Most, if not all of these diseases and conditions have the potential to cause premature death, further elevating their impact (Fowler 2003).

Effects on the Environment

In regard to the environment, some negative impacts resulting from forest fires include injury and death of living organisms, habitat destruction and fragmentation, soil erosion, and air and water pollution (Földi and Kuti 2016). Habitat fragmentation refers to the splitting of an ecosystem into smaller sections, and can lead to diminished ecosystem biodiversity (the variation of living organisms in a given ecosystem). When forest fires occur, the fire acts as a sort of barrier or wall within the ecosystem, preventing essential wildlife interactions. Soil erosion is another big issue caused by forest fires. Because vegetation acts as an anchor for soil, the soil in ecosystems experiencing forest fires become loose due to the burning, and in-turn lack of structural vegetation; this perpetuates soil erosion, especially when these areas experience sudden precipitation afterwards (Földi and Kuti 2016). Furthermore, the release of biomass smoke, particulate matter, and greenhouse gases amplifies air pollution in areas that have encountered forest fires (Fowler 2003). Additionally, the release of these air pollutants leads to the ongoing depletion of the atmospheric ozone layer, heightening global warming (Suri 2023). Harmful chemicals released by forest fires both directly and indirectly affect water quality as well. Some of these effects include: chemical runoff from environments that have experienced forest fires to nearby bodies of water; and the evaporation of chemically infused water particles, and the resulting precipitation of said contaminated water (Földi and Kuti 2016).

Case Study

A particularly recent case of forest fires took place on the coast of California. The Palisades and Eaton Fires, which started on January 7, 2025, have been noted as some of the most destructive fires in history within California's bounds (Woolcott 2025). The preceding Santa Ana Winds, which reached speeds nearly 100 miles per hour, have been said to be the igniting factor of the fires, along with California's perpetual drought (Woolcott 2025). California is considered a fire regime, so forest fires are not a new phenomenon for this region. However, these recent fires have been without a doubt the most impactful, in regard to both human and environmental health. Some of these include injury, respiratory problems, premature death, homelessness, urban devastation, wildlife habitat and national park destruction, and air pollution, which have shown to cause physiological and mental health issues (Woolcott 2025). A study conducted by Gao et al. analyzed the particulate matter concentrations from when the fires started in early-January until early- to mid-February (2025). When looking at PM2.5 and PM10 levels, the results showed that, within

the first three or four days, two major spikes of both PM2.5 and PM10 were identified (Gao et al. 2025). PM2.5 and PM10 stand for particulate matter (or particles present in the air [Fowler 2003]) that is 2.5 micrometers and 10 micrometers in size, respectively. Because of the lasting effects of particulate matter exposure, such as respiratory and cardiovascular complications, as well as the worsening of pre-existing health conditions (Fowler 2003), studies like this are essential to know just how much particulate matter is being released. This study also compared the PM levels from Los Angeles with Delhi, India (which is considered to have high exposures of PM year-round) and Waterloo, Belgium (which is identified as having low PM exposure on average) (Gao et al. 2025). The comparing data showed that the peak PM2.5 levels found in LA exceeded Delhi's highest peak, however, LA's PM10 levels did not reach even half of Delhi's highest. Comparing these locations not only shows us the severity of the Palisades and Eaton fires, but also how poor the air quality of areas like Delhi is consistently year-round. Additionally, it opens up potential new research focal points. The Palisades and Eaton fires were not fully contained until January 31, almost a month after their ignition, which will undoubtedly have long-lasting effects in that area (Gao et al. 2025).

Solutions and Damage Interventions

Preventative Methods

One solution to stop or mitigate the impact of forest fires is to implement preventative measures. Firstly, before anything else, it is important to know the conditions in which forest fires are more likely to spread uncontrollably, and which areas are at higher risk. Informing the general public on this type of information, in a manner that is easily understandable and relatable, will make people more aware of their actions and what warning signs to look out for. It is also essential that moderate- to high-risk areas have sufficient water access. Because many fires are put out with the aid of aerial firefighting with water, it is important that abundant access to water sources is pre-established. Enforcing burn bans in areas with environmental conditions that threaten the emergence of a forest fire is also a great method of prevention. While it is not easy to get people to listen to orders such as this, with the combination of better community knowledge and awareness, it increases the chances that community members will heed these orders.

Responsive Methods

In order to halt or lessen the destruction caused by forest fires, the utilization of methods that are meant to reactively fight fires can be very beneficial. Some of the most effective firefighting methods include aerial firefighting. Aerial firefighting is the use of aircrafts (such as planes, helicopters, drones, etc.) to carry and release water or other retardants in order to suppress the spread of a forest fire (Restas 2023). Aerial firefighting using water is considered to be the most implemented variation, hence why it is so important to have sufficient water access in areas experiencing forest fires. Other aerial fighting resources include mulches and seeding, which are utilized after a forest fire is already extinguished to prevent soil erosion (Ferreira et al. 2015). Aerial mulching essentially drops a blanket of organic material onto post-fire-disrupted soil, protecting it from rainfall. While there are manual applications of mulching, aerial application has

proven to be a cost effective and more efficient approach (Ferreira et al. 2015). Seeding in this context is the process of scattering seeds of plant species with rapid growth rates across an area of soil that has been impacted by forest fires. These vegetation species are meant to provide grounding to the disrupted soil, and act as a placeholder while native plants work their way to growing back (Ferreira et al. 2015).

Comparing Policies of Different Regions

Forest fire prevention and mitigation policies can vary widely between regions. Policies in developing countries typically lack necessary forest fire regulations due to lack of funding, knowledge, and resources. Additionally, regions that are considered "fire regimes" require more constant and intense policy implementation due to the recurrent nature of their forest fires. California and parts of Australia are considered to be fire regimes, meaning it is very important that these areas have proper regulations in place.

While both California and Australia have the same problem, they have many differing policies and regulations regarding forest fires. In California, most fires are dealt with via fire and emission suppression. Suppression has the ability to reduce smoke emissions from forest fires, however this exemplifies a false belief that this method provides completely smoke-free air (Schweizer and Cisneros 2017). On the contrary, "Impacts from fire suppression have the potential to greatly increase both smoke emissions and the subsequent impacts to public health by radically altering the current ecological system and its ability to self-regulate fire size and intensity" (Schweizer and Cisneros 2017). Suppression is essentially an avoidant method of seemingly solving forest fire impacts in an easy and immediate sense, but in the long-term can do great harm on the environment and how it is able to respond to future fires. California also has the Clean Air Act (CAA), which is the primary federal legislation related to air quality (Schweizer and Cisneros 2017). Air Pollution Control Districts (APCDs) work alongside the Environmental Protection Agency (EPA), where these APCDs are required, under the CAA, to pay fines to the EPA when air quality parameters exceed their identified thresholds (Sneeuwjagt et al. 2013). This policy includes effects of prescribed fires, though, and has shown to be a disincentive for them, which have proven to be exceptionally beneficial to forest health and resilience (Sneeuwjagt et al. 2013). Prescribed fires—which are controlled fires intentionally started and typically mandated at the state and federal levels—have proven to increase a forest's resilience for future fires by basically conditioning them to be used to them (Fowler 2003).

