Syndemic Health Impacts and Environmental Risk Perceptions Associated with Mining Among the Ch'orti' of Eastern Guatemala

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ABSTRACT

In low-income, rural, and indigenous communities, metal mining is associated with numerous negative social, political, economic, human, and environmental health impacts. A number of studies from around the world have looked at specific aspects of human and environmental health related to various contaminants from mining and the landscape alterations associated with the processes, along with the growing community resistance and opposition to mining operations. The individual impacts of each of these components are understood, but a deeper understanding of the syndemic effects of a mine operating in a community, particularly in an indigenous community, was needed, especially as the industry is expected to grow around the world. Using a community-based participatory research (CBPR) approach, we utilized a combination of participatory mapping, interviews, and community mapping workshops to examine the underlying patterns and perceptions of environmental risk and healthy and unhealthy spaces in the Ch'orti' communities of Olopa, Guatemala that have been impacted by the Cantera Los Manantiales antimony mine. Results suggest that, since mining operations began, residents have experienced an increase in violence and community divisions surrounding the mine, a higher incidence of a variety of diseases, and an extensive loss of crops and domesticated animals. Furthermore, participants were concerned about both water and air contamination, all of which they attributed to the mine. The results of the study will be useful for local activist leaders and allied NGOs to effectively assess and improve health in indigenous communities impacted by the Cantera Los Manantiales mine in Olopa. The approach, particularly the use of participatory mapping methods, could be implemented in future studies attempting to understand syndemics and other environmental health risks and outcomes.

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GENERAL AUDIENCE ABSTRACT

In low-income, rural, and indigenous populations, metal mining is associated with numerous negative social, political, economic, human, and environmental health impacts. A number of studies from around the world have looked at the specific ways that human and environmental health are impacted by mining processes, along with how and why communities protest mining operations. Each effect is well understood, but a deeper understanding of how those effects of a mine operating in a community interact was needed, especially as the mining industry is predicted to grow. Involving the community throughout the study, we used interviews and maps made by members of the Ch'orti' communities of Olopa, Guatemala that are impacted by the Cantera Los Manantiales antimony mine to understand patterns and perceptions of environmental risk and healthy and unhealthy places. Results suggest that, since mining operations began, residents have experienced an increase in violence and community divisions surrounding the mine, an increase in disease and illness, and an extensive loss of crops and domesticated animals. Furthermore, participants were concerned about both water and air contamination, all of which they attributed to the mine. The results of the study will be useful for local activist leaders and allied organizations to understand and improve health in the communities impacted by the Cantera Los Manantiales mine in Olopa, and the mapping methods that were employed will be useful for future studies that are mapping interacting health threats and outcomes.

DEDICATION

Dedicada a los Maya Ch’orti’ de Olopa y a las otras comunidades que también luchan por defender el territorio, la vida, y a la Madre Tierra.

Dedicated to the Maya Ch'orti' of Olopa and to the other communities also fighting to defend their land, their lives, and Mother Earth.

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CONTENTS

CHAPTER I: Problem Statement

1.1 Problem Statement

Mining provides numerous raw materials that society needs and depends upon, with sectors such as energy, technology, construction, agriculture, communication, and more relying on mined materials for operation and product development. However, mining often results in irreversible landscape alterations that in turn result in an array of negative ecological and human health outcomes if not mitigated. Mining impacts in less wealthy countries, such as Guatemala, are partly due to the lack of mitigation when associated technology shifted to support capital intensive open-pit mines (Smith and Helfgott, 2010) that produce more than fifty times the waste rock of underground mines run by unskilled laborers (Ripley et al., 1978). Many of these new open-pit mines around the world are located on indigenous lands, upon which local indigenous people are dependent for survival.

Several studies from around the world have looked at specific aspects of human and environmental health related to various contaminants from mining, like those by Abdul-Wahab and Marikar (2012), Saha (2011), and Kuecker (2007), who looked at the effects of mining in terms of heavy metal contamination in Oman, environmental degradation in India, and community divisions in Ecuador respectively. We also know from studies done by Fashola et al. (2016) in South Africa and Ngure et al. (2014) in Kenya, and from a literature review by Stephens and Ahern (2001) of community health related to mining, that the negative effects related to mining last long after the mining operations have ceased. Due to this growing knowledge concerning the negative consequences, community resistance and opposition to mining have increased in recent years, along with violence in the communities where mining occurs (Copeland, 2019b; Kirsch, 2014; Nelson, 2015, Bebbington et al., 2008).

Gold, silver, nickel, and other metal and mineral mines are found throughout Guatemala, specifically near rural and indigenous communities (Drewry et al., 2017; Kirsch, 2014), with several international mining companies operating in the country. Though the corporations themselves receive the majority of the benefits, mining as a whole can provide economic benefits for the country in which it takes place by contributing to the national economy and the country's GDP (Drewry et al., 2017), making up .07% of Guatemala's GDP (Banco de Guatemala, 2022), as well as by employing some individuals while in operation (Yagenova and García, 2009). However, mining is also known to be associated with numerous negative human and environmental health impacts, which may outweigh associated economic benefits (Drewry et al., 2017; Stephens and Ahern, 2001).

According to the official data from the Ministry of Energy and Mines, as of 2023 there are 287 mining licenses for extraction and another 76 licensed for exploration in Guatemala (Ministerio de Energía y Minas, 2023). Artisanal miners, subsistence miners using rudimentary methods, have been extracting metals for decades from the Cantera los Manantiales, an antimony mine located in Olopa in Chiquimula, Guatemala on the traditional lands of the Maya Ch'orti' peoples. Now an open-pit mine, Cantera los Manantiales, owned previously by American Minerals SA and later by BC Enterprises, obtained the current permit in 2007 and began operations in Olopa in 2012 under local and current Guatemalan owners Guillermina and Odilio Guzmán (Toro, 2020). The antimony extraction project began operating without obtaining free, prior, and informed consent from the indigenous communities living on the land (PBI Guatemala, n.d.), and tangible effects from the mining operations have been present in the region since at least 2015, including environmental contamination and health concerns (Toro, 2020).

Guatemala boasts a high proportion of indigenous peoples, with 55% of the population identifying as part of one of the 26 distinct indigenous groups present today, one of whom is the Ch'orti' people (Holden and Jacobson, 2008; Minority Rights Group International, 2018). There are 14 Ch'orti' communities surrounding the mine that make up the Consejo Maya Ch'orti' of Olopa, an indigenous council, and all are involved in subsistence agriculture and rely heavily on their traditional lands for sustenance and income (Caxaj, 2014; Holden and Jacobson, 2008). The importance of indigenous knowledge and connection to their land is evident in their concept of buen vivir or "living well," attributing rights to nature and people for the well-being of the entire community (Bastos and de León, 2015; Copeland, 2019b). Buen vivir emphasizes the importance of balance and reciprocity, both between people and between people and the earth (Gudynas, 2011) and in Mayan spirituality, extractive industries harm Mother Earth (Rasch, 2012). They work closely with the land, are easily able to identify problems or changes, and are increasingly impacted by environmental pollution, land cover change, and soil degradation (Holden and Jacobson, 2008; Tengö, 2021), in large part because of their close relationship to the earth. The majority of Mayan communities, the Ch'orti' included, experience extreme poverty, with limited rights, healthcare, and education (Mactaggart, 2018), and they are subject to numerous language, social, and cultural barriers (Cerón et al., 2016), making them a vulnerable population.

Socioeconomic vulnerabilities are heightened by the presence of mining operations (CECON-USAC, 2019). Mining affects every aspect of health, but we do not yet know the combined impacts of the individual factors over time. In particular, we do not fully understand the syndemic effects, when two or more concurrent biological or social problems increase susceptibility to negative outcomes (Singer, 2009), or the community perceptions of these effects in populations near mines. An in-depth study of the perceptions of syndemic effects, environmental risks, and healthy and unhealthy places within a community would be useful for local community activist leaders to effectively assess and improve health in indigenous communities impacted by mining. Identifying the perceived environmental and human health consequences will assist those leaders and other organizations in better understanding the public health needs in indigenous communities where the industry is expected to grow in the coming years (Basu, 2010), and would aid other communities and social movements who oppose this expansion.

Based on interviews during our study, intense mining operations with the use of heavy machinery began in 2016 in the Cantera, with the resistance movement gaining traction six months later. Indigenous peoples have long been aware of the adverse impacts of resource extraction and have fought since the beginnings of colonialism against extractive industries. During the resistance movement in Olopa, the Ch'orti' communities, as well as several other communities from the surrounding areas, came together to protest the mine's operation on their land despite the criminalization of their efforts. Hundreds of people participated in the resistance movement which included a plantón, with people guarding the entrance of the mine day and night for several months to limit the mining operations taking place. Community members worked to suspend the mining license because they understood that they would be vulnerable to the negative impacts associated with mining.

Most studies that investigate relationships between mining and ecological and human health employ statistical techniques using morbidity and mortality data. In areas where such data are not available, such as resource-poor regions, other data collection and analysis techniques are needed. Qualitative techniques such as focus groups, interviews, and participatory mapping can offer a local perspective of the challenges people are facing within the communities. Interviews allow participants to offer explanations in their own words, producing a deeper understanding of the problem or question, while focus groups allow for ideas to be shared and developed between people. While participatory mapping is a frequently used data collection tool, particularly in studies related to land-use and land tenure, disaster risk reduction, and ecosystem services (Brown and Raymond, 2014; Klain and Chan, 2012; Cadag and Gaillard, 2012), it has not often been applied to studies of human health.

Community mapping is an underutilized but empowering tool, allowing both the community and researchers to learn more about local circumstances and community health (Douglas et al., 2019). Participatory mapping can provide a way to visualize syndemic health impacts, highlighting various facets of health and serving as a tool that can be used to analyze and better understand both social and environmental determinants of public health disparities (Douglas et. al., 2020). As systemic inequalities contribute to uneven health outcomes due to unequal access to resources, community mapping serves as a tool to obtain social and spatial knowledge that is based on lived experience in a place that demonstrates the underlying patterns of those inequalities (Douglas et. al., 2020; Forrester et al., 2015). Combined with interviews and stories, participatory mapping can offer distinct cultural understandings of a landscape that are typically omitted from official maps, providing a snapshot of the reality of life in that place, and also provides a baseline for future assessments.

Given the basic and applied research needs discussed above, and the techniques described to explore them, this study will address the following questions:

- What are the perceived human and environmental health risks of the Cantera los Manantiales among the Ch'orti'?

- What areas of the community are perceived as healthy and unhealthy, and why?
- How do perceptions of human and environmental health risks related to mining compare to risks identified in the Environmental Impact Assessment (EIA)?, and
- Where and how should local community activist leaders focus their efforts to improve human and environmental health in the area?

1.2 Positionality Statement

Being a white woman and U.S. citizen that has been fortunate enough to receive an education, I fully understand that I have been afforded numerous privileges and opportunities that my participants have not had. I very noticeably stood out in the villages I worked in, and as a result I had to answer just as many questions as I asked, and I did so openly and honestly. While being an outsider, I do speak Spanish fluently, had traveled to Guatemala on two prior occasions, and have spent extensive time in Latin America as well as with Latin American immigrants within the U.S..

While in the field I worked closely with a Guatemalan organization, OIE, that had a strong pre-existing relationship with the communities I worked with. I continued to work with OIE and other indigenous community leaders throughout the project to ensure that information was regularly shared between all of those involved. Studying extractivism, I wanted to ensure that I was not merely extracting information, but rather producing knowledge together.

I also recognize that I listened to and analyzed stories belonging to other people that I chose how to report, something that I do not take lightly, and I did my very best to convey them truthfully as they were told to me

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CHAPTER II: Literature Review

2.1 Context

This study, looking at the perceived environmental risks and health impacts of mining in Ch'orti' indigenous communities in Chiquimula, Guatemala, contributes to the sub-discipline of medical and health geography. Medical geography relates to a number of allied disciplines such as epidemiology and human ecology among others, and examines the spatial patterns of health concerns and diseases and the underlying population and environmental characteristics that may explain those patterns (Gaile et al., 2003); health geography more specifically examines and addresses well-being and health promotion through overlaps with sociology, often using qualitative methods (Moon, 2009). The sub-discipline studies variations in health across space and time, including the prevalence and impact of conditions and risk factors (Gregory et al., 2011). Examples include the construction of dams and cases of schistosomiasis, water pollution from various sources, vector spread across a habitat, and regional variations of cancer at different scales. Medical geography started with a focus on disease and pathogen-host interaction, examining topics like malaria in tropical climates or the spread of AIDS across Africa. A more recent shift includes an emphasis on health care and health inequalities along with the already present social models that promote those inequalities (Gaile et al., 2003). Some have argued for health geography as the name instead of medical geography as a way to highlight a more holistic focus, emphasizing well-being and socio-cultural theory instead of the mere presence or absence of disease. Related topics include determinants like stress, employment status, malnutrition, housing, and income that can predispose populations to negative health outcomes (Gregory et al., 2011). Medical geography serves as a way to identify patterns and connect health and environmental conditions through spatial analysis, and its ability to combine multiple hazards in both the human and natural environments results in it often playing a role in studies related to environmental justice (Gaile et al., 2003). Based on this, my study looking at the perceptions of various facets of human health and environmental risks in Guatemala fits well in the broader context of health and medical geography.

2.2 History of Guatemala

The ancient Mayan civilization made up of multiple competing kingdoms, from which the majority of the indigenous population in Guatemala descended, reached its peak during the first millennium A.D. (Metz et al., 2009). These peoples lived throughout Central America, primarily in Mexico, Guatemala, Belize, Honduras, and El Salvador, with different groups speaking different languages. They lived in an agriculture-based society with several large cities throughout the region. They developed a writing system using glyphs and a complex calendar systems, and had extensive knowledge of mathematics and astronomy (Minority Rights Group International, 2018). In Guatemala today, most of those who identify as indigenous live in departments in the north and west of the country (Minority Rights Group International, 2018).

This study focuses on the Maya Ch'orti'. The Ch'orti' people of Olopa are one of the more than twenty Maya subgroups that make up the indigenous population of Guatemala today. The Ch'orti' have lived in eastern Guatemala, Honduras, and El Salvador for centuries, with sediment cores, artwork, and pottery confirming their presence in the area as early as A.D. 100 (Metz et al., 2009). This presence has shaped the landscape over numerous generations. The synergistic coexistence contributed to the extensive knowledge that the Ch'orti' people now possess of their lands and Mother Earth. Even today, the majority of Ch'orti' people depend on their lands for shelter, food, and medicine, a dependence that has been put in jeopardy by external forces, such as the Cantera los Manantiales antimony mine.

Colonialism in Latin America began as early as the 1500s. The Spanish first arrived in Guatemala in 1524 led by Pedro de Alvarado, bringing with them a variety of new diseases and forced labor on plantations for the indigenous populations (Minority Rights Group International, 2018). Land was taken from the indigenous people and their books and codices were burned. By 1697, all of Guatemala was under Spanish rule, forming part of New Spain. During this time, gold, coffee, cotton, indigo, and sugarcane were exported from Guatemala (Minority Rights Group International, 2018).).

Historically the word colonialism has a violent connotation which remains true today, as social and economic opportunities, as well as basic rights, are dictated by another (Casanova, 1965). Colonization implies exploitation and control of natural resources and exclusive benefits afforded to the colonizers, while the native population is deprived of not only their resources, labor, and power, but at times their rights as well as the deprivation of resources is a violation of rights. Racism is the foundational principle of colonization, as differences between the colonized and colonizers are starkly emphasized (Cesaire, 2001), which results in those in the colonies frequently being unable to access even the minimum required for subsistence. Tensions between the Spanish colonizers and Guatemalan indigenous populations were high, and those tensions remain even today between the indigenous and non-indigenous.

Guatemala, Mexico, and the other modern day countries in Central America gained their independence from Spain in 1821. Guatemala is still recovering from a recent civil war fought from 1960 to 1996 between the government and rebel groups that were seeking to overcome the economic and political inequalities. The conflict was the longest in Central American history and is known as one of the most violent (World Bank, 2018). Over 200,000 people were killed and 1.5 million were displaced, the majority affected being indigenous, and the death toll included entire communities with an estimated 626 villages that were completely destroyed (Caxaj, 2014). Numerous massacres and executions took place in the Ch'orti' communities of Olopa, details of which are provided in the Comisión para el Esclarecimiento Histórico (CEH, Guatemalan Historical Clarification Commission) (CEH, 1999; Rothenburg, 2012). As part of the Truth Commission, the civil war was later recognized as a genocide by the United Nations (CEH, 1999) The Mayan peoples of Guatemala who suffered the brunt of the war and post-war violence have been on the land within the borders of the country for thousands of years living on ancestral lands. The violence, murders, kidnappings, and rapes that were common during the war have persisted long after the fighting itself ended (Shipton, 2017), still mostly targeting the indigenous populations (Navas et al., 2018).

Building pressure from the World Bank who encouraged economic development through increased industrialization and private investments led many low- and middle-income countries to reform their mining codes in the 1980s, and consequently, more lenient regulations on labor, the environment, and human health became the norm (Moody, 1996). After the signing of the peace accords in 1996 at the end of the civil war, mining corporations flooded into Guatemala due to lax environmental regulations and easy obtainment of mining permits for exploration and extraction (Drewry et al., 2017; Saha, 2011; Shipton, 2017). The mining law of 1997 allowed industries into the country without protections for indigenous populations (Shipton, 2017), despite a new article added to the constitution in 1985 recognizing the existence of Mayan groups in the country. The peace accords included an accord on the identity and rights of indigenous peoples and these communities are now arguing for their right to Free Prior and Informed Consent (FPIC) to approve mining on their lands (Aguilar-Støen and Hirsch, 2017; Caxaj, 2014). The overall lack of information and monitoring (Van de Wauw et al., 2010), and the likelihood of being provided inaccurate information, leads many communities to distrust mining companies (Drewry et al., 2017; Kirsch, 2014). There have been numerous instances of incorrect information on impact statements (Aguilar-Støen and Hirsch, 2017; Kuecker, 2007; Nelson, 2015).