Australia has a similar policy, The Western Australian DEC Air Quality Management Branch, which, contrarily to California, does not charge any fees for smoke exceedances (Sneeuwjagt et al. 2013). Because of this, Australia has no disincentive for prescribed burns, and are able to utilize this method freely without having to face financial consequences (Sneeuwjagt et al. 2013). Additionally, all of Australia's forest-fire-related agencies are unified, allowing them to share staff, infrastructure, and resources, such as models and documentations of treatments; this collaboration of agencies allows for optimal use of potentially limited resources and is cost-effective (Sneeuwjagt et al. 2013).

Discussion and Implications

Many of these disastrous forest fires, one notable example being the recent fires in California, are considered well-known on a global scale, however their environmental and human health implications may not be. Enhancing public knowledge and encouraging education on an individual scale will lead to better community awareness and action related to forest fires. Additionally, it is important to acknowledge not only the direct impacts of forest fires, such as death or destruction of the environment, but also the more "indirect" impacts, like exposure to air and water pollution, or climate change. Furthermore, while there are many policies and regulations currently in place to help prevent and mitigate forest fires and their impacts, more work could be done to improve them, especially in areas that experience consistent fires like fire regimes. California, for example, could greatly benefit from implementing some of Australia's policies, as they have proven to be very helpful in fighting forest fires.

Conclusion

From the various short- and long-term human health effects to the added environmental impact, forest fires have proven to be a destructive force in nature. These effects are especially heightened in fire regimes, an example of this being the Palisades and Eaton fires in California at the beginning of 2025. California, as well as parts of Australia, are categorized as fire regimes, which requires them to have more intense policy enforcement and regulation. Both areas, though, have rather different approaches to their policy styles, which is more so apparent when forest fires in these areas occur; because of the use of prescribed burns in Australia, a method that California does not implement in their own fire-fighting practices, Australia's forests are able to gain resilience when future fires occur. Allowing Californian wildlife agencies to incorporate the use of prescribed fires in their routine would greatly benefit the health of their forests, leading to fewer and less intense naturally-occurring fires in the future. Finally, while much data has been collected on the impacts of forest fires in general, more research could be done specifically on fire regimes and how their short- and long-term effects compare to forest fires in non-fire regimes.

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Hanford 100 Area Site Case Study

[redacted]

Environmental Health 424

Dr. Elias

04-26-25

The Handford 100 Area in southeastern Washington State stands as a site of profound historical significance and considerable environmental challenge within the United States. Established in 1943 as a necessary component of the Manhattan Project, its primary function was the production of plutonium for nuclear armaments during the Second World War (*Manhattan Project*, 2025). Especially since it was at this location that the B reactor, the world's inaugural full-scale plutonium production reactor, commenced operation. The plutonium generated at Handford site was ultimately utilized in the “Fat Man” atomic bomb detonated over Nagasaki (*Manhattan Project*, 2025), an event that precipitated the abrupt and devastating conclusion of the war. Subsequently, the Handford site underwent expansion, with the addition of eight further reactors, including C, D, F, and K-east and K west reactors (*100 K Area - Hanford Site*, 2022), situated along the Columbia river to satisfy the escalating demand for nuclear materials during the Cold War era (Handford site, 2024).

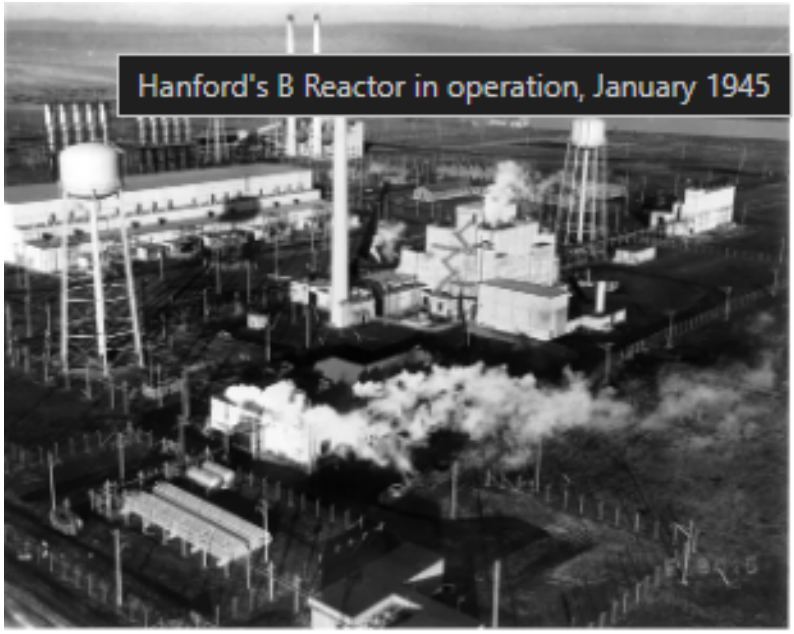
For several decades, radioactive and chemical waste were discharged into the soil, water and atmosphere, often without a comprehensive understanding of the long term ramifications of the pollutants impact. Presently, the primary contaminants in the hanford 100 area includes radioactive contaminants like strontium- 90 and plutonium- 239, along with industrial chemicals and heavy metals (*Manhattan Project,* 2025; Drew & Nyerges, 2004). Because of its potential risk to both people and the nearby Columbia River ecosystem, Hanford was designated a Superfund site by the Environmental Protection Agency in 1989 (*USDOE, 2025)*. Cleanup efforts have been intense and ongoing ever since. One of the main strategies used is a method called “cocooning”, (*Metamorphosis*, 2022), where old reactors are sealed inside massive protective structures to allow radiation to decay safely over decades. Groundwater treatment systems have also been installed to slow or reverse contamination leaking toward the river. Some

areas, like the B Reactor, have been preserved and are now open to public tours to help people better understand Hanfords complicated history. Still, even with all the progress made, groundwater pollution still remains a major concern today, especially because some contaminants move slowly and can persist for centuries (Drew & Nyerges, 2004; Miller, 2024).

The consequences of exposure to toxic vapor on the health of the employees at the Hanford Site, tell their experiences of being exposed to the poisonous fumes. While monitoring the waste in the reactor tanks, they began to develop chronic ailments as a result of their working conditions (*Voices from Hanford*, 2016). According to many of the workers, they "failed" to disclose when and how they were exposed because of all the hoops they would need to jump through. Those that did come out and push for change or compensation had to go through long processes in order to even obtain health care for the ailments. The Hanford 100 Area serves as both a symbol of American innovation and a warning about the environmental cost of rapid technological progress. It shows how decisions made under the pressure of wartime urgency can have lasting consequences that require generations to fix. Cleanup work at Handford site will likely continue far into the future, but the site also stands as a reminder that transparency, the public involvement and long term environmental thinking must be a part of any large scale scientific or industrial project (Gribble, 2025). Ultimately, Hanford is not just a story about nuclear history, it's a lesson about responsibility to those in a position for positive change.

Pictures below*

site reactors *



Hanford, 1960

Nuclear reactors line the riverbank at the Hanford Site along the Columbia River in January 1960. The N Reactor is in the foreground, with the twin KE and KW Reactors in the immediate background. The historic B Reactor, the world's first plutonium production reactor, is visible in the distance.

*ai was used for grammar

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Investigating Water Contamination from Fracking: A Focused Analysis

Course: Environmental Health
Time: 1 class period (if not finished, complete the rest for homework)

Learning Objectives: Analyzing a case study on Dimock, Pennsylvania, and how fracking caused water pollution and affected humans and the ecosystem.
Discuss potential solutions to remediate fracking water pollution. Develop written analysis and arguments analyzing the impact of fracking on water.
Assignment Description: This assignment will focus on the issues of water contamination from fracking. Students will gain an understanding of fracking and water pollution by analyzing a case study and considering different viewpoints.

Part 1: Background Information

Hydraulic fracturing, or fracking, is a technique used to extract natural gas or oil from forms of tight rock formations (Denchak, 2019). The idea of shooting the well or fracking has been practiced since 1862. Well, how does it work? Fracking involves blasting fluid deep below the Earth's surface to crack the sedimentary rock, i.e., shale, sandstone, limestone, and carbonate. This process will expose natural gas and crude oil resources (Denchak, 2019). Doing this process results in fracking fluid. This fluid is 97% water and contains other chemicals that can leak into the Earth's groundwater (Denchak, 2019). Fracking is a huge contributor to water pollution. An analysis done in 2016 showed that uncertainties make it difficult to fully understand the impact fracking can have on drinking water (Denchak, 2019). This leads to Dimock, Pennsylvania.

Dimock, PA, became popular when city residents experienced a water crisis after fracking, which leaked methane into the water (Rubinkam, 2023). An investigation by Pennsylvania found that Cabot Oil & Gas drilled faulty gas wells. This company allowed methane to leak into the community aquifer (Rubinkam, 2023).

1. What is Fracking? Explain what fracking (hydraulic fracturing) is and provide a detailed definition.
2. What is Fracking Fluid ? Describe the composition of the fluid (what it consists of) and how it affects the environment.
3. How Can Fracking Lead to Water Contamination? Identify and explain at least one pathway through which fracking contaminates the environment.

Part 2: Case Study Analysis

Dimock has become a core example in the national discussion over the repercussions of hydraulic fracturing. Residents of Dimock reported contamination in their private wells. The documentary *Gasland* highlighted that the dangerous methane levels caused their water to be lit on fire (Health Consultation, 2016). The DEP and EPA investigations found high methane levels, arsenic, and other harmful chemicals. This case remains one of the most researched and discussed examples of the risks fracking can cause to our limited water supply (Health Consultation, 2016)

1. What evidence links fracking to water pollution in Dimock?
2. What health effects were caused by the water pollution in Dimock?
3. What were the legal responses to the contamination issue of fracking water pollution?

Understanding viewpoints

1. Summarizes the perspectives of these groups: explain how fracking affects these groups.

- Fracking Industry Representative:
- Environmental Advocacy Group:
- Regulatory Agency (e.g., EPA, PA DEP):
- Local Community Members:

Part 3 Takeaways:

The Dimock, Pennsylvania, Case study follows the profound environmental and Public health Impact of fracking. The contaminated water sources, long-term health issues, and ongoing struggles of having adequate clean drinking water demonstrate just how serious the consequences of fracking can be. Beyond the sudden impact, this case is the prime example of how stronger regulations, corporate accountability, and sustainable energy practices can prevent public health crises like this from continuing to happen. Stricter rules, policies, and comprehensive solutions like innovative water treatment technologies are key to remediating the consequences of fracking.

1. Identify some long-term environmental impacts and health issues caused by fracking-related water pollution.
2. What alternative energy sources could reduce reliance on fracking while ensuring energy security?
3. What steps can government officials take to prevent similar water contamination incidents in the future?

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The impact of pesticides in children's brains

[redacted]

Course: Environmental Health (BIO424)

Professor: Dr Daniel Elias

Learning Objectives: Analyzing a case study on pesticides exposure from banana plantations in Costa Rica, and its negative consequences in children's neurodevelopment. Providing possible solutions mentioned by the author on this case study (De Joode et al., 2016), and personal possible solutions from other studies on pesticides exposure. Additionally, providing an insight into this problem to spread awereness on the impact of pesticides exposure in children's brain health.

Analyzing Case Study:

I. Introduction

It is estimated that Banana Companies in Costa Rica use many quantities of different pesticides (fungicides, herbicides, and nematicides) to meet efficiency in production demanded by developed countries like the U.S and Europe (Thrupp., 1991), making their population susceptible to pesticides exposure and health risks. Children are especially vulnerable, and their brain development is more vulnerable to toxic substances in their surrounding environment. Many studies have highlighted the association between pesticides exposure and negative consequences in children's neurodevelopment (learning disabilities, ADHD, memory, developmental delays, behavioral problems, intellectual ability). This case study explores the impact of specific pesticides metabolites (chlorpyrifos: TCPy, mancozeb: ETU, and pyrethroids: 3-PBA) in children's neurodevelopment in Talamanca, Costa Rica, living near banana plantations (De Joode et al., 2016).

II. Background

Banana production in Costa Rica relies on monoculture of Cavendish varieties, exporting more than 120 million boxes (2.18 million tons) of bananas per year, mostly to Europe (53%) and the US (32%) (Bruhl et al., 2023). The earnings of banana production represent 36.6% of Costa Rica's agricultural exports, providing jobs for more than 40,000 people (SEPSA., 2018). Meaning high amounts of pesticides are being used constantly, even high application of insecticides leads to pest resistance. In addition, several of these pesticides, used in banana plantations, have been restricted or banned in the EU (e.g. mancozeb and chlorpyrifos) (Duran et al., 2013). This exposes all the population to pesticides consumption and even more of the population living near banana plantations. Furthermore, children are more vulnerable to the health negative effects due to pesticides exposure.

Historically, the spread of multiple tons of pesticides in the environment has been linked to health risks in living organisms and in humans. Different pesticides are known to affect different parts of our body system. In specific, many studies have linked neurodevelopment problems in children, demonstrating cognitive and behavioral deficits. For instance, one study showed that higher chlorpyrifos concentrations in the cord blood of inner-city children in New York City were associated with developmental delays at age 3 and lower IQ scores at age 7 (Rauh et al., 2011). In addition, another study in the U.S showed an increased parent-reported behavioral problems (attention deficit and hyperactivity) in young children with higher pyrethroid concentrations in urine (Wagner-Schuman et al., 2015). Moreover, children can be exposed to chemical pyrethroids in their houses, since they are used to control indoor pests and control vector borne diseases (ATDSR, 2003)

III. Case Study Focus

This case study focuses on a cross-sectional study conducted in Talamanca County, Costa Rica, between February and August 2007. The objective was to evaluate if children's exposure to chlorpyrifos, mancozeb, and pyrethroids was associated with impaired cognitive, motor, behavior, and sensory outcomes, by evaluating the following variables: intellectual abilities, behavioral problems, sensory function (color discrimination), perception and memory, motor function. They evaluate children (n = 160) from 6 to 9 years-old with no history of neurological disorders and who lived no less than a year near three different banana plantations.