The growing reliance on technology, coupled with low education levels, high rates of local and international migration, the unviability of subsistence agriculture, poor health, and the lack of infrastructure among others, means that there are extremely limited employment and income opportunities for rural workers who lack training opportunities in these communities (Kirsch, 2014). The lack of opportunities present today originated in colonial times as rights were removed at the population level, but oppression came from a different place following independence.

2.3 Internal Colonialism and the Ch'orti'

Traditionally, social classes are believed to be generated and perceived within a nation, an internal process, while colonialism has long been viewed as an international process generated by an outside nation or group. However, this is not always the case, as independence does not end colonialism, because "with the disappearance of the direct domination of foreigners over natives, the notion of domination and exploitation of natives by natives emerges" (Casanova, 1965, p. 1), a form of internal colonialism. The idea of internal colonialism originated in Latin America and has become a systemic barrier to development (Gutiérrez, 2004).

Oppression continues even after the outsiders leave, and colonialism is turned internal. At the population level, the colonized are often of a different race and culture than the colonizers, be it external or internal. Even though Guatemala gained independence from Spain in 1821, the ladinos, or non-indigenous population, maintain control over much of the indigenous population.

Overall, when compared to the colonizers, the colonized will experience limited capital, poor quality land, deficient means for securing the necessary nutrition to maintain health, disease, poor standards of living, increased mortality, decreased literacy, an overall lack of services, oppression, and prejudices (Casanova, 1965). "Internal colonialism [is] a modern capitalist practice of oppression and exploitation of racial and ethnic minorities within the borders of the state characterized by relationships of domination, oppression, and exploitation" (Gutiérrez, 2004, p. 289).

This capitalist practice of oppression related to colonialism and internal colonialism can result in the "unjust distribution of healthy life," (Flynn, 2021, p. 1) due in large part to a variety of social factors. Through the process that Flynn (2021) describes as commodification, resources, knowledge, and even people become commodities, used to garner a profit. Both social and societal determinants can influence the distribution of disease and other inequalities around the world (Flynn, 2021). The commonly referred to social determinants of health are those factors that increase inequality, including education, the environment, and culture, and in turn, these social determinants of health can cause or prevent disease. Taking a step back to understand the processes that contribute to the presence of *social* determinants of health, Flynn (2021) explains that *societal* determinants of health are those that contribute to those social determinants, brought about at the institutional level, often creating systemic and structural problems (Flynn, 2021). Societal determinants of health include patriarchy, capitalism, and colonialism, among others.

The uneven development brought about by internal colonialism and capitalism can result in the "concentration of environmentally detrimental pollution," (Flynn, 2021, p. 3), affecting entire communities; indigenous communities are especially vulnerable, negatively impacting human rights and environmental rights as described in the concept of buen vivir, the balance and reciprocity needed between people and the earth that contributes to overall well-being (Gudynas, 2011). Around the world, cultural, economic, and political climates influence risk factors, exposure, and access to healthcare, with the largest burden of disease falling on those living in poverty (Cureton, 2011; Eyles and Consitt, 2004). Unable to be active participants in "capitalism's need for endless accumulation" (Flynn, 2021) due to economic constraints, those in poverty make up what Robinson (2014) describes as the "global surplus population." This population's inability to develop, stuck in the trenches of the poverty cycle, leads to an unequal concentration of environmental hazards and risks that are exacerbated by the influx of extractive industries.

Capitalism promotes an "unrestrained consumerism [that] created environmental degradation and resource scarcity" (Sklair, 1995, p. 278). According to Flynn, as part of capitalism, "various economic interests also seek to corrupt science and information regarding the impact of their activities [...] that threaten the health of the planet" (2021, p. 3) in order to earn a profit, and the evidence of this can be seen in the EIAs of various projects, including that of the mine in Olopa.

The "structural pathogenesis," described by Sell and Williams (2020) refers to the ability of systemic inequalities and institutional conditions within societies to cause disease. This type of pathogenesis is attributed to capitalism and the resulting negative impacts that are unjustly and unequally distributed form a social gradient of health (Sell & Williams, 2020). That gradient contributes to the syndemic that is experienced in many places around the world that makes accessing and using resources that much harder, ultimately continuing the cycle of poverty, and oftentimes, disease.

Extractivism is one branch of capitalism that worsens the social gradient of health. Anything can be extracted – knowledge, resources, metals, people – and this extraction often provokes resistance (Riofrancos, 2020) that is linked to exploitation as described in colonialism. Capitalism, extractivism, and internal colonialism are systemic issues with long-term effects, such as dispossession of land and rights, contributing to the social, or perhaps structural, determinants of health.

Our study found that the Cantera los Manantiales mine in Olopa is an example of both extractivism and internal colonialism. As the Guatemalan government lessened some of the restrictions and environmental laws surrounding mining, control by non-indigenous elites flourished alongside international corporations. The antimony mine is currently owned and operated by the Guzmáns, non-indigenous Guatemalans extracting the materials from Ch'orti' indigenous land. As a result, the Ch'orti' are experiencing exactly what was described above: increased rates of malnutrition, poverty, diseases, and environmental degradation, along with decreased access to healthcare, income, education, and employment opportunities. Both social and societal determinants of health are impacting the overall well-being of the Ch'orti' in Olopa.

2.4 Mining Conflicts and Impacts

The attention surrounding mining conflicts began to escalate globally in the 1980s and 1990s alongside an environmentalism recognizing that vulnerable and marginalized communities suffer disproportionately from environmental degradation from mining. These conflicts surrounding mining around the world have been based on the unequal distribution of environmental degradation and economic benefits. The extraction projects respond to international markets, not to the community in which they are operating, ultimately exhausting the resources in the area that would have otherwise remained under management by local communities (Kirsch, 2014). There are no enforced international standards in place for how mining companies should handle the waste that the projects generate, and pressure from international markets often discourage investments in environmental controls (Kirsch, 2014), as the lowest operating costs maintain the highest profits. In other words, Kirsch (2014) argues that if mining operations are efficient and resources are extracted quickly, there will not be enough time for an effective resistance to be mounted by locals.

In some cases, mining companies have been allowed to both set the environmental standards and monitor their compliance, often misrepresenting environmental impacts of the process and limiting the collection of baseline and background data (Kirsch, 2014). Potential changes in air, soil, or water quality due to mining activities can't be quantified after the start of mining if there's no original data for comparison. Mines often attempt to misuse science to try to support their claims (e.g. strategic sampling times or locations, falsifying documents) while affected communities use it to try to dismantle them, though this ability hinges on community members' capability to work in conjunction with those who have the scientific skills and resources needed to support them, adding science to their fight for self-determination. However, some people or communities "claiming indigenous rights risk having their testimony judged as inauthentic if they use the language of science when speaking about environmental issues," and indigenous leaders in Latin America are "discredited when they express their political concerns in the language of the state" (Kirsch, 2014, 81).

The economic, social, and human and environmental health struggles in Olopa, Chiquimula are exacerbated by the presence of extractive industries in the area. There are currently 22 mines recognized by the USGS in Chiquimula, Guatemala including zinc, copper, lead, nickel, and antimony mines among others (Mining in Chiquimula, 2022). Minera Cantera los Manantiales is one of these mines, located within the municipality of Olopa.

Artisanal miners have been extracting metals for decades from the Minera Cantera los Manantiales, an antimony mine located in Olopa in Chiquimula, Guatemala on the traditional lands of the Maya Ch'orti' peoples. Now an open-pit mine, Cantera los Manantiales, owned previously by American Minerals SA and later by BC Enterprises, obtained the current permit in 2007 and began operations in Olopa in 2012 under local and current owners Guillermina and Odilio Guzmán (Toro, 2020). The antimony extraction project began operating without obtaining free, prior, and informed consent from the indigenous communities living on the land (PBI Guatemala, n.d.), and tangible effects from the mining operations have been present in the region since at least 2015, including environmental contamination and health concerns (Toro, 2020). Intense mining operations with the use of heavy machinery began in 2016 in the Cantera, with the resistance movement gaining traction six months later. Communities claim that Cantera los Manantiales is furthering the problem of water scarcity by consuming large amounts of water, depleting the aquifers, and polluting both the Jupilingo and Zacapa Rivers in the department of Chiquimula (PBI USA, n.d.).

Antimony is element number 51 on the periodic table and is a silvery-white metal found in the earth's crust, though rarely in its pure metal form. The ore is most often found in the mineral stibnite, a combination of antimony and sulfur (Perpetua Resources, 2021; Periferakis et al., 2022). The pentavalent form of antimony is common under aerobic conditions and the trivalent form, the type usually released through anthropogenic activities, is common under anaerobic conditions and is much more toxic (Periferakis et al., 2022). Several of the historical uses of antimony have been known for centuries (Periferakis et al., 2022). Currently, it is used as a flame retardant, in the production of microchips, in lead-acid batteries, as treatment for some parasitic diseases, and as an alloy to increase the hardness of lead (Arreaga, 2018;4). Antimony is found in iPhones, kitchen appliances, cars, wind turbines, solar panels, and more (Blackmon, 2021).

When possible, antimony is mined in open pits and later processed, on site or at another location as in the case of Cantera los Manantiales, through volatilization, roasting, blast furnace smelting, liquation, reduction, leaching, or precipitation depending on the quality of the ore (Butterman and Carlin, 2004). The extraction process is linked to the release of multiple contaminants resulting in various forms of pollution, similar to processes used to extract gold or silver (Arreaga, 2018), releasing significant amounts of antimony, arsenic, mercury, lead, cadmium, and zinc into the environment (Zhou and Hursthouse, 2019). Antimony itself is considered a priority pollutant and can bioaccumulate (Fei et al., 2017; Jiang et al., 2021; Bolan et al., 2022).

Antimony prices have risen drastically in the last three decades, increasing demand and therefore production and extraction processes around the world. The potential for use in the energy and defense sectors, in addition to manufacturing, has also contributed to the increase in mining operations in recent years (Perpetua Resources, 2021). Antimony was recently included in the critical raw materials (CRM) list, which consists of materials that are "characterized by increased economic importance, high-risk supply chains, and the inability of substitution by materials of commensurate properties" (Periferakis et al., 2022). As demand increases, mines begin seeking lower grade ore. When the demand is high enough, the extra effort it takes to reach this ore is worth the cost, but these processes lead to increased pollution due to the manner in which the metal is extracted (Abdul-Wahab and Marikar, 2012; Fashola, 2016), with more waste that the environment is expected to absorb. In 2021, the price for antimony doubled, and predictions state that the current supply will not be able to meet the expected global demand in the coming years (Blackmon, 2021). The metal, which is currently non-recyclable or biodegradable, remains in the environment for decades even after the polluting factor is halted or removed (Periferakis et al., 2022).

In Guatemala, mining is promoted as a part of economic development by corporations and the government, a way to rebuild after the war (Davis and Tilton, 2005; Dougherty, 2019, Const. Guatemala art. XXV). However, the argument now exists for mining to be labeled as an industry instead of development because of the stark difference in who benefits in each of the two instances (Bastos and de León, 2015; Kuecker, 2007; Nelson, 2015; Rasch, 2012). A development activity is classified as something concerned with the well-being of every individual in society (Merino and de los Ríos Carmenado, 2012) while an industry is simply an "economic activity concerned with the processing of raw materials" (Lexico, n.d.). This distinction is evident in the fact that, while extractive industries make up a portion of the country's GDP (Drewry et al., 2017), approximately 1% percent (Banco de Guatemala, 2022),Guatemala's poverty rates are steadily increasing even as other countries in the region improve economically, meaning that not all Guatemalans benefit from extractive industries (Davis and Tilton, 2005; World Bank, 2013; World Bank, 2018).

It is widely understood that mining can negatively affect the health of entire communities through adverse social and environmental impacts (Drewry et al., 2017). While those living near mines have long been aware of these issues, in more recent years, there has been increased awareness among other groups and classes, and because of this, visible opposition to mining has increased around the world (Saha, 2011). Mines have faced growing resistance in places like

Ecuador, India, and numerous other countries as knowledge and indigenous and other local voices increase regarding the negative impacts mining can have on the community (Conde, 2017; Kuecker, 2007; Saha, 2011). Countries like El Salvador and Costa Rica have national metal mining bans in place in their countries and are encouraging other countries to restrict permits as well (Birn et al., 2018; Witte-Lebhar, 2010). This is especially the case when contaminants from one mine cross national boundaries and affect populations elsewhere, as has occurred with Guatemala's Cerro Blanco mine that El Salvador fought to stop because of their shared rivers, though they were not successful (Witte-Lebhar, 2010, Montoya, 2021).

In the case of the Cantera los Manantiales in Olopa, as resistance and complaints grew, the mining company began offering more unspecified development projects in the surrounding communities and municipalities (Toro, 2020), but communities continued to resist. Dozens of people have been arrested for peaceful protests (Toro, 2020), and many community leaders in the areas surrounding the mines have been the victims of intimidation, threats, and numerous attacks since the beginning of their resistance (Sancir, 2020). To date, the most significant attacks have been the murders of at least three people in separate events due to their participation in the resistance movement (Cherofsky, 2021; PBI Guatemala, n.d.).

2.5 Social and Political Impacts

The mining industry's presence in Guatemala has contributed to numerous wide-ranging and negative impacts on social and political health in indigenous communities and the country as a whole. The extraction and exploration processes happening around the mines have resulted in the displacement of entire communities (Birn et al., 2018; Shipton, 2017). The loss of these traditional and ancestral lands through forced evictions or environmental degradation has led in part to the erosion of the ethnosphere of the affected communities. Davis (2002) defines the ethnosphere as something that is vital to our well-being, “the sum total of thoughts, beliefs, myths, and intuitions brought into being by the human imagination since the dawn of consciousness” (p. 57), able to erode in the same way as the biosphere, often at a faster rate. Several groups are in danger of losing their cultural identity through the loss of or damage to their land because mining disrupts their deep and historic connection to it, making mining a threat to ethnodiversity as well (Holden and Jacobson, 2008; Nelson, 2015). As the significance of places disappear as a result of environmental degradation, memories and histories lose their moorings.

The impact of mining on land can lead to solastalgia, which is the “distress that is produced by environmental change impacting on people while they are directly connected to their home environment” (Albrecht et al., 2007, p. 1). It is a homesickness while at home, “the pain or sickness caused by the loss or lack of solace and the sense of isolation connected to the present state of one’s home and territory” (Albrecht, 2005, p. 45). This longing for home without having left can be the result of a range of environmental or social changes, mining included, and “in many cases, solastalgia is the outcome of social and economic forces that are, in turn, the result of deliberate political policy” (Albrecht, 2020, p. 13). The destruction of land is an attack on one’s sense of place, a spatial problem that affects individual identity, an ongoing loss that is felt in lived experiences (Albrecht, 2005). As literal roots are severed as vegetation is cleared and mountains are deforested, the figurative roots tying people to a place are removed as well. As the environment is a vital part of a community, overall health and wellbeing can be impacted by these changes made to the environment (Albrecht et al., 2007).

The destruction caused by mining results in not only a loss of place but also the lost time that would have been spent in that place, resulting in a longing for something that was but can no longer be (Albrecht, 2005). The place and environment that residents knew are not gone entirely, but have been transformed to the point that the relationship the communities once had with the area are no longer recognizable as what they previously were, removing the comfort associated with being "home" (Albrecht, 2005). However, "solastalgia offers hope in that damaged places can be repaired. Where extinction is possible, rebellion is a proper response" (Albrecht, 2020, p.8), and those in Olopa are actively resisting the destruction of their home.

The mines of Guatemala have also contributed to the growing fractures in indigenous society and broken community bonds (Caxaj, 2013; Yagenova and García, 2009). Because of the rise in opposition, many indigenous communities in Guatemala have turned to *consultas* (referendums) as a way to share their voice as a form of resistance (Aguilar-Støen and Hirsch, 2017; Dougherty, 2019; Yagenova and García, 2009). Consultas serve as a way for communities to come together and formally vote for or against mining in their community in a way that is informed by local customs (Rasch, 2012). In order for a consulta to apply, the community must meet the local and international definitions of an "indigenous community" according to the International Labor Organization Convention (ILO 169) (ILO, 1989). This becomes an issue as many companies in Guatemala claim that there are no indigenous peoples in the east of the country, which includes Olopa. Between 2005 and 2013, over 1 million people from 78 indigenous communities in Guatemala participated in consultas, and that number continues to grow (Bastos and de León, 2015; Wiebe, 2021). On nearly every occasion around the country, communities have voted "no" to mining, offering the phrase behind the activist movement "yes to life, no to mining" (Yagenova and García, 2009; Wiebe, 2021; Falconer, 2019). Consultas can serve as a legal tool to remove the company from the territory and as a result, these consultas are not always met with support from government officials. There have been instances where companies have attempted short surveys or offered very basic informational presentations as required by the EIA, promising jobs or other benefits, and then claiming those activities as a consulta that gave them approval to mine in the area. The government has worked hard to limit the indigenous communities' right to hold consultas (Copeland, 2019a), another example of the lasting impacts of internal colonialism.

Differing perceptions surrounding the mine have dissolved trust within the community, both between community members and between the community and local officials. The violent repression of resistance also divided the community, and the giving of jobs and other gifts to pro-mining residents These differences in opinion, regarding the legality of the mine's actions and the resulting impacts of the mine's operations, are most often drawn along the lines of who benefits and who doesn't benefit financially during the mine's operation (Caxaj, 2014; Dougherty, 2019), and violence has been shown to increase when mining operations commence (Navas et al., 2018). In several instances, those opposing a mine have received threats from the government, the mining company, and even fellow community members (Caxaj, 2014). Environmental activists, including many community leaders, are among those who experience the highest rates of violence (Witte-Lebhar, 2010), and communities in many places have reported a surge in kidnappings, murders, and rapes since the start of mining operations (Caxaj, 2014). Indigenous communities in Guatemala have gone as far as comparing mining operations to a continuation of the civil war given the common violence (Brand, 2015; Rasch, 2012).