- The first village with large-scale banana plantations with extensive pesticide use, including aerial spraying of mancozeb and chlorpyrifos-treated bags.
- The second village had a small plantain farm using pesticides (ground-level applications of mancozeb and use of chlorpyrifos-treated bags).
- The third village where small holders grew organic plantations.

A.

B

C.

IV. Data & Analysis

The study assessed children's (between 6.5 to 9.3 years-old) exposure to pesticides found in banana plantations in Costa Rica by measuring pesticide metabolites (chlorpyrifos: TCPy, mancozeb: ETU, and pyrethroids: 3-PBA) in their urine. The major findings included that higher TCPy concentrations in urine were significant associated with lower working memory and visual-motor coordination in boys, increased prevalence of parent-reported cognitive problems/ inattention, oppositional disorders and ADHD, and decreased ability to discriminate colors. Moreover, higher ETU concentrations were significantly associated with poorer verbal learning

outcomes; and higher 3-PBA concentrations were significantly associated with poorer processing speed scores, particularly in girls. Additionally, they observed null associations of urinary ETU and 3-PBA concentrations and parent-reported behavioral problems and motor outcomes.

Table 2. Description of urinary pesticide concentrations (μg/L) in children aged 6-9 years, Talamanca County, Costa Rica, 2007.

Pesticide metabolite	Samples collected on the day of neurodevelopment assessment (n = 140)			Repeated samples (n = 207, children = 140)			
	% > LOD[a]	Median (P25-P75)	Max	% > LOD[a]	Median (P25-P75)	Max	ICC
TCPy	57	1.4 (0.7-3.1)	9.6	62	1.6 (0.7-3.2)	26.8	0.52
ETU	96	1.2 (0.7-3.0)	11.0	97	1.6 (0.8-3.8)	34.5	0.67
3-PBA	94	0.8 (0.5-1.5)	20.4	94	0.7 (0.4-1.3)	20.4	0.32

Abbreviations: LOD, limit of detection; ICC, intraclass correlation coefficient; TCPy, 3,5,6-trichloro-2-pyridinol; ETU, ethylenethiourea; 3-PBA, 3-phenoxybenzoic acid.

[a] LOD for TCPy = 1.0 μg/L; and for ETU and 3-PBA = 0.1 μg/L.

Table 6. Odds ratios (and 95% CI) of adjusted[a] logistic models for neurobehavioral outcomes in children aged 6-9 years, per 10-fold increase in urinary pesticide concentrations (μg/L), Talamanca County, Costa Rica, 2007 (n = 124).

Outcomes[b]	TCPy	ETU	3-PBA
Sensory function (color discrimination)			
LDD-15 (mean CCI ≥ P50)	3.5 (1.0, 12.9)*	1.2 (0.5, 2.9)	0.8 (0.3, 2.2)
LDD-15 (mean CCI ≥ P75)	6.6 (1.6, 30.3)*	1.1 (0.4, 3.1)	1.7 (0.5, 5.8)
Behavioral problems			
CPRS-R (T-scores ≥ P50):			
Cognitive Problems/Inattention	3.2 (0.9, 11.8)#	1.0 (0.4, 2.4)	0.5 (0.2, 1,4)
Oppositional Disorder	3.8 (1.2, 13.5)*	0.6 (0.2, 1.3)	1.6 (0.6, 4.5)
Hyperactivity	1.9 (0.6, 6.3)	1.4 (0.6, 4.3)	1.1 (0.0, 10.1)
ADHD Index	2.0 (0.6, 6.7)	0.7 (0.3, 1.4)	0.6 (0.2, 1.6)
CPRS-R (T-scores ≥ P75):			
Cognitive Problems/Inattention	5.8 (1.6, 22.9)**	1.0 (0.4, 2.4)	0.7 (0.2, 2.0)
Oppositional Disorder	3.9 (1.0, 16.0)*	0.7 (0.3, 189)	1.5 (0.5, 5.0)
Hyperactivity	2.6 (0.6, 10.8)	1.1 (0.4, 2.8)	0.8 (0.2, 2.6)
ADHD Index	6.8 (1.8, 28.6)**	0.9 (0.4, 2.2)	0.8 (0.2, 2.6)
Psychomotor speed			
Reaction time test (raw scores ≥ P50)[c]	2.4 (0.7, 8.9)	1.3 (0.6, 3.1)	0.4 (0.1, 1.3)
Reaction time test (raw scores ≥ P75)[c]	2.1 (0.5, 8.5)	1.5 (0.6, 4.3)	0.7 (0.2, 2.6)

Abbreviations: TCPy, 3,5,6-trichloro-2-pyridinol; ETU, ethylenethiourea; 3-PBA, 3-phenoxybenzoic acid; OR, odds ratio; CI, confidence interval; CPRS-R, Conner's Parent Rating Scale-Revised; ADHD, attention deficit/hyperactivity disorder; LDD-15, Lanthony Desaturated D-15 test; and CCI, color confusion index.

[a] Models adjusted for maternal education, child's sex, age at assessment, body mass index, number of siblings, urinary creatinine levels (measured in the same samples in which pesticide concentrations were quantified), and visual acuity impairment.

[b] Reference category for all outcomes: raw scores, T-scores, or mean ICC < 50 or 75th percentile, respectively.

[c] Data missing for 5 children.

# $p < 0.10$; * $p < 0.05$; ** $p < 0.01$.

V. Solutions & Interventions

For this case study, the authors concluded that children (boys and girls) living near banana plantations in Costa Rica are exposed to pesticides and its negative effects on their neurodevelopment. They recommended implementing measures to reduce pesticides exposure in children living close to banana and plantain plantations, to prevent possible neurobehavioral effects. No more solutions and interventions were mentioned by the authors. However, looking at other studies, a possible solution is by educating people about pesticides exposure and human health risks (Gilden et al., 2009). For instance, in this study they educated doctors too, so they are aware when doing a diagnostic. Therefore, it is crucial to educate professionals and the community about the health risks of being exposed to pesticides, to protect their health. By doing workshops on pesticides health risks, how to use less pesticides on crops (e.g. Integrated Pest Managment), and incentivizing organic farming for the community.

VI. Discussions & Implications

The authors discussed how this study could be improved and some studies that would have different or similar results. For instance, they mentioned that one of their strengths was estimated pesticides exposure by using biomonitoring, which is considered the best standard for exposure assessment. Additionally, they explained that they obtained repeated urine samples which allowed them to understand pesticides concentration in the urine for long-term exposures. On the other hand, they highlighted that it was a relatively small sample size, and it is a cross-sectional study designed. Therefore, even though the study had its limitations, it has many strengths and shows the possible negative effects on children's neurodevelopment who lived near plantations, exposing them to pesticides.

VII. Takeaways

This case study shows that children living near banana plantations in Costa Rica are at risk of neurodevelopmental issues due to exposure to pesticides like chlorpyrifos, mancozeb, and pyrethroids. The findings linked these exposures to significant problems with memory, behavior, learning, and coordination.

Despite some study limitations, the results highlighted the need for stricter pesticide regulations, greater public awareness, and education, especially in vulnerable communities in developing countries. Overall, the case study emphasizes the importance of protecting children's health through better environmental policies, practices and the urge for a more equal system.

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Pyrethrins and Pyrethroids | Public Health Statement | ATSDR

Introduction

The unprecedented demand for high-efficiency batteries for electric vehicles and other electronic devices has generated increased demand for lithium-ion batteries (Kaunda, 2020c). Lithium is highly coveted due to its lightweight nature and ability to store large amounts of energy (Kaunda, 2020c). Some estimates suggest that demand for lithium-ion batteries will reach 2.2 million tons by 2030 (Díaz Paz et al., 2023b). Consequently, lithium mining and extraction has generated significant interest across various sectors of industry and society (González & Snyder, 2022b). Abundant sources of lithium on Earth are scarce, but where it is present, it can be found in brines and a type of granitic rock called pegmatite, which typically contains minerals such as spodumene, lepidolite, petalite, and zinnwaldite. Although little information exists on the environmental impacts of lithium extraction, the current raw material (Kaunda, 2020c). This often overlooked extractive facet of the transition to a green economy is clearly seen in South America, where there has been a lithium mining boom. The countries of Bolivia, Chile, and Argentina are very important in the lithium industry, as they make up the Lithium Triangle (where the world's largest lithium deposits are located) (Dorn & Gundermann, 2022b). These three countries contain more than half of the world's lithium resources and more than 80% of lithium brine reserves (Argento and Zícari, 2017; Dorn, 2021a). Of these countries, only Argentina allows exploitation freely through concessions, and this permissive regulation, combined with low taxes, makes it especially attractive to foreign mining companies (González & Snyder, 2022b). The industries are mostly considered in the northwestern provinces of Catamarca, Jujuy, and Salta. Lithium mining has many implications, Lack of water in the region is not only the single potential problem. Toxic chemicals can leak from the evaporation pools to the water supply, such as hydrochloric acid, which is used in the processing of lithium – as well as waste products that can filter out of the brine (Kaunda, 2020c).

Background

In Argentina, lithium exploitation began in 1997 in the Salar del Hombre Muerto, with the Fénix Project of the Food Machinery Corporation (FMC) (Escosteguy et al., 2024b). In 2014, the company Sales de Jujuy managed the Olaroz Project to exploit the Salar de Olaroz-Cauchari, which has rapidly increased Argentine production (Dorn & Gundermann, 2022b). Argentine lithium carbonate exports reached US$356 million in 2018, ranking second only to Chile, with exports of US$1 billion (OEC, 2020)(Díaz Paz et al., 2023b). As more mining companies develop sustainable development programs, the insight provided by life cycle assessment will be invaluable to management. As part of the push towards good global citizenship, mining companies have been adopting ISO 14001 certification of environment management systems (Kaunda, 2020c). Political institutions, histories, and cultures as neighboring subnational units in a federal system, there is striking variation both among and within them in the modes of extraction; that is, how lithium mining projects launched by transnational mining companies (TMCs) articulate with local actors, especially Indigenous communities and the provincial government (González & Snyder, 2022b).

Case study focus

The major problem with lithium mining in Argentina stems from various environmental issues, but more specifically the drying up of the Los Patos River in the city of San Juan (Díaz Paz et al., 2023b). For this reason, in March 2024, the Supreme Court of Catamarca ordered the suspension of new mining projects (Escosteguy et al., 2024b). This occurred on the grounds that decisions regarding mining operations were authorized without proper consultation regarding environmental impact assessment (Escosteguy et al., 2022b). This problem also seriously affected the society, as its rivers were experiencing drought, affecting their daily activities, which required the use of this river (Díaz Paz et al., 2023b). Conflicts within society were also generated by the lack of consultation with communities and their lack of consent for mining activities (Escosteguy et al., 2022b). Problems were also generated by the appropriation of indigenous lands by mining industries (Dorn & Gundermann, 2022b). At the same time, the distribution of benefits was not economically equitable since indigenous peoples did not receive a reward for it and were also at a disadvantage in terms of land and water (Díaz Paz et al., 2023b).

Data and analysis

This major problem has led to evidence of various defects in the ecosystem and human health. As mentioned above, lithium extraction requires large amounts of water in regions where this resource is scarce. Levels of water pollution were also recorded, which could have been caused by improper handling of the chemicals normally used in the extraction process. Lithium mining activities in this specific area alter hydrological flow and that of the salt flats. The intensive use of water also causes dry land and destabilization of soil structures. Finally, another environmental factor altered by this activity is the destruction of the habitat of different species that depend on this specific ecosystem, such as migratory birds. Regarding human health, this activity can generate dust that causes problems for workers or nearby communities. Some of these problems can include respiratory irritation, coughing, or pneumoconiosis (Kaunda, 2020c). The release of particulate matter into the air can cause bronchitis, asthma, etc (Kaunda, 2020c). The lack of available water can lead to a lack of drinking water and poor hygiene, among other conditions, often leading to waterborne diseases (Díaz Paz et al., 2023b). The loss of water quality due to accidental spills or improper waste management can also cause various waterborne diseases (Kaunda, 2020c). Finally, due to water scarcity, there was a significant loss of indigenous agricultural activities, leading to malnutrition, stress, uncertainty, and, in many cases, mental health issues (Díaz Paz et al., 2023b).

Solutions and interventions

To regulate this situation, which was seriously affecting Indigenous peoples and the rest of the community, various laws and reforms were created. First, the 1994 reform recognized the ethnicity and cultural preexistence of Indigenous people (Dorn & Gundermann, 2022b). This

reform ensured that mining industries would consult Indigenous communities and give them a voice in the management of their natural resources and in decisions that could directly affect them (Escosteguy et al., 2022b). In 2002, the General Environmental Law was also created, which establishes minimum requirements for environmental protection (Kaunda, 2020c). Finally, there are certain actions that individuals can take to contribute to a possible solution. Some of these actions we can take includes educating ourselves and the community about the impact of water resources, Indigenous communities, and ecosystems. We can also use the vast influence of the media to amplify awareness of this issue. It's important to mention that reducing the use of lithium batteries, recycling them, and promoting new regulations and laws for lithium mining would be a significant help in addressing this issue.

Discussion and implications

Lithium mining in Argentina represents a major advance in energy production, but it also leads to various social and environmental conflicts. In northern Argentina, specifically in the Salar del Hombre Muerto and Olaroz-Cauchari salt flats, mining activity has led to water shortages, ecosystem damage, and violations of indigenous rights (Díaz Paz et al., 2023b). As a result, various legal actions have been taken, such as the suspension of new projects and stricter regulations on environmental justice and protection of the rights of local indigenous communities (Escosteguy et al., 2024b). For lithium extraction to truly contribute to sustainable energy, its extraction must be regulated and responsible for the environment and society (Kaunda, 2020c).