2.6 Economic Impacts

In the same way that mining in a community can have negative social and political impacts, there are negative economic impacts associated with the industry as well. In line with the resource curse theory (Kirsch, 2014; Owen et al., 2021), Guatemala is a region rich in natural resources that suffers from extreme poverty rates. The resource curse goes hand in hand with the concept of colliding ecologies, when two competing systems built on the use of the natural resources of an area interact, creating both macroeconomic and microeconomic problems for the people and countries dependent on mining (Kirsch, 2014). Mining and nearby subsistence agriculture are rarely compatible. Those living in areas around and downstream of the mine bear a disproportionate share of the impacts of mining as costs are externalized onto the environment and the communities. Mining is sometimes described as a slow-motion disaster. Some of the most devastating impacts can take years to become visible, which can make it easier for some people to intentionally ignore (Kirsch, 2014). However, those impacts are still perceived in the short-term and the long-term by those most directly impacted, and the companies often benefit from this latency period (Kirsch, 2014).

The majority of the population in Guatemala is impoverished, with some 80% of the rural population living on less than $2 a day (Holden and Jacobsen, 2008; About Guatemala, 2019), and there are enormous disparities and inequalities in wealth and resource distribution in rural and indigenous communities (Mactaggart, 2018; Saha, 2011). Approximately 28% of Guatemalans are considered to be living in multidimensional poverty, a measure that includes not only income but also access to education and standard of living as well (UNDP, 2022). From studies of other communities surrounding mines, it is evident that though a select few community members may secure employment with the mine, the overwhelming majority of the community experiences increased poverty with the arrival of a mine (Birn et al., 2018; Yagenova and García, 2009, CECON-USAC, 2019). The supposed benefits of mining rarely reach the communities in which mines operate (Kirsch, 2014; Shipton, 2017), and the costs far outweigh the limited gains that few people experience for a brief period (Caxaj, 2013). The loss of land mentioned previously results in the loss of income-producing opportunities through the reduction in subsistence agriculture, and some families are no longer able to grow or sell crops (Nelson, 2015). This increase in poverty also contributes to greater levels of food insecurity, with the inability to grow or purchase foods then resulting in higher rates of malnutrition (Caxaj, 2014), and the bioaccumulation of contaminants in the crops that do grow can contribute to stunting and other negative health consequences (Da Silva, 2004; Franco-Hernandez, 2010).

Higher poverty levels also worsen the general lack of resource availability into the future even beyond the cessation of mining. Accessing health care and other community services can become more difficult with reduced income, changing community public health needs, and growing populations during the mining operations (Mactaggart, 2018). Of the families who are not displaced, many report structural damages to their homes from explosives used in the extraction process (Yagenova and García, 2009), and these families then either lose their homes or live with the damages as many cannot afford repairs. After the metals have been extracted and mining operations cease, the community is typically left in economic collapse (Caxaj, 2013; Mactaggart, 2018). Any money that was coming into the community through employed individuals stops when the mine is closed (Caxaj, 2013). The community will have already lost other alternative revenue sources from agriculture (Copeland, 2019b; D'Souza et al., 2013) due to environmental degradation (Abdul-Wahab and Marikar, 2012), fractured social structures in the communities (Dougherty, 2019), and poor health (Cerón et al., 2016). Migrant workers who moved to the area because of the mine will leave, along with some workers originally from that area who will be forced to look elsewhere for a new source of income, leaving behind the children born to local women while they were working there (Mactaggart, 2018; Shipton, 2017).

2.7 Environmental Impacts

Mining has severe environmental impacts in the surrounding areas. Mining activities lead to the overall degradation of the environment through various avenues, and studies have shown that these effects are worse in close proximity to the mine itself (Basu et al., 2010; Owen et al., 2021; Van de Wauw et al., 2010). Mining can be linked to deforestation (Kuecker, 2007; Ogola et al., 2002), habitat loss (Abdul-Wahab and Marikar, 2012; Harish, 2015), land cover change (Shipton, 2017), water pollution (Marcillo et al., 2020; Ogola et al., 2002; Trudeau, 2018), lowered groundwater tables (Abdul-Wahab and Marikar, 2012; Van de Wauw et al., 2010), air pollution (Harish, 2015; Ogola et al., 2002), and soil erosion and contamination (Da Silva, 2004; Franco-Hernandez, 2010; Song et al., 2013; Yagenova and García, 2009).

Open-pit mining techniques, such as those used by the Minera Cantera los Manantiales, negatively affect the surrounding area beginning with deforestation to initiate and expand mining operations (Kuecker, 2007; Ogola 2002). Clear cutting is employed in open-pit mines around the world, precipitating the loss of thousands of square kilometers of forests in recent decades (Alvarez-Berríos, 2015; Yagenova and García, 2009), including the 2 km^2 conceded to the Minera Cantera los Manantiales for extraction (Ministerio de Energía y Minas, 2020). The destruction and loss of ecosystem services (Shelton, 2012) and biodiversity associated with deforestation (Copeland, 2019b; Kuecker 2007) negatively impact the relationship that many indigenous communities have with traditional and ancestral lands (Birn, 2018; Shipton 2017), and worsens the struggle with malnutrition with the loss of firewood for household cooking (Nelson, 2015). Deforestation also increases soil erosion, increasing the likelihood of landslides (Steinacher, 2009) and multiplying the already-present issues of water pollution with the introduction of contaminated soils into rivers (Franco-Hernandez, 2010; Ogola, 2002).

Furthermore, the resulting land cover change is often linked to the accumulation of standing water, made warmer without shade from the trees (Kweka et al., 2016), aiding in the development of vector habitats for disease-transmitting organisms like mosquitos (Berger et al., 2012; Saha, 2011). These new breeding grounds increase the rate of infectious diseases in communities around the mine (Birn, 2018; Trudeau, 2018), contributing to the cumulative negative effects that mining has on both human and environmental health.

Water contamination is one of the biggest environmental problems related to mining. Drinking water quality in Guatemala is already poor, with various contaminants exceeding standards set by the World Health Organization, the World Bank, the US, and even Guatemala itself (Caxaj, 2014; Trudeau, 2018, World Bank, 2018), and numerous bacteria and parasites are commonly found in the drinking water in Guatemala (Marcillo et al., 2020; World Bank, 2018). Additionally, arsenic exists naturally in geothermal and volcanic regions, often together with fluoride, and associated health risks are greater when both contaminants are present (Alarcón-Herrera et al., 2013; López et al., 2012). This presents a natural challenge to water treatment, and mining can concentrate these naturally occurring contaminants in source water (Alarcón-Herrera et al., 2013).

Contaminants from mines can wash into the rivers (Franco-Hernandez, 2010; Witte-Lebhar, 2010), infiltrate groundwater (Franco-Hernandez, 2010; Van de Wauw et al., 2010), and pollute point of use (POU) water sources (Marcillo et al., 2020). Heavy metals including lead, cadmium, and zinc among others have also been measured in water sources near mines in concentrations far exceeding Guatemalan, US, and World Health Organization standards (Nelson, 2015; Van de Wauw et al., 2010; World Health Organization, 2004; Yagenova and García, 2009). We know from sampling in studies like those by Van de Wauw et al. (2010) and

Basu et al. (2010) that overall poor water quality and higher concentrations of pollutants are often related to proximity to the mine. River contaminants have shown to be at highest concentrations in areas directly downstream from the mines (Basu et al., 2010), and can then be carried further downstream affecting even more communities, including those with no employment benefits from the mine (Witte-Lebhar, 2010). These heavy metals, including lead and cadmium, contribute to a domino effect of health and environmental problems, killing fish and resulting in higher levels of food insecurity (Ogola, 2002). Bioaccumulation of heavy metals in fish and crops irrigated with contaminated water make their way into the food chain (Abdul-Wahab and Marikar, 2012; Ngure, 2014), furthering the problem of malnutrition and negative human and environmental health effects.

In addition to the increase in heavy metals, mining can also increase total dissolved solids (TDS) in surrounding rivers and bodies of water. These minerals, metals, salts, and other ions are the result of accelerated weathering of disturbed geologic materials (Sarver and Cox, 2013; Van de Wauw et al., 2010), and affect multiple species (Sarver and Cox, 2013). The increase in TDS affects surface and subsurface waters. Different concentrations of the various minerals, metals, and ions can have different effects on the environment (Cañedo-Argüelles et al., 2016), and few mitigation strategies exist (Sarver and Cox, 2013). The distrust of water sources due to mining increases the prevalence of household water storage, which can also lead to an increase in bacteria due to improper storage techniques (Trudeau, 2018).

Mining is often a water-intensive economic activity, which affects water quantity. Mining processes can use more than 250,000 liters of water every hour, the amount that a family in Guatemala would use in 22 years (Nelson, 2013). Typically, mining permits require that mines draw their water from rivers, but there have been instances where, even with this specification, mines have extracted groundwater to complete processes, lowering the nearby water table (Van de Wauw et al., 2010). As communities increase their dependence on groundwater because of the perception of contamination in surface sources (Abdul-Wahab and Marikar, 2012; Van de Wauw et al., 2010), the water table can drop below household drinking water well levels. Natural arsenic can increase in water as people begin extracting water from deeper and deeper levels where these concentrations are higher as the water table lowers; this problem has grown with the limited recharge of groundwater due to changes in climate patterns (Van de Wauw et al., 2010).

Regardless of actual water quality, community members' perceptions of water can significantly affect usage patterns. Surveys in studies like the one conducted by Marcillo et al. (2020) looked at water sources and peoples' perceptions of them, finding that most participants did not drink the point of use (POU) water, even when supplied by a centralized treatment and distribution system, for fear of illness. Others have also identified perceptions associated with water services and monitoring (Sherry et al., 2019; Van de Wauw et al., 2010). Understanding these perceptions is important in predicting water usage to better understand community member behavior and the relationship between water quality and health effects.

Air pollution is another environmental hazard often associated with mining. Pollution from the assorted mining operations used in the antimony extraction processes releases chemical fumes into the air (EPA, 2000). Silica dust is another threat (Shipton, 2017; Stephens and Ahern, 2001), linked to asbestos-like health effects (Ogola, 2002), that is released as part of the mining process. All of the particles associated with air pollution not only affect those in the immediate area through workplace exposure but are also disturbed by explosives used in the mines and transported by wind to nearby communities (Fashola, 2016). Contaminants that settle on the ground could then contaminate soil.

Metalliferous dusts are especially a problem in areas with poor regulatory systems and can be produced and distributed through various mining processes, including the removal of overburden, extraction, and transport of materials (Entwistle et. al., 2019; Duarte et al., 2022). The dust produced from the mining processes puts communities near the mine at a higher risk, as dust can move across the area and has been found in previous studies in crops, in surface and groundwater, on roads, and in homes (Entwistle et. al., 2019; Duarte et al., 2022; Abdullah et al., 2016; Tian et al., 2019). Other factors such as humidity, wind speed and direction, and particle size also impact dust dispersal and pollution near mines (Oguntoke et al., 2013).

Soil is another important component of environmental and community health, and like water and air, is subject to multiple contaminants from mining processes (Harish, 2015; Song et al., 2013). The same heavy metals found in water near the mines have also been found in soils (Da Silva, 2004; Fashola, 2016), affecting agricultural production (Franco-Hernandez, 2010) with some crops no longer growing in the area surrounding a mine due to poor soil quality or the accumulation of heavy metals in the plants themselves (Abdul-Wahab and Marikar, 2012; Franco-Hernandez, 2010). Those that do grow contribute to the accumulation of metals in the food chain, ingested when animals or people consume them (Song et al., 2013). Indigenous populations work closely with the land and directly depend upon it for food, specifically in the realm of subsistence agriculture, making them and other poor populations more vulnerable to soil contamination (Holden and Jacobson, 2008).

Soil erosion that results from the removal of vegetation as lands are cleared for mining can compound problems with contamination. The soil that remains is of poor quality, further reducing agricultural yields. This reduction in agricultural productivity reduces available food and income, increasing the struggle with food insecurity and malnutrition (Caxaj, 2013).

Through erosion, this contaminated soil then makes its way into rivers and groundwater, multiplying the already-present struggle with water pollution in the areas around and downstream of the mine (Franco-Hernandez, 2010).

Several studies have analyzed the perceptions of environmental harm as a result of mining. Holden and Jocobson (2008) found that the main objection to mining is because of environmental harm, and Drewry et al. (2017) noted growing concerns related to environmental health effects, questioning whether or not the mine was worth the cost for economic growth. The findings of these studies repeatedly show that, from the perspective of the communities opposing mining operations, the real and perceived benefits of the mine are often not worth the cost to the environment, and the short-term benefits in the form of employment do not outweigh the environmental degradation (Mactaggart, 2018).

These environmental concerns do not end when mining operations cease (Fashola, 2016; Kirsch, 2014), and contaminant persistence can result in long-term negative environmental effects. Heavy metals in the water, soil, and plants do not simply disappear (Da Silva, 2004), and through bioaccumulation, contaminants can persist and spread, rising higher in the food chain (Ngure, 2014). As evidence of the persistence of mining-related contaminants in the environment, acid mine drainage from a mine dating back to Roman times continues in the present (Holden and Jacobson, 2008). Even with promises of land rehabilitation following the cessation of mining activities, which are often not kept, the damage has already been done and ecological recovery is a slow process. The combined effects of the long-term contamination produce livelihood issues with the destruction and degradation of the environment and community members' way of life (Kirsch, 2014; Rasch, 2012), damaging connections with the land that some indigenous cultures promote through their belief in buen vivir (Gudynas, 2011).

2.8 Human Health Impacts

Significant impacts from mining are evident in the effects associated with human health. Mining is associated with an increase in infectious diseases (Drewry et al., 2017) in part due to changes in vector habitats, the in-migration of workers potentially introducing new pathogens, and bacterial contamination of water sources. The landscape modifications associated with open-pit mining techniques can increase the presence of standing water in areas surrounding the mine, which along with increased water storage near homes from distrust of the water quality in rivers, can contribute to increased vector habitats, offering a breeding ground for mosquitoes (Berger et al., 2012). Studies have also shown an increase in diseases like malaria (Saha et al., 2011), tuberculosis (Drewry et al., 2017), and HIV (Lyatuu et al., 2021) associated with mining due to the influx of workers and standing water in the area. A potential explanation is the introduction of pathogens related to the in-migration of people from other areas taking advantage of employment opportunities, often working in crowded areas, resulting in outbreaks of new diseases or increased spread of existing ones (Ogola, 2002).

High levels of bacteria can be found in household water supplies near mines due to improper water storage. If nearby water sources are perceived as contaminated, residents may travel farther to a source perceived as uncontaminated, and store extra water in open containers. Drinking or cooking with contaminated water from these sources can cause diarrheal diseases in children, worsening struggles with malnutrition (World Bank, 2018). Specifically, data from the World Bank (2018) shows that ⅕ of households in Guatemala reported children with diarrheal diseases. Frequent diarrheal diseases are still one of the leading causes of child mortality and have been linked to stunting (Trudeau, 2018; World Bank, 2018). Even though efforts have been made to improve water quality in Guatemala, sanitation infrastructure and water treatment services are still poor (World Bank, 2018). Studies have shown that despite these efforts, even one day of water service interruptions, which are frequent in Guatemala, can increase the bacterial intake, resulting in disease (Trudeau, 2018). Distrust or lack of water can influence behaviors leading to reduced hygiene practices (Trudeau, 2018). Perceiving the water as dirty or unsafe (Marcillo et al., 2020) or experiencing water scarcity because of dried-up wells (Van de Wauw et al., 2010) can lessen hand washing prevalence and increase water storage (Trudeau, 2018), which can then lead to increased disease incidence.

In addition to an increase in infectious diseases due to in-migration or improper water storage, environmental pollution is another threat, and is the largest environmental cause of disease and premature death in the world (Entwistle et. al., 2019), with nearly 92% of pollution-related deaths occurring in low- and middle-income countries (Landrigan et al., 2018). The environmental damage coupled with mental health effects brought about by the increased stress and community instability, combined with the climate of fear, displacement, and lack of trust, weaken the immune system (Canu et al., 2017; Salleh, 2008). This predisposes community members to negative health outcomes attributed to mining contamination in soils via food, air, and water, as “mining wastes, the poor and deprived, and the most vulnerable members of the community are often found in juxtaposition” (Entwistle et. al., 2019).

In mining areas, heavy metals are the main pollution risk, with exposure occurring through inhalation, direct contact (Stephens and Ahern, 2001), drinking contaminated water (Yagenova and García, 2009), or eating contaminated foods (Bundschuh et al., 2012). Heavy metals are known to cause serious and irreversible negative health outcomes (Fashola et al., 2016), and can cause serious health risks to the local environment and population (Tian et al., 2018; Zhu et al., 2014). Metals accumulate in the body in the same way they do in plants, and specific metals are associated with specific resulting health complications. Heavy metals have been linked to cancers, neurological problems, and heart conditions (Van de Wauw et al., 2010), and have been attributed to developmental problems in children (Abdul et al., 2015).

Environmental pollution associated with mining can result in an increase in respiratory problems (Saha, 2011). Poor air quality leads to higher rates of asthma and respiratory infections, and data from the World Bank (2018) show that 1 in 3 households reported children with respiratory diseases. Occupational and ambient exposure to silica released through mining can lead to silicosis, kidney disease, other lung problems, and cancers (Goldsmith, 2018; Bhagia, 2012). Carbon monoxide released from water pumps associated with mining has been linked to breathing problems and even death (Ogola, 2002; Raub et al., 2000).

Exposure to airborne pollutants can be increased by some features of the socio-economic environment, including the physical characteristics of homes and unpaved roads, which can increase airborne dust and dust accumulation indoors. Children are also at a higher risk of dust-related exposures due to more frequent hand-to-mouth contact (Entwistle et. al., 2019; Tian et al., 2019). The harm caused by this dust depends not only on the abundance and particle size, but also the route of exposure: inhalation, ingestion, or dermal contact (Entwistle et. al., 2019; Fei et al., 2017). Dust particles can adhere to clothing and shoes and can then easily be carried into the home or other environment, exposing other people to pollutants through "bystander exposure" (Entwistle et. al., 2019; Abdullah et al., 2016).

Arsenic, exposure to which is increased as mines draw down groundwater levels, is known to produce many carcinogenic and non-carcinogenic effects (Lotter et al., 2014), affecting entire organ systems, including the nervous, hematopoietic, respiratory, reproductive, cardiovascular, hepatic, endocrine, immune, and renal systems (Abdul et al., 2015). Arsenic accumulates in plants from contaminated soil and irrigation waters and can be found in livestock, milk, and cheese, as well as in tea and spices (Bundschuh et al., 2012). It has also been found in high concentrations in processed foods, foods prepared in restaurants, and meals served in schools, specifically foods that require large amounts of water to prepare (Bundschuh et al., 2012). Arsenic and antimony are often found together and are known to behave similarly in the body and in the environment (Entwistle et al., 2019; Jiang et al., 2021; Zeng et al., 2015; Sundar & Chakravarty, 2002; Litwin et al., 2021; Periferakis et al., 2022).

Antimony itself, which could contaminate the surrounding environment during the extraction process, is linked to numerous negative health impacts. Antimony has high acute toxicity, but toxicity of the metal depends not only on the exposure dose, duration, and route, but also on age, gender, nutritional status, and overall health (Jiang et al., 2021; Cooper and Harrison, 2009). Water, soil, or air polluted by antimony-contaminated dust in the community can affect local food sources through accumulation in crops, hence affecting the diets of local people, with immediate and long-term health effects as a result (Entwistle et. al., 2019; Abdullah et al., 2016; Cooper and Harrison, 2009). Studies have confirmed toxicity but have not yet confirmed carcinogenicity (Jiang et al., 2021; Sundar & Chakravarty, 2002). Other studies also suggest that antimony could potentially be genotoxic, causing oxidative DNA damage (Cavallo et al., 2002; Sundar & Chakravarty, 2002; Cooper and Harrison, 2009; Litwin et al., 2021).

The oral reference dose for antimony is set at 4×10^{-4} mg/kg/day, however confidence for this dose is low. Researchers were unable to determine a NOEL (no observed effect level) during laboratory testing and report an uncertainty factor of 1000 (Antimony, 1987). Testing has not yet been conducted to determine the reference dose for inhalation exposure, which is of major concern in the communities surrounding the Olopa mine. The EPA's IRIS Chemical Assessment

Summary for antimony has not been updated since 1987 (Antimony, 1987). Similarly, research on dermal contact is also lacking. The EPA's maximum contaminant level (MCL) for antimony is 0.006 mg/L, which is less than the MCL for arsenic or lead (EPA, 2023)

Antimony has known impacts on the skin, eyes, gastrointestinal, cardiac, and respiratory systems, with micro amounts of the metal known to cause disease (Jiang et al., 2021; Zeng et al., 2015; Sundar & Chakravarty, 2002); hazard quotients are higher for children, indicating a greater vulnerability to impacts (Jiang et al., 2021; Landrigan et al., 2018). In the gaseous phase, or on dust particles, antimony can spread through the air. Acute exposure can irritate the eyes and skin (EPA, 2000). Long-term airborne exposure is linked to chronic bronchitis and emphysema along with inflammation of the lungs (EPA, 2000). If ingested in sufficient quantities, antimony can be fatal, damaging the liver, intestines, kidneys, and stomach (Institute for Rare Earth Metals, 2021). Antimony is also known to weaken the immune system, reducing the number of T cells along with red blood cells and platelets, opening the body up to new diseases and infections. Some studies have shown an increase in spontaneous abortions in women working in an antimony plant, along with disturbances in menstrual cycles (Sundar & Chakravarty, 2002; Cooper and Harrison, 2009). In other studies, the metal has been detected in the placenta and amniotic fluid of pregnant women who were exposed (Periferakis et al., 2022). Antimony levels can be measured in the urine and blood and have been associated with increases in cardiac and respiratory problems (EPA, 2000).

Antimony trioxide, the most important commercial compound of antimony, is a recognized cause of occupational dermatitis, causing eczematous, pustular, and follicular skin lesions known as antimony spots, that have been known to last for months during continued exposure (White et al., 1993). These antimony spots are often found near sweat glands and are known to be worse in warmer weather (Sundar & Chakravarty, 2002). The lesions usually exhibit lichenification and can resemble smallpox (Periferakis et al., 2022). Stibine, a gas containing antimony, can sometimes cause mild jaundice, as it is a hemolytic agent (Cooper and Harrison, 2009).

Several studies have looked at community perceptions of health in indigenous communities in relation to mining. Studies by Dougherty (2019) and Caxaj (2013) looked at the role of mining in community health and found that communities perceived public health as more important than environmental or resource issues, and more important than a job, with social and environmental risks outweighing the real or perceived benefits of the mine. Other studies have specifically addressed perceptions of water as it relates to health (Marcillo et al., 2020; Sherry et al., 2019), and still more have looked at perceptions of access to health care for the indigenous communities, and the real and perceived barriers experienced in seeking care (Cerón et al., 2016).

2.9 Syndemic Effects

In the original theory (Singer, 1996), a syndemic follows three rules: "two or more diseases cluster together in time or space; these diseases interact in meaningful ways, whether social, psychological, or biological; and harmful social conditions drive these interactions" (Mendenhall et al., 2022). Though the concept began with studies surrounding HIV and TB, it has been used more recently for explaining interactions between both different infectious diseases, as well as between infectious and non-communicable illness. It does also "acknowledge the association of poor health with social, cultural, economic and physical environmental factors" (Manderson, 2012).

Syndemics are based around the interactions of multiple factors that contribute to worse health outcomes. These interactions can occur at multiple scales, affecting both individuals and entire populations, often resulting from the "unjust exercise of power" (Singer, 2009). Syndemics and their characteristics can vary over space, with the region, country, community, or individual affecting how and why the syndemic changes and spreads (Mendenhall et al., 2022). The term is still most often used to refer to diseases, and more recently to describe certain aspects of the COVID-19 pandemic (Hortons, 2020; Irons, 2020), but pathogens alone are not the only things impacting health.

A syndemic "emerges when two or more health conditions co-occur in environments of aggravated adversity and interact synergistically to yield worse health outcomes than each affliction would likely generate on its own" (Willen et al., 2017). It refers to the "synergistic interaction between multiple health threats, often exacerbated by societal circumstances, which together contribute to an excess burden of disease" (ASTHO, 2023). As a syndemic emerges, it moves along the "fault lines of society" (Mendenhall et al., 2022), lines carved by pre-existing structural forces and inequalities often rooted in capitalism and colonialist practices. These fault lines can also make it harder for these syndemics to be resolved. Social and environmental instability further contribute to the formation and spread of syndemics, as social support networks are frayed and subsistence becomes more difficult (Singer, 2009). The syndemic framework is useful to understand the multiple interactions among factors that influence health, but more research is still needed on exactly how to best measure them.

The impacts of the Cantera los Manantiales mine experienced by the Ch'orti' is one example of a syndemic. The presence of the Cantera los Manantiales near the Maya Ch'orti' communities in Guatemala has led to a combination of negative social, political, economic, environmental, and human health impacts explained previously. Previous research suggests the negative impacts of the individual effects of each of these components, and offer evidence that these impacts are worse in closer proximity to the mine. However, we do not fully understand the long-term effects or consequences of mines in the region or the synergistic effects of the situation affecting the people in Olopa, making it a pressing issue. A mixed-methods approach, like those used in studies by Marcillo et al. (2020) and Basu et al. (2010), using both qualitative and quantitative data, is one effective way to more completely understand the syndemic effects of mining.

2.10 Participatory Mapping

Participatory mapping is one way to better understand syndemic effects and community perceptions of healthy places. Participatory mapping is a co-creation of knowledge that increases understanding by combining knowledge from multiple groups (Weyer et al., 2019) and "attempts to make visible the association between land and local communities" (Corbett, 2009). Both scientific and indigenous knowledge can be included, and maps can be used to examine health disparities through social and environmental determinants, specifically by exploring the conditions and perceptions in places where people live, work, and play (Douglas et al., 2020). It serves as a way to gather spatial and social knowledge based on the lived experiences in a place. This information can be used to identify patterns in perception, place values, and potential conflict areas (Brown et al., 2017; Douglas et al., 2020; Ramirez-Gomez et al., 2016). These maps then aid in the transfer of knowledge (Weyer et al., 2019) and can serve as a way to empower the community to use that information for change (Douglas et al., 2019).

Mapping has been done throughout history by communities themselves, but the facilitation of community mapping by outsiders is more recent, with mapping applications spanning a variety of fields and disciplines (Chambers, 2006). The methodology has been used around the world for numerous purposes with varying methodologies and goals. For example, participatory mapping has been used in studies related to land-use and land tenure (Brown and Raymond, 2014), disaster risk reduction (Cadag and Gaillard, 2012), and ecosystem services (Klain and Chan, 2012). Problems that affect entire communities tend to be complex, and the process of participatory mapping along with the collaboration and interdisciplinary methodologies involved aid in the development of knowledge, resources, and ideas to create solutions to these problems (Lasker and Weiss, 2003). This type of mapping engages communities across language and literacy rates, crossing disciplinary boundaries (NCVO, 2010) and allowing for a broader and more complete representation of local knowledge (Douglas et. al., 2020). The coproduction of knowledge enhances understanding for all parties involved, making research both more sustainable and more just (Weyer et al., 2019).

A range of positive impacts has been associated with community mapping through the production of a visual representation of community perceptions of a place, which can be more compelling than just words (Cochrane and Corbett, 2020; Parker, 2006). It can support diverse interests, promote social change, communicate community development needs, and be used as a tool for resistance (Cochrane and Corbett, 2020), all while empowering the community (Stocks, 2003) and explicitly recognizing residents as capable research collaborators (NCVO, 2010). This approach involves community members in all phases, from design to implementation and outcomes (Kesby, 2005). Maps are made within a culture and need to be interpreted and analyzed within that same cultural context (Rundstrom, 1990); they encompass history and identity, and are publicly visible (Stocks, 2003). If the story doesn't fit on the map, it needs to be written somewhere else, and in the language being spoken (Flavelle, 2002).

Participatory mapping ‘‘opens up cartography to the amateurs. It asks participants to share their experience, their values, and their vision about a particular place’’ (Lydon 2003, 4). It shows what a community perceives as its place and what's significant within it (Corbett, 2009). It's not always necessarily mapping the community itself; it's mapping residents' values and visions too (Parker, 2006), as "maps are more than pieces of paper. They are stories, conversations, lives, and songs lived out in a place and are inseparable from the political and cultural contexts in which they are used" (Rambaldi, 2005).

Mapping perceptions allows for the initiations of a map-based dialogue that expands upon the state of public space, and the implications that the state of those places has on the community (Pánek, 2018). Perceptions can impact a person's identity, ecosystem services, and more (Palacio et al., 2021), though the presence of emotions or perceptions, like those related to risks, is extremely rare in maps and spatial data (Griffin and McQuoid, 2012), even though emotions (perceptions) and places are interconnected (Pánek, 2018). These perceptions can be regarding specific locations or general zones (Preto et al., 2016).

People who work and depend on the land to meet daily needs already have true maps in their minds (Flavelle, 2002). Maps represent the places where people live, showing the features that they believe are important, and the combined results are a representation of the knowledge of the entire community. It presents expert spatial knowledge of the local community in a universally recognized geographical framework (Rainforest Foundation, 2015). Maps have long been symbols and instruments of power, so what is or is not included on a map, and how those things are represented, is vital and needs to be decided by the community participating in the mapping project.

Participatory mapping is a process, not a resolution (Bryan, 2011), and a plan is needed for after the map is made. In some projects, as noted by Nelson and Wright (1995), communities can actually be disempowered by the process by giving them a sense of their problems but no means to tackle them. The purpose and how the maps might be used should be discussed from the beginning (Flavelle, 2002). When done correctly, mapping can shine a light on community concerns and contribute to social justice issues (Cochrane and Corbett, 2020) by exploring problems, questions, and opportunities (Klonner et al., 2021).

The majority of ethical concerns regarding participatory mapping are found in the maps aiming to identify important resources that may then be exploited or in solidifying the location of territory boundaries and borders in land disputes (Chambers, 2006; Flavelle, 2002; Weyer et al., 2019). This type of mapping can be problematic when the process is only meant to extract information or when the data is manipulated (Cochrane and Corbett, 2020). For this reason, it's important to include people from all groups of the community, as marginalization can be magnified if not everyone is represented (Cochrane and Corbett, 2020). Maps convey information immediately, and they do so with a sense of authority (Rambaldi, 2005).

Limitations of participatory mapping include working with participants who might not have previously been exposed to physical maps. For this reason, explaining the symbols and information portrayed on the map is important to help orient participants. Similarly, some participants might not have prior experience writing, which depending on how the map is being made, might be necessary. This can be remedied by allowing participants to signal what should be marked and having someone else actually make the mark.

2.11 Conclusion

Mining impacts numerous aspects of community well-being including social, political, economic, environmental, and human health. We often see increases in displacement, poverty, food insecurity, and violence as a result of mining are well documented, as is concurrent degradation of natural resources, including water, air, and nonhuman ecology. The individual impacts of each of these components are understood, but no other study has examined the syndemic effects of a mine operating in a community. All of these factors contribute to poorer human health and increased rates of negative disease outcomes. At this point, the health, environment, security, and culture of indigenous Guatemalan communities, including the Ch'orti' communities in Olopa, may be severely impacted if these potential risks are not mitigated, but any mitigation measures require a baseline examination of any impacts.

We need to learn from their perspectives in order to grasp the problem in its entirety. By understanding community members' perceptions of environmental risk, health impacts, and healthy places, local leaders can better focus their efforts to improve human and environmental health in the area for the indigenous community. Mining is expected to increase globally in the coming years, partially due to the clean energy transition (Turner, 2022), and consequently, an increase in associated poor health outcomes are anticipated as well. As opposition to mining grows, people will be looking for ways to remediate the negative impacts, and understanding the syndemic, the interaction of various health impacts, will be necessary in order for policy makers to address the balance between clean energy needs and indigenous rights.

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CHAPTER III: Manuscript

3.1 Introduction

Mining provides numerous raw materials that society needs and depends upon, with sectors such as energy, technology, construction, agriculture, communication, and more relying on mined materials for operation and product development. Mining is often promoted as an economic development activity by the government, corporations, and the World Bank (Davis and Tilton, 2005; Dougherty, 2019, Const. Guatemala art. XXV). Though it is true that mining can stimulate local economies in less wealthy places, these benefits are rarely equitably distributed, and often come at the cost of irreversible landscape alterations and associated negative ecological and human health outcomes if not mitigated. Mining impacts in less wealthy countries, such as Guatemala, are exacerbated by poor mitigation planning and enforcement, and the recent technological shift from underground to open-pit design (Smith and Helfgott, 2010). Many of these new open-pit mines are located on indigenous lands, upon which local indigenous people are dependent for survival, and rely more heavily on machinery than unskilled labor, offering few economic opportunities.

In Guatemala, mining is promoted as a part of economic development by corporations, the World Bank, and the government, a way to rebuild after the 1960-1996 civil war (Davis and Tilton, 2005; Dougherty, 2019, Const. Guatemala art. XXV). This conflict was the longest in Central American history and is documented as one of the most violent with over 200,000 people killed (83% of whom were indigenous) and 1.5 million displaced (World Bank, 2018). Evidence suggests that these sufferings were disproportionately endured by indigenous populations; the death toll included entire communities with an estimated 626 villages that were completely destroyed (CEH, 1999; REHMI, 2003; Caxaj, 2014).

Building pressure from the World Bank, who encouraged economic development through increased industrialization and private investments, led many developing countries to reform their mining codes in the 1980s to establish more lenient regulations on labor, the environment, and human health, in order to be more industry-friendly (Moody, 1996). After the signing of the peace accords in 1996 at the end of the civil war, mining corporations flooded into Guatemala due to lax environmental regulations and easy permitting (Drewry et al., 2017; Saha, 2011; Shipton, 2017). Given documented impacts associated with mining, and the accompanying inequities in benefits and risks between different communities, many now argue that it is more accurately labeled as an industry instead of a development initiative (Bastos and de León, 2015; Kuecker, 2007; Nelson, 2015; Rasch, 2012; CECON-USAC, 2019); communities and movements reject the claim that mining is development. According to a document released by the World Bank, development combines: "(1) self-sustaining growth; (2) structural change in patterns of production; (3) technological upgrading; (4) social, political and institutional modernization; and (5) widespread improvement in the human condition" (Adelman, n.d., p. 1). A development activity is classified as something concerned with the well-being of every individual in society (Merino and de los Ríos Carmenado, 2012) while an industry is simply an "economic activity concerned with the processing of raw materials" (Lexico, n.d.). The mining law of 1997 allowed international industrial corporations into the country without protections for indigenous populations, clearly failing to protect some communities while benefitting others (Shipton, 2017).

Although Guatemala gained independence from Spain in 1821, the ladinos, or non-indigenous population, have maintained control over much of the indigenous population. Independence does not end colonialism, because "with the disappearance of the direct domination of foreigners over natives, the notion of domination and exploitation of natives by natives emerges" (Casanova, 1965, p. 1), a form of internal colonialism. The concept of internal colonialism was coined to describe patterns that took hold in Latin America and has become a systemic barrier to development (Gutiérrez, 2004). "Internal colonialism [is] a modern capitalist practice of oppression and exploitation of racial and ethnic minorities within the borders of the state characterized by relationships of domination, oppression, and exploitation" (Gutiérrez, 2004, p. 289).