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Impact of Mining Pollution including Lead, Cadmium and Mercury: Health Crisis in Cerro de Pasco, Peru

[redacted]

[redacted] Environmental Helath BIO 424

Profesor: Dr. Daniel Elias

1. Introduction:

   Cerro de Pasco is a mining town in the Andes, founded in the 16th century at over 4,000 meters high. Since the 1950s, an open pit mine has been growing in the middle of the city, destroying much of its historic center. Even though the mine has made millions in profits, the people who live there face poverty and harsh living conditions. Most residents don't have clean drinking water, and the little water they do get is very expensive and only available for a few hours a day. It's also very cold, and most homes don't have hot water.

   Cerro de Pasco has a long history of being controlled by mining companies. Since colonial times, everything the town produced was sent abroad, and the mine even had its own railroad to the coast. Over time, the company bought local farmland and encouraged people to move to the city and work in the mines (Lefevre 2022).

2. Background:

   The extensive mining and lack of regulations have led to extensive environmental contamination and health crises resulting in cognitive impairments in the population, children are the most affected.

   The Raúl Rojas open pit Mine Central, operated by Volcan Compañía Minera S.A.A., is the primary mining site today. Volcan is Peru's largest zinc and silver producer, and its biggest shareholder is the Swiss commodity trader Glencore (Mongabay, 2023).

3. Health Impacts

    a. Lead

    Lead exposure has significant impacts on multiple physiological systems, with the hematological system being among the first to show signs of toxicity. One of the key mechanisms involves the inhibition of enzymes critical for heme synthesis; this is a process essential for producing heme, the iron-containing component of hemoglobin and other vital proteins. This biosynthetic pathway occurs partly in the mitochondria and cytoplasm and is tightly regulated by several enzymes. Lead specifically interferes with heme synthetase, which causes the accumulation of free erythrocyte protoporphyrin (FEP), which results in anemia (Hernberg & Nikkanen, 1970).

    The nervous system is also affected to lead toxicity. Lead disrupts mitochondrial function, which may impair neurodevelopment, especially in vulnerable populations like children (EPA 1977). In children, moderate lead exposure has been associated with various central nervous system impairments, including attention deficits, cognitive delays, fine motor dysfunction, and abnormal electroencephalogram (EEG) patterns. In more severe cases, lead toxicity can progress to encephalopathy, coma, and even death (Kim et al., 2013). In adults, lead exposure can affect the peripheral nervous system (PNS).

    In addition, lead affects the renal system, especially on kidney tubules. Functional impairments may include proteinuria glycosuria, and hyperphosphaturia. Structural damage is also visible, with mitochondrial injury and the formation of inclusion bodies within renal cells. Long-term or high-level lead exposure can result in irreversible nephropathy. These renal effects are more frequently observed in occupational settings and there are not enough studies in pediatric populations (Hutton, 1987).

    b. Mercury

    Mercury, particularly in the form of methylmercury, poses a significant risk to the central nervous system (CNS), with its most pronounced effects observed in sensory, visual, and auditory functions. It also targets brain regions responsible for coordination and balance, making motor control a primary area of concern in mercury toxicity (WHO 1976). Early clinical manifestations of methylmercury poisoning include tingling sensations (paresthesias) in the tongue, lips, and extremities, as well as blurred vision, narrowing of visual fields, and ataxia—a condition marked by impaired muscle coordination and balance (Piotrowski & Inskip, 1981).

    Some populations are particularly vulnerable to methylmercury exposure. Fetuses and infants are at elevated risk, often exhibiting neurological effects even when the mothers show no symptoms, underscoring the heightened sensitivity of the developing nervous system (WHO, 1976). Pregnant women are also more susceptible to the toxic effects of methylmercury than other adult populations. Research

indicates that even low-level exposure during pregnancy can have lasting consequences on fetal development (Marsh et al., 1977).

c. Cadmium

Cadmium primarily targets the kidneys, especially under conditions of long-term exposure. The renal system serves as the main site of cadmium accumulation and toxicity, with the proximal tubules being particularly vulnerable. One of the earliest and most consistent clinical indicators of cadmium-related kidney damage is proteinuria, which results from the impaired reabsorption function in these tubules. This dysfunction typically involves the loss of low molecular weight proteins such as α_2-, β_2-, and γ-globulins, reflecting the disruption of normal tubular processing and filtration mechanisms (WHO 1992)

4. Environmental Impacts

a. Soil and Water pollution:

Soil and water pollution caused by heavy metals is an environmental concern. Major sources of heavy metal contamination include mining activities, industrial waste disposal, and agricultural runoff. The mentioned processes release metals such as lead, cadmium, mercury, and arsenic into the environment, where they accumulate in soils and freshwater ecosystems (FAO 2018). The presence of these metals in soil affects microbial activity, reduces soil fertility, and lowers crop productivity. In addition, contaminated soil can facilitate the transfer of toxic metals to plants and food crops, causing serious risks to human health and food security through the food chain (WHO 2007; FAO 2018).

b. Air Pollution:

The heavy metals studied are significant contributors to air pollution. Lead and mercury are primarily emitted into the atmosphere through activities like coal combustion, metal smelting, and waste incineration. In a similar way, cadmium is released during zinc and phosphate mining, battery production, and the burning of fossil fuels. These metals often attach to fine particulate matter (PM2.5), making them easily inhalable by humans. Inhalation of metal-bound particulates has been linked to serious health effects, including cardiopulmonary disease, neurotoxicity, and an elevated risk of cancer (World Health Organization (WHO 2013).

c. Water resources problem:

Industrial and mining operations across the world contribute to water resource problems by diverting and overconsuming freshwater supplies, which affects surrounding communities and ecosystems (United Nations Water 2021).

Water scarcity becomes a bigger problem when groundwater and surface water become contaminated with heavy metals, making these sources unsafe for consumption and irrigation.For example, mercury contamination from gold mining activities, particularly in the Amazon region and Sub-Saharan Africa, is a major concern; these heavy metal bioaccumulates in fish, causing severe risks to both wildlife and Indigenous human populations who rely on this ecosystem. industries (WHO 2017)

d. Loss of Biodiversity

Heavy metal contamination causes biodiversity loss, particularly in aquatic and wetland ecosystems. Metals such as lead, mercury, and cadmium disrupt aquatic food webs by inducing toxicity in key organisms often in the first stages of the trophic level like invertebrates, fish, and amphibians. These toxic effects lead to declines in survival rates, impaired reproduction, and developmental abnormalities (WHO 2017). Mercury is especially concerning because it can be transformed into methylmercury, which is a neurotoxin that bioaccumulates in predatory species like tuna and birds of prey, magnifying its effects up the food chain (UNEP 2019). Lead exposure in birds has been shown to interfere with neurological functions and reproductive success, and cadmium exposure can alter enzyme activity and weaken immune system responses in wildlife (WHO, 2017).