This capitalist practice of oppression resulting in the "unjust distribution of healthy life" (Flynn, 2021, p. 1) is due in large part to a variety of social factors. Through the process that Flynn (2021) describes as commodification, resources, knowledge, and even people become commodities, used to garner a profit (2021). The uneven development brought about by internal colonialism and capitalism can result in the "concentration of environmentally detrimental pollution," (Flynn, 2021, p. 3) affecting entire communities, and indigenous communities are especially vulnerable, negatively impacting human rights and environmental rights as described in the concept of buen vivir, the attributing of rights to nature and people for the well-being of the entire community (Bastos and de León, 2015).

The oppressed population's inability to develop economically, and entrapment within the poverty cycle because the dominant economic system relies on their exploitation, inevitably leads to an unequal concentration of environmental hazards and risks that are exacerbated by the influx of extractive industries. The "structural pathogenesis" described by Sell and Williams (2020) refers to the ability of systemic inequalities and institutional conditions within societies to cause disease. This type of pathogenesis is attributed to capitalism and the resulting negative impacts that are unjustly and unequally distributed form a social gradient of health (Sell &

Williams, 2020). attributed to capitalism and the resulting negative impacts that are unjustly and unequally distributed form a social gradient of health (Sell & Williams, 2020). That gradient contributes to the syndemic, the interaction of health threats that results in worsening health outcomes, that is experienced in many places around the world. The negative health impacts associated with syndemics make accessing and using resources that much harder, ultimately continuing the cycle of poverty, and oftentimes, disease.

Extractivism, one branch of capitalism including rock and mineral mining, is defined by Gudynas (2016) as the high volume exploitation of natural resources for purposes of export. It is long associated with widening the social gradient of health and related economic inequities. Anything can be extracted– knowledge, resources, metals, and people– and this extraction provokes resistance (Riofrancos, 2020) and is linked to exploitation which also happens during colonialism. Capitalism, extractivism, and internal colonialism are systemic issues with long-term effects, contributing to the social, societal, and structural determinants of health. The Cantera los Manantiales mine in Olopa, Guatemala is an example of both extractivism and internal colonialism. As the Guatemalan government lessened some of the restrictions and environmental laws surrounding mining, control by non-indigenous elites flourished alongside international corporations. The antimony mine is currently owned and operated by non-indigenous Guatemalans extracting the materials from Ch'orti' indigenous land. As a result, the Ch'orti' are predictably beset by increased rates of malnutrition, poverty, diseases, and environmental degradation, along with decreased access to healthcare, income, education, and employment opportunities. Both social and societal determinants of health (Flynn, 2021) are impacting the overall well-being of the Ch'orti' in Olopa.

The aim of this research is to identify how the Ch'orti' people in Olopa, Chiquimula, Guatemala perceive the environmental health risks of the Cantera los Manantiales antimony mine, focusing on perceptions of syndemic effects and environmental risks, and mapping healthy and unhealthy locations in the region. The communities are still actively resisting the mine's operations and the Consejo Maya Ch'orti' of Olopa, the indigenous council, expressed interest in a study to better understand the effects of the mine. Using a community-based participatory research (CBPR) framework, we partnered with the Consejo Maya Ch'orti' of Olopa and the Observatorio de Industrias Extractivas (OIE), a research platform in Guatemala that was already working in the communities (OIE, 2022), to design a study to better understand community perceptions. The research focused on the following questions:

1) What are the perceived human and environmental health risks of the Cantera los Manantiales among the Ch'orti'?,

2) What areas of the community are perceived as healthy and unhealthy, and why?,

3) How do perceptions of human and environmental health risks related to mining compare to risks identified in the Environmental Impact Assessment (EIA)?, and

4) Where and how should local community activist leaders focus their efforts to improve human and environmental health in the area?

These questions, accompanied by a mapping project, draw attention to the health risks of mining, which has expanded in Guatemala in recent years (Basu et al 2010), and will help local activists effectively assess health needs and target their efforts to improve health in communities where mining operations are present.

3.2 Background

Guatemala boasts a high proportion of indigenous peoples, with 55% of the population identifying as part of one of the 26 distinct indigenous groups present today, one of whom is the Ch'orti' people (Holden and Jacobson, 2008; Minority Rights Group International, 2018). In the 2018 census more than 112,000 people identified as Ch'orti', with communities mostly situated in Chiquimula, Zacapa y Petén (INE, 2018). They work closely with the land through subsistence agriculture, are easily able to identify environmental problems or changes (e.g. disappearance of springs and other wild species), and are increasingly impacted by environmental pollution, land cover change, and soil degradation (Holden and Jacobson, 2008; Tengö, 2021), in large part because of this close relationship to the earth. The importance of indigenous knowledge and connection to their land is evident in their concept of buen vivir or "well living," and ascribed to the idea from Mayan spirituality that extractive industries harm Mother Earth (Rasch, 2012). There are 14 Ch'orti' communities surrounding the Cantera los Manantiales antimony mine that make up the Consejo Indígena Maya Ch'orti' de Olopa, and all are involved in subsistence agriculture and rely heavily on their traditional lands for sustenance and income (Caxaj, 2014; Holden and Jacobson, 2008).

The majority of Mayan communities, the Ch'orti' included, live in high-poverty situations, with limited rights, healthcare, and education (Mactaggart, 2018), and they are subject to numerous language, social, and cultural barriers (Cerón et al., 2016), making them a vulnerable population. Based on data gathered from participants in the communities, schools in the region do not teach in the Ch'orti' language are not always open for students to attend classes, and health centers are not always staffed and can be difficult to reach. The Ch'orti' have lived in eastern Guatemala for centuries, with sediment cores, artwork, and pottery confirming their presence in the area as early as A.D. 100 (Metz et al., 2009). This presence has shaped the landscape over numerous generations. The synergistic coexistence contributed to the extensive knowledge that the Ch'orti' people now possess of their lands and the earth. Even today, the majority of the Ch'orti' people depend on their lands for shelter, food, and medicine, a dependence that has been put in jeopardy by external forces, such as the Cantera los Manantiales antimony mine.

Now converted from an underground to an open-pit mine, Cantera los Manantiales (LEXT-033-07), an antimony mine located on Ch'orti' land, owned previously by American Minerals SA and later by BC Enterprises, obtained its current mining permit in 2007 and began operations in Olopa in 2012 under Guatemalan and current owners Guillermina and Odilio Guzmán (Toro, 2020), extracting between 60 and 170 tons of antimony annually (USGS, 2016). The antimony extraction project began operating without obtaining free, prior, and informed consent from the indigenous communities living on the land (PBI Guatemala, n.d.), and tangible effects from the mining operations have been present in the region since at least 2015, including environmental contamination (e.g. perceived water and air contamination attributed to the mine) and health concerns (e.g. skin rashes, respiratory problems, infectious diseases) (Toro, 2020). Intense mining operations with the use of heavy machinery began in 2016, with a resistance movement gaining traction six months later.

Indigenous peoples have long been aware of the adverse impacts of resource extraction and have fought since the beginnings of colonialism against extractive industries. During the resistance movement in Olopa, the Ch'orti' communities, as well as several other indigenous and non-indigenous communities from the surrounding areas, came together to protest the mine's operation on their land despite the criminalization of their resistance. Hundreds of people participated in the resistance movement which included a plantón, with people guarding the entrance of the mine day and night for several months to limit mining operations. Dozens of people have been arrested for peaceful protests (Toro, 2020), and many community leaders in the areas surrounding the mines have been the victims of intimidation, threats, and numerous attacks since the beginning of their resistance (Sancir, 2020). Community members fought to suspend the mining license because they understood that they and their land would be vulnerable to the negative impacts associated with mining.

The metal antimony is element number 51 on the periodic table and is a priority pollutant under the US Clean Water Act due to its documented toxicity and risk of bioaccumulation (Fei et al., 2017; Jiang et al., 2021; Bolan et al., 2022). Currently, it is used as a flame retardant, in the production of microchips, in lead-acid batteries, as treatment for some parasitic diseases, and as an alloy to increase the hardness of lead (Arreaga, 2018;4). Antimony is found in iPhones, kitchen appliances, cars, wind turbines, solar panels, and more (Blackmon, 2021). The metal has recently been included in the critical raw materials (CRM) list composed by the European Union, which consists of materials that are "characterized by increased economic importance, high-risk supply chains, and the inability of substitution by materials of commensurate properties" (Periferakis et al., 2022). As a result, antimony prices have risen drastically in the last three decades, increasing demand and therefore production and extraction processes around the world.

It is widely understood that mining can negatively affect the health of entire communities through adverse impacts on numerous aspects of community well-being, including social, political, economic, environmental, and human health (Drewry et al., 2017). Several studies have looked at specific aspects of human and environmental health related to various contaminants from mining, like those by Abdul-Wahab and Marikar (2012), Saha (2011), and Kuecker (2007), who looked at the effects of mining in terms of heavy metal contamination in Oman, environmental degradation in India, and community divisions in Ecuador respectively. We also know from studies done by Fashola et al. (2016) in South Africa and Ngure et al. (2014) in Kenya, and from a literature review by Stephens and Ahern (2001) of community health related to mining, that mining's negative effects last long after mining operations have ceased. These effects are often worse in close proximity to the mine, lessening as distance increases, in line with the distance decay theory (Hasova and Wolf, 2022). Mining activities lead to the overall degradation of the environment through various avenues, and studies have also shown that these effects worsen as proximity to the mine increases (Basu et al., 2010; Owen et al., 2021; Van de Wauw et al., 2010).

The loss of these traditional and ancestral lands through forced evictions or environmental degradation has led in part to the erosion of the ethnosphere of the affected communities. Davis (2002) defines an ethnosphere as something that is vital to our well-being, "the sum total of thoughts, beliefs, myths, and intuitions brought into being by the human imagination since the dawn of consciousness" (p. 57), and able to erode in the same way as the biosphere, often at a faster rate. As the significance of places disappear as a result of environmental degradation, memories and histories lose their moorings.

Therefore, it is unsurprising that the impact of mining on land can lead to solastalgia, which is the "distress that is produced by environmental change impacting on people while they are directly connected to their home environment" (Albrecht et al., 2007, p. 1). This *longing for home without having left* can be the result of a range of environmental or social changes, mining included, and "in many cases, solastalgia is the outcome of social and economic forces that are, in turn, the result of deliberate political policy" (Albrecht, 2020, p. 13). As literal roots are severed as vegetation is cleared and mountains are deforested, the figurative roots tying people to a place are removed as well.

Mining can also be also associated with an increase in chronic health conditions from environmental hazards. In mining areas, heavy metals are the main pollution risk, with exposure occurring through inhalation, direct contact (Stephens and Ahern, 2001), drinking contaminated water (Yagenova and García, 2009), or eating contaminated foods (Bundschuh et al., 2012). Antimony has known impacts on the skin, eyes, gastrointestinal, cardiac, and respiratory systems, with even very small amounts of the metal known to cause disease (Jiang et al., 2021; Zeng et al., 2015; Sundar & Chakravarty, 2002); the current USEPA maximum contamination level for antimony in drinking water is 6 ppb, less than half the action limit for lead (EPA, 2023). The environmental damage coupled with mental health effects brought about by the increased stress and community instability, combined with the climate of fear, displacement, and lack of trust, weaken the immune system (Canu et al., 2017; Salleh, 2008). This predisposes community members to negative health outcomes attributed to mining contamination in soils via food, air, and water, as "mining wastes, the poor and deprived, and the most vulnerable members of the community are often found in juxtaposition" (Entwistle et. al., 2019).

Community health can be defined broadly as "a positive concept, encompassing all of the environmental, social, and economic resources as well as the emotional and physical capacities that enable people in a geographic area to realize their aspirations and satisfy their needs" (Lasker and Weiss, 2003). Multiple factors interact to affect overall health, of both a community and an individual, and for that reason it is important to look at health from a syndemic perspective. A syndemic is something that emerges when two or more social or biological conditions co-occur and interact synergistically to yield worse health outcomes than each condition would likely generate on its own (Willen et al., 2017). It refers to the "synergistic interaction between multiple health threats, often exacerbated by societal circumstances, which together contribute to an excess burden of disease" (ASTHO, 2023). As a syndemic emerges, it moves along the "fault lines of society" (Mendenhall et al., 2022), lines carved by pre-existing structural forces and inequalities often rooted in capitalism and colonialist practices. These fault lines can also make it harder for these syndemics to be resolved.

We argue that the impacts of the Cantera los Manantiales mine experienced by the Ch'orti' is one example of a syndemic. The presence of the Cantera los Manantiales near the Maya Ch'orti' communities in Guatemala has led to a combination of negative social, political, economic, environmental, and human health impacts that are broadly associated with mining, as explained previously. We know and understand the individual effects of each of these components, and we know that these impacts are worse in closer proximity to the mine. However, we do not fully understand the long-term effects or consequences of mines in the region or the synergistic effects of the situation affecting the people in Olopa, making it a pressing issue.

Most studies that investigate relationships between mining and ecological and human health employ statistical techniques using morbidity and mortality data. In areas where such data are not available, such as resource-poor regions, other data collection and analysis techniques are needed. Qualitative techniques such as focus groups, interviews, and participatory mapping can offer a local perspective of the challenges people are facing within the communities. Interviews allow participants to offer explanations in their own words, producing a deeper understanding of the problem or question, while focus groups allow for ideas to be shared and developed between people. While participatory mapping is a frequently used data collection tool, particularly in studies related to land-use and land tenure (Brown and Raymond, 2014), disaster risk reduction (Cadag and Gaillard, 2012), and ecosystem services (Klain and Chan, 2012), it has not often been applied to studies of human health.

Community mapping is an underutilized but empowering tool, allowing both the community and researchers to learn more about local circumstances and community health (Douglas et al., 2019). Participatory mapping can provide a way to visualize syndemic health impacts, highlighting various facets of health, and serving as a tool that can be used to analyze and better understand both social and environmental determinants of public health disparities (Douglas et. al., 2020). As systemic inequalities contribute to uneven health outcomes due to unequal access to resources, community mapping serves as a tool to obtain social and spatial knowledge that is based on lived experience in a place that demonstrates the underlying patterns of those inequalities (Douglas et. al., 2020; Forrester et al., 2015). Combined with interviews and stories, participatory mapping can offer distinct cultural understandings of a landscape that are typically omitted from official maps, providing a snapshot of the reality of life in that place.

3.3 Study Area

Guatemala is the most populous country in Central America with 18.5 million inhabitants, approximately 1 million of whom live in Guatemala City; the population is steadily growing despite negative net migration (Guatemala Population 2021; SINTET, 2022). As of 2022, the fertility rate stood at 2.5 per woman, with the rate of natural increase at 1.42% (Macrotrends, n.d.). The country has one of the poorest health ratings in Latin America, with one of the highest infant mortality rates (18.7 per 1,000 live births) and one of the lowest life expectancies (70 years) (World Bank, 2020; SINTET, 2022). Guatemala as a whole has the second-highest rate of mortality attributed to unsafe water and sanitation and lack of hygiene in the Americas, with 90% of surface and groundwater contaminated by sewage (Campbell, 2018). The growing population combined with low education levels, high illiteracy rates, poor training for workers, and an overall lack of economic options all contribute to increased susceptibility and vulnerability to environmental and economic shocks, such as natural disasters and malnutrition, in many of the twenty-two departments in the country (SINTET, 2022).

The department of Chiquimula, located in eastern Guatemala and bordering both Honduras and El Salvador, has some of the highest rates of extreme poverty in the country. More than 73% of the population of Chiquimula lives in rural areas (INE, 2014), more than half of the population is under age 19, and 93% of the population speaks Spanish with the remaining 7% speaking indigenous languages (Guatemala Population, 2021). Olopa is a municipality within the department of Chiquimula, located 215 km from Guatemala City on the historic lands of the Ch'orti' people; Ch'orti' means "milpa en la boca," or "corn in the mouth," signifying their connection with the land and the most important Mayan subsistence crop (SINTET, 2022).

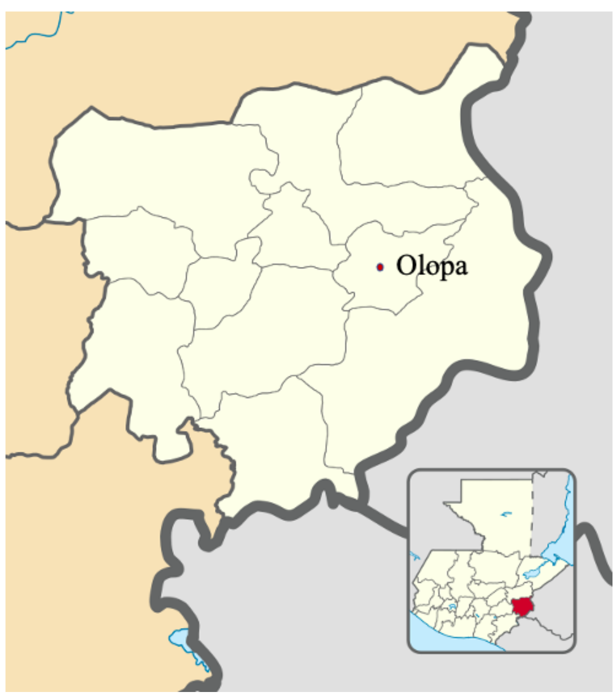

Figure 1: Map of the municipalities in the department of Chiquimula, Guatemala

Olopa is currently home to more than 27,000 people and covers an area of 112 km^2, including one town and 29 villages. More than 91% of the population is rural and lacks access to healthcare, education, and other basic services and opportunities (SINTET, 2022). Approximately 17% of the land in Olopa is part of Ch'orti' territory, which extends into Honduras and El Salvador (SINTET, 2022) along with the surrounding Guatemalan municipalities of Camotán and Jocotán (PBI Guatemala, n.d.). Few studies and ethnographies have been conducted among the Ch'orti', although it is known that poverty in the Ch'orti' region is higher than in other areas of the department (SINTET, 2022).