5. Case Study: Heavy metal exposure in children and women of childbearing age in three mining communities. Cerro de Pasco, Peru. May 21 – July 4, 2007

a. Purpose: Conducted in 2007 by the CDC, requested by MINSA and DIGESA to assess heavy metal exposure in children (1–12 years) and women of reproductive age from three communities: Chaupimarca, Ayapoto, Paragsha. Biological and environmental samples were taken (blood, urine, soil, dust, water). State-of-the-art laboratory techniques (ICP-MS) used to detect 14 heavy metals (but I'm going to focus in Pb, Hg and Cd)

b. Population Studied

- 357 participants total: 163 children and 194 women of reproductive age.
- 91% of children and 82% of women had at least one metal level above the reference.
- Lead: 53.3% of children and 9.4% of women had lead blood levels ≥10 μg/dL (CDC's level of concern). Max levels: 64 μg/dL (child), 51 μg/dL (woman).
- Cadmium and Mercury also detected, but not as prevalent as lead.

c. Health Implication Measured

- Lead: Neurocognitive effects in children, anemia, developmental delays.

- Cadmium: Kidney damage, skeletal effects.
- Mercury: Neurological disorders (especially in fetuses and young children).

d. Environmental Results

- Soil contamination: 79% of homes had soil lead >400 ppm, and 60% >1200 ppm (EPA limits). Dust inside homes and public areas (schools, football fields) also had elevated lead.
- Water samples: Most were under the 15 μg/L EPA limit, but some exceeded, up to 2100 μg/L near mineral piles.

e. Risk factors highlighted:

- Living in Ayapoto or Paragsha possess higher risk.
- Other major factors:
  - Living with a miner.
  - Children who ate dirt/paint (pica).
  - Homes with high soil lead.
  - Washing contaminated clothes.
- Strong correlation between soil lead and blood lead.

f. Recommendations

- Community level: Cover mining transport trucks. Reroute mining traffic away from neighborhoods. Create barriers around mineral piles.
- Household level: Encourage handwashing, cleaning surfaces, storing water in covered containers. Replace dirt floors, remove contaminated soil.
- Individual: Medical monitoring of pregnant women and young children. Chelation therapy for BLL ≥45 μg/dL.

(Laura etal. 2007)

6. Data and Graphs from Case Study

Tabla 1. Participación en el estudio por comunidad, Cerro de Pasco, Perú, mayo-junio 2007

Comunidad	Número de lotes seleccionados	Meta de reclutamiento		Número de participantes inscritos (% de la meta)	
		Mujeres en edad fértil	Niños	Mujeres en edad fértil	Niños
Chaupimarca	500	268	318	99 (37%)	87 (27%)
Ayapoto	70	70	70	48 (69%)	41 (59%)
Paragsha	108	35	42	47 (134%)	35 (83%)
Total	678	373	430	194 (52%)	163 (38%)

Tabla 2: Disposiciones y normas sobre el plomo en los Estados Unidos

Agencia	Medio	Nivel	Comentarios
Centros para el Control y la Prevención de Enfermedades	Sangre	10 µg/dL	Advertencia; nivel de manejo individual
Agencia de Protección Ambiental	Suelo (residencial)	400 ppm (áreas recreativas) 1200 ppm (áreas no recreativas)	Nivel límite para el análisis de las muestras de suelo; requisito para programas que reciben fondos del gobierno federal de los Estados Unidos.
Agencia de Protección Ambiental	Polvo (piso)	40 µg/ft^2	Nivel de acción para actividades de limpieza
Departamento de Vivienda y Desarrollo Urbano	Polvo (piso)	100 µg/ft^2	Nivel de acción para actividades de limpieza
Agencia de Protección Ambiental	Agua (potable)	15 µg/L	Nivel de acción en instalaciones de suministro público
		0 µg/L	Meta no obligatoria; MCLG

Tabla 5. Resultados ponderados de los niveles de metales pesados en sangre y orina comparando las medias geométricas y los rangos de los participantes con las medias geométricas y los rangos en los Estados Unidos, Cerro de Pasco, Perú, 2007 †

	Nivel de detección (LOD)	Valores de referencia≠	Nivel de acción‡	Mujeres en edad fértil				Niños			
				Media	IC 95%	Rango	Elevado¥	Media	IC 95%	Rango	Elevado¥
SANGRE											
Plomo	***0.25***	***<10.0****	***10.0***	***5.8***	***(5.5, 6.2)***	***1.8-51.0***	***9.4%***	***10.5***	***(9.7, 11.3)***	***3.6-64.0***	***53.0%***
Cadmio	0.20	0.3-1.3	-	0.72	(0.67, 0.78)	0.23-3.4	10.5%	0.32	(0.30, 0.34)	0.14-2.2	1.0%
Mercurio (total)	0.33	0.3-1.9 (niños) 0.3-4.6 (MEF)	10	1.12	(1.03, 1.19)	0.33-4.8	0.9%	0.88	(0.81, 0.95)	0.23-3.7	7.0%
ORINA											
Antimonio	0.032	0.13-0.34	-	0.13	(0.11, 0.14)	<LOD-1.56	12.8%	0.16	(0.14, 0.17)	<LOD-1.01	17.5%
Arsénico (total)	0.74	<100*	100	18.2	(16.2, 20.4)	2.7-361.5	3.4%	19.3	(17.1, 21.7)	2.0 -278.7	2.5%
Bario	0.12	1.63-7.48	-	0.86	(0.75, 0.98)	<LOD-14.80	1.4%	0.68	(0.59, 0.78)	<LOD-8.98	0.9%
Berilio	0.072	<0.13	-	<LOD	(<LOD)	<LOD	0	<LOD	(<LOD)	<LOD	0
Cesio	***0.066***	***5.5-12.6***	-	***19.4***	***(17.0, 22.1)***	***2.0-489.0***	***69.6%***	***19.0***	***(16.3, 22.1)***	***2.56-382.0***	***63.1%***
Cobalto	0.041	0.41-1.27	-	0.55	(0.49, 0.63)	0.06-19.40	15.0%	0.43	(0.37, 0.49)	<LOD-6.02	10.3%
Molibdeno	0.92	52.4-165.0	-	67.9	(59.6, 77.3)	5.4-489.0	17.8%	70.2	(60.9, 80.9)	9.5-1440.0	17.3%
Platino	0.009	<0.04	-	<LOD	(<LOD)	<LOD-0.014	0	<LOD	(<LOD)	<LOD -0.012	0
Talio	***0.015***	***0.18-0.44***	***20***	***0.77***	***(0.68, 0.86)***	***0.16-33.30***	***70.7%***	***0.65***	***(0.57, 0.74)***	***0.015-23.6***	***70.5%***
Tungsteno	0.021	0.06-0.45	-	0.09	(0.07, 0.10)	<LOD-1.36	3.6%	0.13	(0.11, 0.15)	<LOD-6.39	6.3%
Uranio	0.0017	0.008-0.046	0.05	0.0029	(0.0027, 0.0032)	<LOD-0.021	0	0.0036	(0.0033, 0.0040)	<LOD-0.017	0%

Figura 1. Porcentajes de niños y mujeres en edad fértil con niveles elevados de metales pesados, Cerro de Pasco, Perú, 2007*