Olopa is characterized by rolling hills, with most of the land mountainous, averaging around 1350m above sea level (SINTET, 2022). Steep slopes contribute to erosion and highlight the need to implement soil conservation techniques (e.g. terracing) along with forest preservation, or reforestation if vegetation cover is removed. Olopa's vegetation cover is considered to be a humid temperate subtropical forest (SINTET, 2022) and temperatures range from 4-21℃, with the majority of the 636 mm of rainfall occurring between May and November (SINTET, 2022). Though four rivers exist in the department, Chiquimula has some of the lowest rates of improved access to water in all of Guatemala, falling below the national average with more than 20% relying on unimproved sources, and rates are worse in Olopa itself (Guatemala WASH Poverty Diagnostic, 2015). Problems with access to potable water are correlated with an increase in deaths from infectious diseases associated with environmental causes (INE, 2014), and extractive industries further reduce water quality and quantity in this area (PBI Guatemala, n.d.).

The communities that make up Olopa are part of a traditionally agricultural society, with 93% of people dependent on agriculture for income and subsistence (SINTET, 2022). Crops are sold to larger farms that then sell them at markets or package them for export. Most people grow corn, beans, coffee, and a variety of other fruits and vegetables. Many community members keep chickens and turkeys, and a few have cows or pigs, for subsistence purposes. In Guatemala, children are considered part of the active economy at age seven, often working instead of attending school, thus continuing the poverty cycle (SINTET, 2022). Because of this cycle, Olopa is considered as having limited development potential because of declining agricultural yields and resulting struggles with subsistence, along with limited educational and employment opportunities (SINTET, 2022).

Communities in Olopa have noted increasing struggles in accessing wood for fuel and building construction and water to support household and agricultural needs (SINTET, 2022). Poverty rates in Olopa have increased in recent years and are now higher than the national average, with 79% of the population considered to be impoverished (INE, 2014; Guatemala WASH Poverty Diagnostic, 2015). The majority of people living in Olopa have low education levels and limited or no job training (SINTET, 2022). Approximately 49% of the population has no schooling and 71% of adults are illiterate. Currently, 57% of children begin primary school, though only 45% of the total population in the municipality has a primary school education, and only 5% of students attend middle school (SINTET, 2022). Due to low education levels, there is evidence of what is considered "social deterioration," the inability to satisfy the basic needs necessary to maintain an acceptable quality of life, as a result of the limited future capacity for earning and subsistence potential (SINTET, 2022).

Around 95% of people own their own homes in Olopa (SINTET, 2022), though the characteristics of the houses themselves vary greatly depending on household income. The majority of homes, 85%, are one-room structures with dirt floors, averaging 7 people per household. Most of these homes are made from natural materials with 60% of homes having mud walls (SINTET, 2022). The materials that the homes are made of foster insect activity within the home that contributes to the spread of Chagas disease and other negative health effects, especially for young children who crawl on the floor (SINTET, 2022). Around 50% of people have running water, though this water is not necessarily treated, as there is no municipal-level water treatment and no sewage treatment (SINTET, 2022). Of the homes in Olopa, 50% do not have sanitation services or latrines, 66% of homes do not have electricity, and 72% of homes have no waste disposal (SINTET, 2022). Roughly 93% of homes use wood for cooking, contributing to exposure to indoor air pollution (SINTET, 2022). All of these factors together impact individual and community health.

Many of the health problems in Olopa originate in malnutrition and poverty (SINTET, 2022). Leading causes of death in the municipality are diarrhea, pneumonia, perinatal asphyxia, malnutrition, and neonatal sepsis (SINTET, 2022). Malnutrition has increased more than 20% in the last five years, with more than 66% of children in the area consistently being identified as chronically malnourished (Moloney, 2020; SINTET, 2022). There is a lack of medical equipment and transportation in the area, and a shorter life expectancy in this municipality when compared to other regions (SINTET, 2022). There is strong dependence on herbal remedies derived from locally-grown plants due in part to the lack of nearby doctors and health care infrastructure, and the cost of accessing them.

The previously described conditions and statistics represent the municipality of Olopa as a whole. Data are not available at a finer spatial scale, and through conversations and observations, the villages in which this study occurred have higher rates of poverty and malnutrition, with lower literacy rates and less access to health care, than the broader municipality.

3.4 Methods

Data collection

This study employed the use of primary data collected in six of the fourteen Ch'orti' communities in Olopa, Chiquimula, Guatemala from May 16 to June 24, 2022 through a partnership with the Ch'orti' indigenous leaders, the Consejo Maya Ch'orti' de Olopa, and OIE. The study protocol was approved by the Virginia Tech Institutional Review Board [VA, USA, IRB#22-142] prior to beginning the study. In order to assess the relative influence of the Cantera los Manantiales mine on perceptions of environmental risk and the health of spaces within communities, we employed purposeful sampling to ensure that communities in close proximity to the mine, further from the mine, and both upstream and downstream were included in the study. Communities were selected with the help of indigenous leaders; communities in which data were collected are La Prensa, El Amatillo, El Carrizal, El Cerrón, La Cumbre, and El Paternito.

Before beginning fieldwork, we met with community leaders to make sure the project and research questions aligned with their needs and goals and to obtain informed consent to conduct the research in their communities; these communities had already expressed interest in a study of this type to support their opposition to the mine's impacts. All methods and data collection were guided by and developed with community leaders in Olopa as a form of CBPR, a process that seeks to "engage people in a learning process that provides knowledge about the social injustices negatively influencing their life circumstances" (Cammarota and Fine, 2008). CBPR is grounded in local knowledge and struggles, and gives voice to people's experiences (Hay and Cope, 2021).

Ch’orti’ residents of Olopa fully participated in most aspects of the study from finalizing research questions to participating in a two-way exchange of information to better understand the syndemic effects of the mine operating in their communities.

We met with the Consejo Maya Ch’orti’ de Olopa and with representatives from the fourteen communities on May 22, 2022, as it was important to build trust in the communities, making sure participants understood their rights and had the opportunity to ask questions. Furthermore, we ensured that the communities would have access to the maps and data that were produced and collected. Obtaining free, prior, and informed consent was essential before beginning the project to be able to work with the communities as collaborators. All information about the process, objectives, goals, and data were discussed before any data collection started, allowing the communities to decide in a way informed by their culture whether or not to participate in the project (Rainforest Foundation, 2015). Communication throughout the process was crucial for the co-production of knowledge that was desired (Cochrane and Corbett, 2020; Forrester et al., 2015), and it was an interactive process (Emmel, 2008).

We worked with leaders to identify adult community members who would be interested in participating in the study, seeking a representative balance of men and women of various ages. Due to the tense social situation and continuing threats, we were unable to speak with those who supported the mine; we only talked to people that supported and/or participated in the resistance. Our data collection process consisted of community mapping workshops, interviews, participatory mapping, community health mapping, and observation noted with photographs and fieldnotes. Table 1 provides information on interviewees and communities where data collection took place.

Table 1: Study participants and community information

Community	# of participants in mapping workshop	# of days spent in the community	# of people interviewed	Avg. age of interviewees	Distance from mine	Upstream/ downstream from the mine
El Amatillo	3	4	10	(30-75) 55	2 km	Upstream
La Prensa	3	2	5	(33-80) 61	0.5 km	Upstream
El Carrizal	3	3	4	(48-72) 62	0.8 km	Downstream
La Cumbre	2	2	5	(23-65) 42	5 km	Upstream
El Cerrón	7	3	7	(40-69) 53	3.8 km	Upstream
El Paternito	5	1	0	-	2.3 km	Upstream
Totals	23	14	31	(23-80) 55	Avg: 2.4 km	–

Community Mapping Workshops

On our first day in each of the six communities, we conducted a community mapping workshop at the community's Catholic church. This served as a central meeting place that was easy to find, and offered a space large enough to accommodate several people. Before beginning the workshop or collecting any information, we explained the purpose of the project and the types of questions we would ask. Groups of community members ranged in size from two to seven people, depending on the community and availability of participants.

This workshop had several motivations. First, it was a way to introduce ourselves to the community and orient ourselves to the area to better be able to assist individuals during the mapping portion. It also served as a way to further familiarize community leaders with the project so that they could better identify potential participants. Using tracing paper, markers, and a base map, leaders were asked to identify key areas or neighborhoods in the community, the location of current or past water sources, any areas of contamination, and general areas of any families known to be sick. The combined knowledge helped to create a starting point and base level of understanding from which to build over the days that followed working in that community. These workshops were not recorded but handwritten notes were taken throughout the meeting.

Interviews

The primary method for data collection in this project was individual, semi-structured interviews with a participatory mapping component. We conducted 32 individual semi-structured interviews with Ch'orti' community members from households across six villages in the study area. Each interview and participatory mapping activity, conducted in Spanish and typically in the participants' homes or a community church, lasted approximately one hour. The interview script is available in Appendix 1.

Interviews consisted of questions related to household demographics, knowledge and perception of the mine, perception of local environmental quality, and perception of health. Perception, in this case, was defined in the sense of one's understanding or interpretation of the surrounding environment, dependent upon experience and motivation, and like in the study by Preto et al. (2016), risk can be seen as a threat or vulnerability to well-being. Following receipt of informed consent, interviews began with collection of basic demographic information including the participant's age, the number of children, the number of people living in the home, education level, employment, number of years of residence in Olopa, primary foods consumed, and access to land for crops. I then asked questions regarding their knowledge and opinions of the Cantera Los Manantiales mine. Next, I asked about perceptions of the surrounding environment and potential environmental changes since the start of mining operations; follow-up questions addressed perceptions of local water, soil, and air. Finally, health-related questions considered health both before and after the mine began operating, and included symptoms and their perceived causes experienced in the last year. Interviews were recorded and later transcribed using only a participant ID number. Transcription took place as soon as possible following the interview by a contracted transcriber. The interviews were not translated, except on an as-needed basis, and transcriptions were analyzed in Spanish.

Participatory mapping

Participants were asked to complete a participatory mapping component during the second part of each individual interview. Each participant was provided with a blank piece of tracing paper laid over a base map of their community to assist with the creation of their map. The area shown in the base map was decided alongside community leaders and contained known and easily recognizable landmarks. Usually the church, school, soccer field, and health center, if present, served as reference points in the community. I showed them roads and explained where the roads led off of the map to further orient them on the page. Many participants had never seen a map before, and we worked together to increase cartographic literacy. The majority of them, when asked where their crops were planted or where their children go to school, would point in the actual direction of the place in question, and then we'd find it on the map. Many of those interviewed did not know how to read or write. During the mapping component, participants were given the option of marking the locations on the map themselves. If they were not comfortable with this, they would point out the locations on the map for me to mark instead.

Participants were provided with several markers along with the base map and tracing paper, allowing them to choose how to represent features however they wished. The majority of the mapping was in terms of perceptions and risks. The location of their home, their land used for agriculture, and water sources were marked. If they had children in school, attended a church, used the health center, or frequently visited another community location, those areas were marked as well. We also asked them if they knew of anyone who had been sick in recent years with a specific disease, and if so, the approximate locations of those homes were marked. Some of the key points mentioned in the interviews were brought back up during the mapping component so that their locations could be identified.

These maps represent the actual experiences of participants in the mapping project (Boschmann and Cubbon, 2014), provide a clear picture of community perceptions (Flavelle, 2002), and have a spatial reference that was used for further analysis (Klonner et al., 2021). Mapping while conducting an interview was a helpful approach, as the map remained as an additional record of the conversation (Emmel, 2008). The conversation during map creation added another layer to the interpretation of the map, increasing its value as a research tool (D'Antona, Cak, and VanWey, 2008; Klonner et al., 2021; NCVO, 2010).

Though many studies have created maps in small groups or with input of the entire community, in some cases, it is better to make a series of maps completed by individuals instead of with a group, as those with the pen have the power (NCVO, 2010). For this reason, the mapping was done both at the community level during a mapping workshop with community leaders, as well as individually, as each person can have different perceptions of the environmental risks and healthy places within the community. This strategy also allowed the maps to be combined with the interviews, increasing the information that was acquired. The aim of the interview and map was not necessarily to be representative of the larger community, but rather to understand the way each individual made sense of their own life and experiences, and interpreted the space around them (Flowerdew and Martin, 2005).

This type of mapping can be problematic when the process is only meant to extract information or when the data are manipulated (Cochrane and Corbett, 2020); we attempted to minimize ethical concerns associated with participant mapping by involving the community in all aspects of the study, sharing results after data collection and analysis, and maintaining regular contact with community leaders throughout the study.

Community health maps

A community health map that depicted household-level health and symptom data was made in one of the communities with the assistance of the local comadrona, or midwife, who lives in the community and has a thorough understanding of the state of health due to frequent visitation with residents. The map was made in the comadrona's home using the same base maps, tracing paper, and markers as employed in the individual participatory mapping step. We were able to gather information for each household in the community, as the comadrona knew who lived in each home and the type of health problems residents in each household had experienced in recent years. For each family or household, we marked a different colored dot for each of the following based on the information provided by the comadrona: skin problems, fever, late term miscarriage/stillbirth, vision problems, respiratory diseases, death of household animals, sick children, and deaths.

Fieldnotes and photographs

Photographs and fieldnotes were taken throughout the study. Pictures were taken with permission and did not include faces or other identifying information. Photographs included landscapes, the mine and other locations that were part of the resistance, mapping workshops, community members who assisted us, skin disease attributed to the mine, and other related content. Fieldnotes included information from informal conversations with community members, stories we were told regarding the resistance and related events, observations, and information gathered during the mapping workshops.

Data analysis

Interviews

Interview data were analyzed once fieldwork was completed using content analysis. Interview recordings were transcribed by a paid professional transcriber. The transcripts were analyzed for pattern construction and interrelationships through both manifest content analysis and latent content analysis, and through coding and the identification of themes. Manifest content analysis looks at the text at the surface level, identifying specific words or phrases in the transcripts that can later be coded. Latent content analysis goes beyond that, focusing on the implicit themes and meanings within the text, Iing beliefs, stereotypes, and other underlying points. Transcripts were coded using both a priori coding, codes established prior to the interviews based on concepts that would be relevant in answering the research questions, and emergent coding, related codes that were offered by the participants during the interview process. The transcriptions were then coded for qualitative analysis using Nvivo software. The initial codebook, which contained 46 codes, was made based on common themes identified in the interviews and fieldnotes. After additions and deletions during the first round of coding, the final codebook contained 56 codes. Each interview, note from the community mapping workshops, and field note was coded using the same codebook. The codes were then categorized for analysis to identify relevant themes and patterns related to perceptions of the syndemic effects, including social, political, economic, environmental, and human health. Codes were also analyzed to evaluate the perceived environmental risks and how they compare to those identified in the EIA, and healthy and unhealthy locations in the region.

Maps

Qualitative analysis of individual maps involved visually examining the various maps to identify commonalities and differences of attributes and perceptions on each of the paper maps. All of the maps from each community were compared to one another. The maps created by participants were analyzed to identify relevant themes and patterns related to perceptions of the syndemic effects, environmental risks, and healthy and unhealthy locations in the region. The map findings were then compiled with the interview findings.

For the community health map made with the comadrona, each household identified on the map was labeled from 1 to 86. The health afflictions for each household as evidenced by the colored dots were entered into a table and the total number of households experiencing each affliction were summed. Through this process the proportion of households in El Amatillo experiencing each condition could be determined.

Environmental Impact Assessment

The EIA for the Cantera los Manantiales antimony mine was conducted by Jorol Barrios in January of 2008. The EIA recognizes the presence of indigenous people and communities in the area where the mine is located. However, according to the EIA, all minerals and metals on Ch'orti' land are considered property of the Republic, therefore belonging to Guatemala, and not the local community.

The Environmental Impact Assessment for the Cantera los Manantiales was reviewed and coded for qualitative content analysis, with similar codes and themes to those described above using Nvivo, focusing on potential impacts, especially those related to health. The final codebook contained 26 codes which ranged from aesthetic impacts to landscape alterations and proposed mitigation. Like with the interviews, some initial codes used for the EIA were established before analysis, though new codes arose during the content analysis process. Once coded, the EIA was analyzed in conjunction with the coded interview data, and the data from each were compared with the goal of determining how the perceptions of environmental risks related to mining identified during the interviews compare to those risks identified in the EIA.

3.5 Results and Discussion

We provide initial evidence that, based on perceptions of residents in six communities, the Cantera los Manantiales antimony mine is negatively impacting health in the Ch'orti' communities of Olopa, Guatemala. In fact, all residents participating in this project perceived negative human, environmental, political, social, and economic health impacts that they attributed to the mine. While community members associated many of the negative health effects with the mine, it is important to note that other causes could be at least partially responsible. Our findings align with results of other studies conducted surrounding mining sites around the world, specifically regarding the negative impacts in indigenous communities. However, instead of focusing on just one aspect of health impacted by the mine, like many previous studies, this work sought to look at the health impacts from a wider, syndemic perspective, addressing the multiple interacting components of health.

The results section is organized by theme, and each theme includes findings from interviews, mapping, and the EIA content analysis. Each theme is one area of health that contributes to the overall syndemic health effects and impacts of the mine in the Ch'orti' communities. Some results could span more than one theme due to the interacting synergistic effects, affecting both human and economic health for example, but each finding is only discussed in one of the themes.

Environmental Impact Assessment

Overall, the EIA poorly integrated the expected social, economic, and human health effects of the mine into the report. As expected, the EIA mainly focused on aspects related to environmental conditions and impacts. Human health impacts were not discussed in the EIA except for those associated with workplace accidents and injuries, as the document did not address potential risks for the surrounding communities. With its focus on environmental impacts, the EIA did not mention any economic risks, stating only that mining is an important part of the local economy; however according to the EIA, between all required personnel, guards, and operators, only six to eight people would be employed. The EIA specifically noted that the project would improve the quality of life in the community of Las Escobas, however, per information from the Ch'orti' council and interviews, this community does not exist. The EIA also noted the importance of the communities' opinions in regards to the project and included a list of names of people that they claim to have spoken to, stating that "in general, there was backing and support for the project." According to participants, all of the names are those of previous mine workers, and interviews were never conducted to ask opinions of community members.