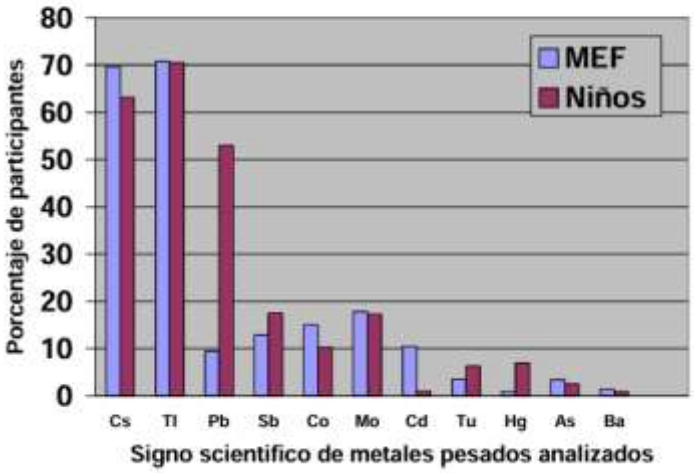
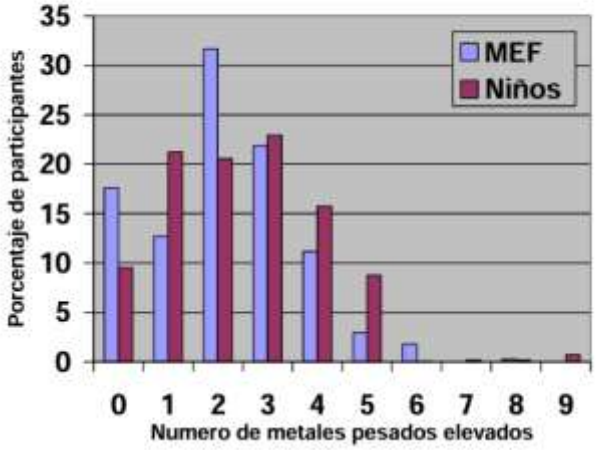
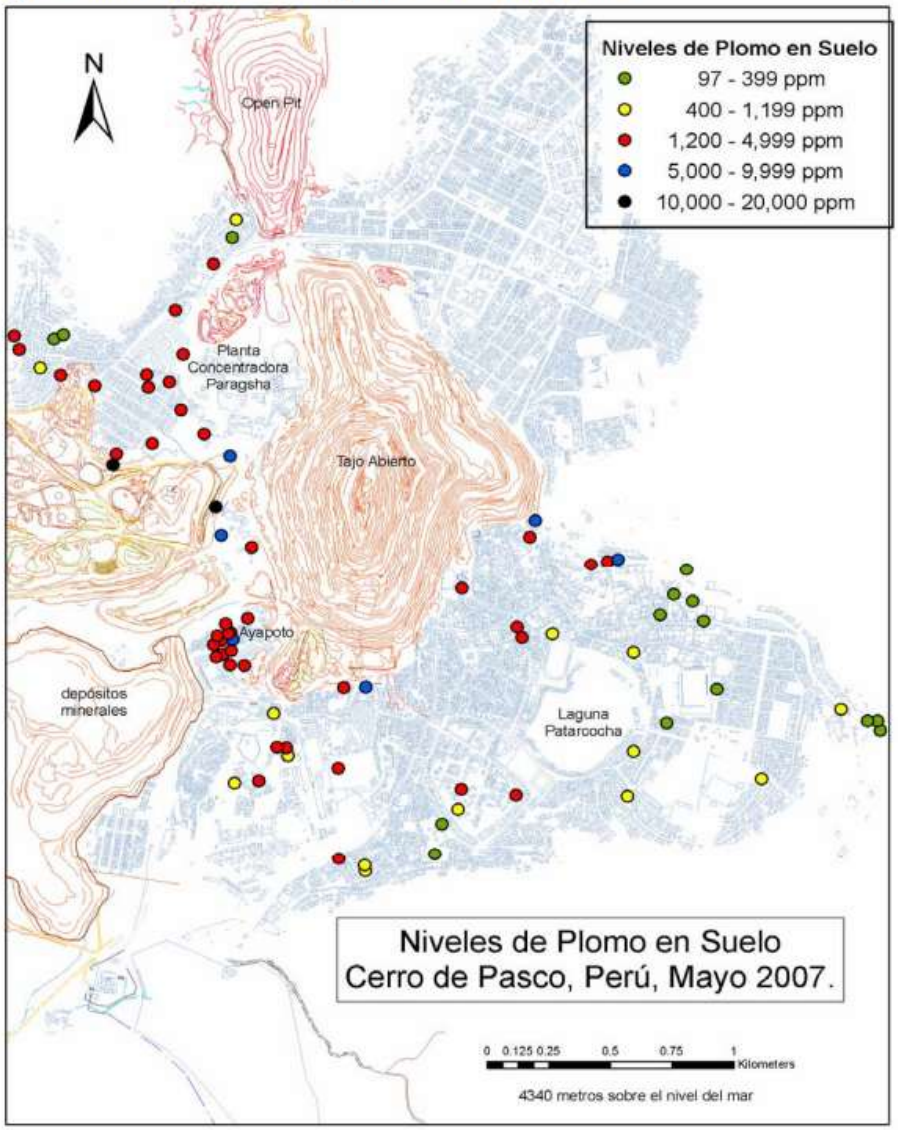


Figura 2: Porcentajes de Niños y mujeres en edad fértil con más de un nivel elevado de un metal pesado, Cerro de Pasco, Perú, 2007



Mapa 1. Niveles de plomo en suelo, Cerro de Pasco Peru - 2007



7. Solutions and Remediations

   Focus on the thesis: Environmental Pollution Cerro de Pasco, Approaches and Proposals Pasco - 2022.

   a. Household-Level Actions

      - Soil replacement in homes with dirt floors to reduce lead ingestion risks.
      - Frequent cleaning with wet cloths to minimize indoor dust contamination.
      - Encourage handwashing, particularly in children, to reduce ingestion of contaminated particles .

   b. Community-Level Interventions

      - Fencing off contaminated areas, especially around tailings piles and mineral stockpiles (e.g., Quiulacocha and Excelsior) .

- Re-routing mining trucks away from neighborhoods to reduce airborne heavy metals.
- Dust control measures, such as covering trucks and wetting down roads.

c. Water System Improvements
   - Installation of water filtration systems to remove metals like cadmium, arsenic, and mercury from household water supplies.
   - Infrastructure upgrades to prevent leakage from tailings into drinking water sources.

d. Medical and Public Health Monitoring
   - Chelation therapy for individuals with blood lead levels ≥45 μg/dL.
   - Regular biomonitoring of children and pregnant women for early detection.
   - Nutrition interventions (e.g., calcium and iron supplementation) to reduce heavy metal absorption.

e. Legal and Institutional Reforms
   - Strict enforcement of environmental liability laws: companies must remediate environmental damage, including historical liabilities (e.g., from Cerro de Pasco Copper Co.).
   - Creation of a regional health registry for exposed populations.
   - Recognition of mining-related health issues as public health emergencies, requiring rapid government response.

f. Long-Term Restoration and Justice
   - Environmental reforestation and soil recovery projects to rebuild ecosystem functions.
   - Community-led environmental watchdog groups to ensure ongoing transparency.
   - Resettlement of highly exposed communities as a last resort, ensuring full compensation and access to clean environments.

Resources

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