According to the EIA, the mining project could result in limited noise pollution, associated only with trucks entering the area, but that all operations would be performed during the day to reduce the impact of that noise. The visual impacts would be associated with the introduction of artificial elements and construction into a previously minimally disturbed area, but mining equipment and materials would be located in less visible areas to reduce that visual impact. During interviews and conversations in the communities, residents complained of large speeding trucks and blasting from explosives, occurring both during the day and throughout the night.

The EIA noted that mining operations would remove the top layer of soil and vegetation to access the metal underground, and that wastes would be deposited in a specified area to reduce the impact on the surrounding land. However, according to community members, mining waste, visualized on satellite images outside of the area granted in the mining license, was dumped along roads and on fields where children play. Three of the communities, El Amatillo, La Prensa, and El Carrizal, marked the location of mining waste dump sites along roads and on fields on their community maps. Figure 2 shows these locations.

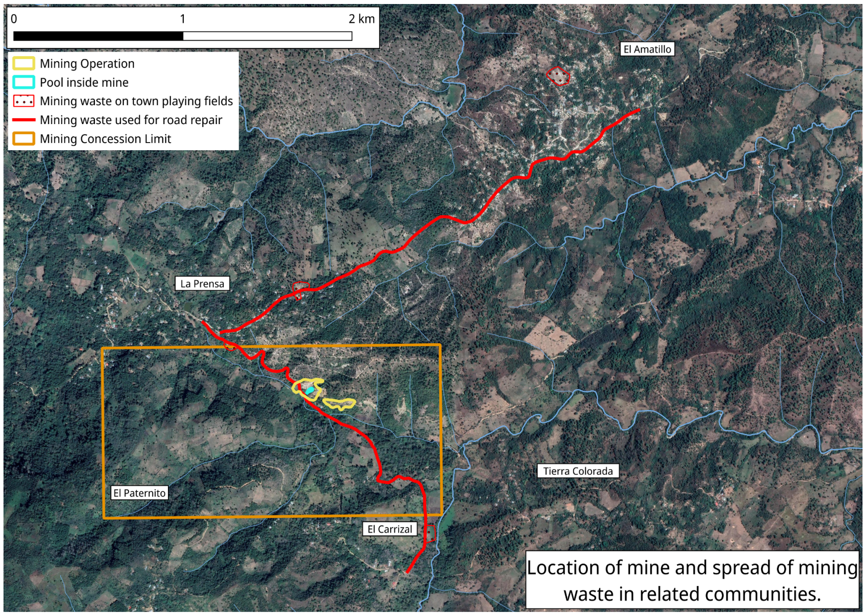

Figure 2: Location of mining waste in communities surrounding the Cantera los Manantiales

The EIA specifically notes that the project is located in an area used for agriculture, reducing the land available for crops, and furthermore, it states that explosives will not be used in the project, which was contradicted by interviewees who noted the damage caused by the use of explosives.

According to the EIA, multiple visits were made to the site to monitor air quality before the start of mining operations, and no existing air quality problems were identified. The EIA notes that both above ground and below ground sources of water could be affected by mining operations, and that impacts on the atmosphere could include noise, dust, suspended and respirable solids, and other gas emissions, though they note that impacts will be mild, temporary, and only during the summer, with concentrations always staying below the recommended health limits. Instability and erosion could result from mining activities as well, and local ecosystem impacts could include effects on both flora and fauna. Gas and oil used in the mining equipment could contaminate the waters if the equipment is not maintained properly. All risks, according to the EIA, will be mitigated, through the secure storage of machinery, the creation of drainage systems, and an enforced speed limit for example, and should therefore be of no concern, and all impacted areas will be reforested at the closure of the project. Community members have a different perception of risks.

Antimony Exposure

Interviews identified four possible pathways for antimony exposure from the mine: air, water, mining waste, and other people. Proximity to the mine was also identified as an additional risk factor, with those living closer to the mine perceived to have greater exposure to contaminant pathways, in line with the distance decay theory. Several people mentioned that the effects of the mine were worse in areas or communities that are closest to the mine. One person noted, "the most affected are those that live close to the mine," and a resident of El Cerrón said, "the communities that are closest, it affected them the most. Here it was a little less, we're higher up." Twenty-five people of the 31 interviewed attributed some of the human and environmental health effects that will be discussed to air contamination, exposure to which increased with the dust that coated the villages during mining operations. One person in El Cerrón said, "shortly after they started mining, they blew up the hill. 'That hill and that dust are going to reach us', they said. It turned out to be granazón [a blistering skin rash that interviewees perceived to be caused by the mine].” Water contamination and exposure to antimony through water was mentioned by twenty different people, a total of 50 times. One person in El Amatillo said, “the water is damaged, and since you bathe… I have suffered, look. An itching rash on my body, yes, a terrible rash on my body,” and another in El Cerrón said, “cattle died just from drinking that water.” Finally, eight of the ten people in El Amatillo, four of the five in La Prensa, and two of the four in El Carrizal mentioned exposure to antimony through mining waste and soil contamination. In these three communities, and in El Paternito, mining waste was dumped along the roads and on soccer fields where children play and was delineated on the maps made in those four communities. One person in El Amatillo said, “they dumped waste and that affected the animals, too.” Some people also noted the possible introduction of antimony dust into homes on the clothing or shoes of those going near the mine to participate in the resistance, suggesting the need to mitigate possible exposure routes.

Impacts Related to Political Conditions

During interviews, community members placed some responsibility on political leaders for the destruction of their land by the mining operation, the criminalization of their opposition to mining and their involvement in the resistance movement, the questionable legality of the mine’s operations, the use of dynamite that was not revealed in the EIA, and the lack of a consulta, or consultation, in compliance with ILO 169 (ILO, 1989) that would have given the indigenous community an opportunity to permit or deny permission for the mine to operate on their land. Every interviewee in El Amatillo, La Prensa, and El Cerrón and three people in both La Cumbre and El Carrizal mentioned the involvement and corruption of political leaders in relation to the mine, including the mayor and the Consejos Comunitarios de Desarrollo Urbano y Rural

(COCODES, Community Councils of Urban and Rural Development). One person in El Amatillo explained the corruption, saying, "the old man [both the mine owner and other powerful rich people] keeps it up since he has money and pays a mayor, pays the judge, pays the Public Ministry, pays off human rights." Another woman in El Carrizal said, "one looks for the law, but there is no law for them."

Eighteen people out of the 31 interviewed mentioned the criminalization of those involved in the resistance with arrest warrants in place for approximately 20 people in the Ch'orti' communities. One person noted, "accused, we're all accused. For defending our land." Every person we spoke with, except for one in La Prensa, highlighted the lack of information provided by the mine, stating that the mining corporation never met with them nor held a consulta to gain their perspective on the matter. The Ch'orti' communities used the lack of a consulta to temporarily suspend the mining license in 2019, as noted by Yagenova and García (2009) and Wiebe (2021), and the Ch'orti' communities are still actively resisting the mine's presence on their land and fighting to obtain a permanent suspension. Seventeen people explicitly stated that they believed the activities in the mine to be illegal because the mine did not obtain permission from the communities to operate on their land. One person from El Amatillo described it as follows, "it's illegal, because they would have to ask for permission and they didn't ask for it," and two others from El Cerrón said, "they come to mine like a robbery, stealing things from the earth."

Impacts on Social Structures

Beyond mistrust of politicians and the political system, the mine impacted the area's social conditions with the creation of community divisions, violence, challenges associated with participation in the resistance movement, and the destruction and degradation of important land

and territory for the Ch'orti', according to our findings. Every person in El Amatillo, La Prensa, and El Carrizal, one interviewee in La Cumbre, and four in El Cerrón mentioned an increase in community divisions since the start of mining operations, with divisions between those in favor of the mine and those opposed. They noted a loss of confidence, increased fear due to threats and opposition, and an increase in social tensions, like Caxaj et al. (2013) did in their findings from a study near the Marlin Mine in Huehuetenango in western Guatemala. One person in El Cerrón, while talking about the threats said, "I go protest, I go. I'm not complaining, if they kill me there let them kill me, but I'm going to die for what's ours." All but three people in total noted an increase in violence in the communities over the last few years, which they attributed to the mine's presence in the area, finding it worse in the communities closest to the mine. Several interviewees stated that weapons were distributed by the mine owner to those who worked at the mine and to other guards to intimidate community members, and threats persist even today. Several people reported shootings, and at least three people have been killed. One mother who lost her son in the resistance said, "they killed my son like a dog in the street."

Every interviewee mentioned the resistance movement against the mine and their involvement in it multiple times. Participation ranged from attending meetings to guarding the entrance of the mine at night for almost a year, and several quotes suggest a willingness to die to defend their land. One mother in El Amatillo brought her children along, saying "everyone went, even children would go. We went and we would bring our children. Like I told him, 'if they killed us they would kill the kids, too', because they were with us." Another person offered an alternative situation to justify her participation in the resistance "imagine if the whole community had said that they agreed to let them mine, what would it be like right now? Already dying of thirst, one by one like fish in the sea." Another person reminded us, "it's a saying, that the people united will never be defeated." There was very limited information, if any, offered by the mine to the communities about the operations on their land, and information sharing in the communities has lessened as well with the growing number of fractured social bonds. Multiple people noted that the mine owner and employees offered large sums of money to several people in exchange for ceasing participation in the resistance movement, even promising them a job. Others noted that they were called ungrateful for the things the mine had given them, but they all claim to have never received anything.

Economic Impacts

Interviews revealed extreme poverty in communities and the lack of development, namely economic opportunities and improvements in the quality of living standards, promised by the mine in the EIA. Though many people in the study area lived in poverty before the start of mining operations, they perceive that the mine has led to further complications. As health worsens and the food supply diminishes, more money is required to meet basic needs. The mine has brought a growing need for purchasing power, as more medicines are needed to treat the influx of disease, and access to herbal remedies has been greatly reduced due to either the direct removal of vegetation or the death of medicinal plants following initiation of mining activities. Similarly, more food now needs to be bought as environmental degradation has contributed to decreased crop yields in a largely subsistence economy. Twenty-four people highlighted the effects of poverty on their family, with 92 references to its impacts across the six communities; one person in El Amatillo mentioned mine-related poverty seventeen times. One woman spoke of difficulties in trying to obtain the medicines they needed, "we get into big problems with illnesses since we have limited resources. We can't afford to buy what they say to get, so for me that is a big problem that mining has left." Another woman, whose daughter died "of contamination" due to lack of access to treatment, couldn't afford the medicine the doctor prescribed; "'to get rid of that poisoning there is medicine, but it's expensive', he told her...we can't afford that, right. She died, uh huh, she died." One person in El Carrizal described it like this, "yes, because as... you know that medicines need money to work."

Twenty-six people noted that, despite the advertisement of mining as economic development, the mine in fact did not bring development opportunities to their communities, and operates instead as an industry. Residents perceive that the mine instead brought poverty, sadness, and disease. One person in El Amatillo said simply, "it's not development, it's sadness," while another in the same community explained it further saying, "it brings development for the one, the businessman who mines it, but not for you. You're left with poverty, disease. That's what you're left with. For you there is no development." One person in El Cerrón said it this way, "what kind of development is it going to bring? It's bringing poverty, sickness, that's what it brings. What development is it giving us? Nothing."

The mine attempted to bribe people for their support or their silence, offering food, money, and materials to improve their homes, taking advantage of a vulnerable population. All who discussed these offers shared that, to their knowledge, no one accepted the bribes. Just as Birn et al. (2018) explained in their case study of poor health related to Canadian mining in Latin America, we found that while a few people were employed by the mine, the large majority experienced increased poverty. Very few jobs were provided by the mine, with only a handful of people from the nearest communities securing temporary employment, usually as a guard.

Environmental Impacts

The environmental impacts that began after the initiation of mining operations identified during interviews, including the effects on water quality and quantity, animals, crops, wild species, and vegetation cover, were more severe than those presented in the EIA. Our participants identified overall environmental degradation like Kirsch (2014) did in his book *Mining Capitalism* that focused on mining in Papua New Guinea, and water contamination like in the studies near the Marlin Mine in Guatemala by Van de Wauw et al. (2010) and Basu et al. (2010). Ecological health in the region, especially the health of the forests and the medicinal plants found within them, is directly related to the health of the residents.

Every person interviewed, except for one who did not discuss water quantity, noted the recent lack of water in the area, stating that there is never enough. Residents in every community marked the locations on the maps of wells and springs that had dried up, had disappeared, and/or had been contaminated. They spoke of dried up wells and springs and less rainfall in recent years, all of which they attributed to operations in the mine. Lack of water was mentioned a total of 121 times and was clearly a major concern in each of the communities. One man in La Prensa said "perhaps we'll die of thirst. And the wells, today there are no wells. Before there were springs, good wells, not anymore. They dried up." Many people in the communities believe that trees catch clouds to bring rain, and mining-related deforestation has removed most of the trees; therefore, participants attributed a reduction in precipitation to the mine as well. Similarly, the negative effects on water quality and quantity attributed to the mine was mentioned by every person in every community, sometimes multiple times by a single interviewee, for a total of 125 times. One person in El Amatillo said, "the water became scarce. It was because the springs were upland, they were blasting down below. So supposedly the water, they broke a vein and the water went another way."

Twelve people across the six communities confirmed that dynamite was used by the mine, although the EIA explicitly states that dynamite and explosives would not be used. Many of those same people attributed the lack of water and the drying up of wells, along with the increase of dust in the area to the explosives. Blasting in quarries has been known to impact the flow of groundwater, disrupting flow paths, movement patterns, and water quantity (Ekmekci, 1990). One person from La Prensa while describing the use of explosives at the mine said, "ah yes, wells have already dried up on the hill near here, because as they drop bombs and the water is consumed there. The earth is cracking, the water is consumed. Several wells have dried up, even the springs," while another in El Carrizal noted, "in those days, when they were there bombing, the waters were ruined" and "in the summer, bombs exploded and that smoke came. Well, the air was contaminated."

All but one person across the six communities noted perceived effects of mining operations on domestic animals, including chickens, cows, and turkeys, with nearly all of the animals getting sick and dying in each community. A study by Gankhuyag (2013) described an increase in livestock mortality associated with mining and toxicology studies performed in laboratory settings reported organ damage and death in animals exposed to antimony (ATSDR, 2019). Animal deaths were mentioned 81 times. All but one person noted the effects on agriculture, with a significant decrease in crop yields over the last few years. One woman noted, "there is a plague in the land and a plague for the little vine seed. Things like that, that do not recover, but the disease is in the soil, yes, it's in the land," and another person from El Amatillo said, "so we do see that it has harmed us, in everything. In everything because our crops no longer produce." Areas where crops were no longer growing and where animals had died were identified on the maps in every community.

Seventeen people, including eight of the ten in El Amatillo and three of the four in El Carrizal, noted the perceived effects of the mine on wild species, including fish, plants used for herbal remedies, and mango trees, and how the quantity of each has been drastically reduced since the start of mining operations. A study by Rehman et al. (2021) also reported significant losses of flora and fauna in areas surrounding a mine in Pakistan. Twenty people across all of the villages talked about deforestation and the loss of the forests that used to cover the hills where the mine now operates. One woman in El Amatillo noted, “there was a mountain of pine trees that had everything there. There was avocado. That mountain was very beautiful you see, but we are going to see it now, it is bare, bare.”

The importance of the land itself, consistently referred to as Madre Tierra or Mother Earth by the Ch’orti’ participants in this study, was mentioned a total of 44 times by 20 different people, and for many people, *she* was the reason they participated in the resistance. They noted the harm that the mine had done to “her,” referring to the mine as having removed the bones, strength, and heart of the earth, cutting her veins and letting all of the water bleed out, and the sadness they felt as a result. This emotional distress experienced by community members is an example of solastalgia. One woman in El Amatillo asked, “would that mountain not feel shame now that she’s naked?” Another man said, “that’s not development because they’re taking what’s in our community and leaving us with the dirt. They’re taking the heart of the earth, the stone is the strength of our Mother Earth, so that’s why we’re fighting.” Still another said, “the mine is the strength of the earth, the land no longer gives anything, so the mine is strength, it is the heart of the earth. Once you mine, you’re left with a desert.” In defending the land, one person in El Cerrón said simply, “our Mother Earth is not for sale.”

All of these changes were perceived by residents to be effects of the mining operations in the Cantera los Manantiales mine. However, broader-scale climate variability and change could also have contributed to the recent decrease in the water supply, and resulting reduction in crop yields and those of other wild fruits. Similarly, the overuse of land for farming and worsening soil quality and erosion could also play a part in the shrinking food supply and degradation of the environment.

Human Health

In terms of human health, residents spoke of a significant increase in disease after initiation of mining operations, in line with the study by Drewry et al. (2017) that found an increase in infectious diseases associated with mining as well as negative impacts on the mental health of nearby populations. All but three people perceived that recent negative health outcomes in the area were directly related to mine activities, with direct links mentioned 117 times in total; one interviewee in El Carrizal discussed human health problems associated with the mine thirteen times during our conversation. While baseline health data was not acquired prior to the initiation of mining activities, interviewees perceived and self-reported an increase in both disease incidence and prevalence since the start of mining operations. A resident of El Amatillo said, "there are sicknesses that used to not exist, today they are present. Those are the effects of the mine. They exploit. They don't leave anything good, only sickness and poverty. That's what we're left with," and another said simply, "the mine is why we have so many illnesses."

Interviewees discussed new vision, skin, pregnancy, mental health, and respiratory problems, along with issues securing herbal remedies, upon which they depend for treatment, as directly linked to mining operations. Similar effects were explained in a study on antimony toxicity by Sundar and Chakravarty (2010) that found respiratory, dermal, and gastrointestinal effects and another study on the health impacts of antimony in atmospheric particulate matter by Jiang et at. (2021) that reported impacts on the skin, eyes, and respiratory and gastrointestinal systems. Residents described gastrointestinal diseases that could be linked to an increase in improper water storage and malnutrition that plague the communities. Each person we talked to mentioned new recent skin afflictions experienced in the communities. Not only did I receive permission to take pictures, but they asked that they be shown to others. This affliction, commonly referred to as "granazón," was described as a blistering, burning rash that was difficult to heal; upon personal observation, granazón appeared as a chemical burn, with raw, peeling skin and blisters (Figure 3).

Figure 3: Rash on woman's legs after contact with water perceived to be contaminated

This skin issue was mentioned 108 times across all of the interviews. One person from El Amatillo described it as follows, "it seemed like sores, like blisters," and another in El Cerrón said, "yes, there were quite a few children who got covered in little bumps. There were people and children, yes. They got sick, they said it was from the mine." One woman in El Cerrón who had been sick for more than three years said, "I couldn't find medicine. I went to a health center, they told me they would take a picture. They told me there was no medicine for what I had." In all six communities, community members physically marked locations on the maps where people experienced granazón. The severe skin rashes are similar to those described and depicted in an occupational study by White et al. (1993) in a manufacturing plant where workers were exposed to antimony.

An increase in respiratory and vision problems, both marked on maps and both mentioned by fifteen people across the six communities, were attributed to dust from mining operations. Many people described severe burning in their eyes, with one child having their eye removed because of a severe eye problem attributed by an interviewee to mining-related dust. Many also described coughing and chest pain, explained as "ahogamiento," or drowning, with people feeling as though they were suffocating; the onset of these symptoms occurred shortly following the initiation of mining activities, and some of these cases were marked on the maps in El Amatillo, El Cerrón, and La Cumbre. One person in El Cerrón said, "coughing, we suffer from that. They also say that it is from the mining dust."

Sixteen people talked about both adults and children dying of "contamination" in recent years. One person in El Amatillo mentioned it twelve different times. A mother in El Amatillo said, "we were left with the contamination, because yes, the diseases are hitting us and I think my daughter died from that." Some people, twelve of those we spoke with, also talked about the increase in problems related to pregnancy, including birth defects, spontaneous abortions, and stillbirths. One woman in El Amatillo noted, "it contaminates the baby. The babies were born dead." Another mother who lost her baby said, "the children formed, and when it was time to be born, they were born dead. I had one like that, my sister too, other cousins, uh-huh, several children died like this in their mother's womb." Again, some of the locations where these stillbirths occurred were mapped in El Amatillo.

Mental health, mainly related to increased fear over the community divisions and violence, along with the recent lack of food and water resources, increase in sickness, and destruction of land, was indirectly reported by 23 people. One person in El Amatillo spoke of the constant worry saying, "I think then, because I remember. It seems that it already happened but I always keep remembering. I always remember everything that has happened. I live remembering." Every interviewee spoke of their dependence on herbal or mountain remedies (e.g. ruda, hierba del toro, yuquilla, altamisa), and their strong preference for these over the medicines provided by health clinics; such local remedies were mentioned a total of 90 times. However, with the resulting deforestation and loss of vegetation, many medicinal plants have also been lost. One woman said,

> yes, oh God, that's why we fight for the forests, because the forests, look, they say, 'we are going to reforest.' They are going to reforest a single kind of tree. Instead, the forests that God left, they're full of medicines, all kinds of medicines. And instead the man comes to destroy. He comes to plant one kind of tree that is not even medicine. No. So we always say that the forest planted by God is good, but the one planted by man is not, no.

Many of the people in Olopa felt the emotional effects of landscape modifications. People spoke lovingly and tearfully about Madre Tierra, and the harm caused by the mine and how it affected her. Her veins were cut and the water flowed out, while at the same time her strength was taken as they removed the stones, her bones. According to interviewees, the mine took the heart of the earth, and now, everything is dying because of it. This individual emotional distress caused by environmental change, an example of solastalgia (Albrecht et al., 2007), combined with the increase in communicable and noncommunicable diseases in the Ch'orti' communities, collectively and severely affected the region as a whole. Several studies, including a study on ecological grief in response to environmental change by Cunsolo and Ellis (2018) and a 2022 policy brief from the Intergovernmental Panel on Climate Change detail the need to address mental health with climate- and environmental-related hazards and change (World Health Organization, 2022).

Few healthcare professionals work in the region, but an interview and participatory mapping exercise with a comadrona [midwife] from one of the communities gave us the opportunity to gather information from someone with expert local knowledge and an extensive understanding of the health of her community at the household level. According to the map made with the comadrona (Figure 4), 83 of the 86 households suffered from fever and had lost animals to disease in recent years since the start of mining operations. She also identified 81 households with breathing difficulties, 69 households where children had been sick, 65 households with someone who had experienced granazón, and 53 households with vision problems, all of which were at least in part perceived to be attributed to the mine. Additionally, the comadrona also marked seven households with unexplained deaths, and another seven households with stillbirths, several of which had severe facial and cranial deformations. The detailed information provided by the comadrona supports the data collected through interviews and maps in other communities.

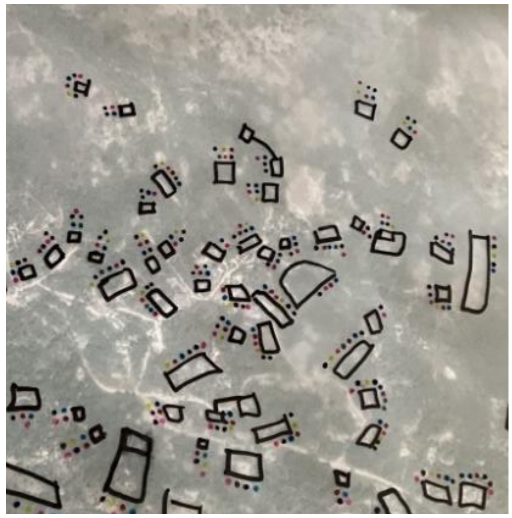

Figure 4: Map made with a comadrona in one of the communities, with each dot representing a different health affliction

Limited access to healthcare across the region means that infections and chronic conditions are not easily prevented and curable diseases go untreated, increasing disability adjusted life years (DALYs) tremendously (Rauh et al., 2008). While respondents were confident that the increase in health problems was closely related to mining activities, it is possible and even likely that the recent COVID-19 pandemic, or a variety of other illnesses, contributed to some of the respiratory conditions and other symptoms explained by many of the participants.

Syndemic Conditions

Our work strongly suggests that the combined political, social, economic, environmental, and human health impacts of antimony exposure from the Cantera los Manantiales mine intersect to produce various negative health outcomes and syndemic conditions in the surrounding communities. Several interviewees and participants in the workshops highlighted the overarching impact of the syndemic effects of the mine in their statements and maps, summarizing the problem in its entirety (Figure 5). The reported malnutrition, increase in infectious and chronic diseases, potential exposure to heavy metals, reduced water quality and quantity, stress from the community divisions, violence, and environmental harm, loss of medicinal plants, increased need for purchasing power, and weakened immune systems among other health impacts all interact and contribute to overall worse health in the surrounding communities.

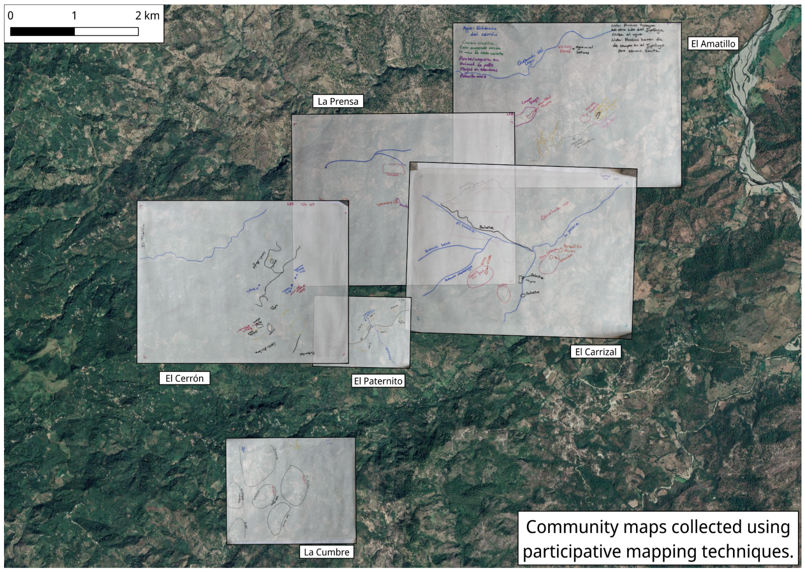

Figure 5: Layered community maps made during the community mapping workshops

One person from El Amatillo said, “that company didn’t come to leave anything good, but it came to take away our peace of mind. Because it divided us, and on top of that, it left us with disease. We were contaminated by that mining, because if I tell you the truth, there is a lot, a lot. It is causing a lot of nausea, a lot of stomach pain, pain here in the lungs, see.” Another woman said,

> they started with pickaxes but now it’s with bombs, with bombs and machines. Right now has been the hardest because the last springs that were there don’t have any water. There was a good forest. They destroyed everything… so that’s why there’s now a desert, a desert. And the waters are polluted, there are no fish. There were lots of fish, not today, because of the pollution. Today there is nothing, today there is nothing, it’s all barren.

A person from La Prensa said,

> a better development for me? That there is water. That there is firewood. That there is wood to build a house. That is a better development. That they don't come to destroy us. Well, that is a better development, because if they wanted to help with a project, why don't they provide better pipes to make an ideal water project and take it to the community? That would be better development, and that there would be food, that's development. Now they come to destroy us or they bring us scraps in exchange for what we have here on our land. There is no need for that or for them to bring us disease, that is not development.

When asked what mining brings to the community, one person in La Cumbre said, "diseases, damage, plagues for the crops. Crops no longer grow because of the disease it brings. Yes, that is what mining brings."

Due to these perceived risks, there were no healthy places identified by our participants, further contributing to the solastalgia felt by so many of those in the communities. All areas of communities were perceived as unhealthy due to the contamination and overall degradation of the environment, along with the social tensions and threats, creating a deep sense of loss within the communities. This finding was unexpected; we expected there to be several places linked to the mine and therefore identified as unhealthy, however, we did expect the delineation of some places that were still perceived as healthy, though this was not the case.

We also expected the perceived negative effects to be mostly concentrated in the communities nearest the mine, changing along a gradient with much lesser effects felt further from the quarry. As Basu et al. (2010), Van de Wauw et al. (2010), and Owen et al. (2021) highlighted in their studies of metal exposure near the Marlin Mine in Guatemala, groundwater overextraction near the same mine, and the microeconomic resource curse theory in relation to mining, respectively, our participants also perceived worse effects in areas closest to the mine. However, while there was a consensus that conditions were worse in closer proximity to the mine, there were still numerous negative health effects identified even in communities much further from the mine, and because of this, thousands of people joined the resistance to support the Ch'orti' people. Studies by Conde (2017) and Kuecker (2007) reported on the resistance movements against mines as the knowledge of negative impacts grows, which was also the case in Olopa. Considering that the mining license has been temporarily suspended since 2019, we also did not expect negative effects to still be so persistent by our data collection in 2022, which indicates the long-term impacts of mining activities.

3.6 Limitations and Future Research

Limitations, which we attempted to minimize, include a lack of baseline human health and environmental data, participants' limited experience with maps, and only including those community members involved in the resistance movement due to social tensions. While every person we interviewed spoke of human health problems and an increase in new diseases and conditions, all of the collected data were self-reported. As the participants do not often visit medical professionals given their minimal access to clinics and lack of financial resources, there are no confirmed diagnoses or biomarker data available to support their claims. There is also no pre-existing baseline health data prior to the start of mining in the area for those same reasons. While nearly all children receive all of their vaccines, we do not have data on the incidence and prevalence rates for any illnesses before the mining began or at this time. We attempted to reduce this limitation by speaking with local comadronas and a health clinic employee in one of the communities, who are more familiar with health conditions in the region, which was one way to validate the participants' descriptions.

Another limitation was the limited experience of the participants with paper maps. Many people had not previously seen a map, and many did not know how to write. To account for this, time was taken with each participant to explain the base maps and point out their homes and other key locations in the community to help orient them. Those that were not comfortable writing would point out and confirm the locations on the maps that I would mark. Additionally, because of social tensions in the area regarding the resistance movement and current court case, we were unable to speak with anyone who supported the mine, and spoke only to those involved in the resistance movement.

An important next step in this research is to test the water and soil for heavy metals, namely antimony, to determine the extent of contamination in the area. A similar study with those who support the mine would be helpful to understand other perspectives and perceptions. It would also be important to try to determine if there were areas perceived as healthy places before the mining began. Additionally, confirming the health diagnoses of the self-reported conditions of the interviewees would further strengthen their reports.

3.7 Conclusion

Using a CBPR approach, this study addressed four research questions related to health and environmental risks associated with the Cantera los Manantiales mine in Olopa, Guatemala, and the presence or absence of healthy places in surrounding communities using interviews and participatory mapping. Interviews provided a deep understanding of the perceived effects of the mine by allowing participants to offer explanations in their own words. We used participatory mapping to visualize health impacts of the mine and mapped perceptions as described by Pánek

(2018) to include space and place in the health impacts participants shared, and in doing so, better understood the conditions of the community as a whole. These methods and findings highlight the future potential for the use of participatory mapping in visualizing syndemics and other health risks and outcomes within a population.

Mining can affect most aspects of community well-being including social, political, economic, environmental, and human health. Previous work indicated that mining operations have been associated with increased displacement, poverty, food insecurity, and violence, and reduced water and soil quality and quantity, resulting in environmental degradation that further deepens previously described impacts. The individual impacts of each of these components are understood, but a deeper understanding of the syndemic effects of a mine operating in a community, particularly in an indigenous community, was needed.

This study revealed that residents in communities surrounding the Cantera los Manantiales mine perceive a range of impacts and risks including an increase in disease incidence and prevalence, increased community divisions and violence, a decrease in water availability and crop production, and more since the initiation of mining operations, and did not identify any healthy areas within their communities. The risks identified in the EIA were found to differ significantly from those perceived by community members, with the EIA claiming that any impact would be mild, temporary, and mitigated, which according to residents, has not been the case. Moving forward it is important that EIAs be comprehensive and enforced so that health risks can be both identified and mitigated.

Community leaders and activists who are attempting to mitigate impacts of the mine and improve health in the area can use the improved understanding of the perceived syndemic environmental and human health impacts of the mine developed through and in collaboration with this study to improve local conditions. According to participants, the health of a people, a community, and the environment are deteriorating. Access to sufficient food and clean water are necessities, as is access to healthcare and education, and all are currently lacking in the communities studied. The syndemic issues described in Olopa are probably a combination of previously-occurring problems, including climate variability and change, the pandemic, and a corrupt political system, that have been exacerbated and multiplied by the presence and operations of the mine. If the mine is to continue operating, significant mitigation and remediation measures will need to be developed and enforced to improve the present degraded conditions, but any mitigation measures require a baseline examination of any impacts, which was established through this study.

The projected increase in extractivism as the need for raw materials grows (Lenero & Thompson, 2014) will only further impact communities surrounding mines, communities that, in many places, will likely consist of indigenous people whose rights have been restricted since the beginning of colonialization and still today through the maintaining of those structures in internal colonialism. Negative health effects and resistance will grow alongside the industry if mitigation and remediation efforts are not put in place to reduce perceived and actual impacts. People are increasingly demanding that negative impacts are addressed, and understanding the syndemic interactions of various health impacts will be necessary in order to do so. If not, as countries and people continually pursue the capitalist riches advertised as part of the system, other vulnerable populations and the environment will continue to lose as health becomes a commodity reserved for a privileged few.

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Appendix
Interview Script English

Meghan Albritton #22-142
Korine Kolivras (PI)
Ch'orti' Perceptions of Environmental Risks in Chiquimula, Guatemala
Interview Guidelines

*Interviews will be tailored for specific individuals and situations in collaboration with communities participating in the research
*Interview questions will be translated into Spanish and, as needed, into indigenous languages

<u>Demographics:</u>

- How long have you lived in Olopa?
- How old are you?
- What level of education do you have?
- How many people live in your home?
- What are your main jobs? Do you work seasonally, what jobs are there in the different seasons? What jobs are there that last all year?
- Where do you move to for work?
- Do you have migrant family members? Do you receive remittances from them?
- How many children do you have? Have you had any miscarriages?
- Do you have access to land to plant?
- How much land do you have? What type of crops do you grow?
- Do you save or buy seeds? Do you buy them at an agroservice? Do you buy or exchange them in the community?
- Do you collect food from forests, rivers, or other places?
- What do you typically eat? What other foods do you eat irregularly (for special occasions)?
- Which market do you visit? From what other places do you get your food?

<u>Mining in the community:</u>

- How were you related to the space where the mine is located? Did you have some kind of relationship with the hill where they extracted? Was this land communal?
- How long have they been extracting in the area known as the mine?
- How did the extraction begin? Who have been extracting there? (Do you have old pictures of the mine or community)
- How does it feel to have the mine there?
- What are they mining? How did they do it? Where do they take what they extract?
- How have the mine and their employees acted in the community? (What have they said? What have they done?)
- Are there people in the community that have worked for the mine?
- What are the biggest changes in the community since the start of the mine? (in the environment, in families, in the community?)
- Has the installation of the mine affected the unity of the community?

- In what way has the mining activity affected agriculture, rivers, animals, trees? Why do you relate it to the mine?
- Since the arrival of the mining project, do you feel that your mobility has been limited, you've lost freedoms, or confidence in moving within the territory? If so, how?

Water:

- Do you have potable water service in your home?
- Where does your drinking water come from? (Ask if its a well, spring, municipal water, community water project; and if they can give a name)
- How often do you have water in your home? How many hours a day is there water?
- Can you describe this water? Taste? Smell? Color?
- Do you filter or boil the water before drinking it?
- Do you think it's safe to drink?
- If not, why?
- Have you noticed a change in the water?
- Do you irrigate your crops? With what water?
- Has the mine affected the quality of water? How?
- Have springs disappeared? Where? Has the quantity of water decreased?
- Are there problems with water in the community? If so, what are they?
- Do you have alternatives or what are the alternatives to supply water?

Health:

- What are the main illnesses or health problems in the community? Do you know why these problems exist?
- Has the health center said anything about the illness outbreaks? Do you associate them with the mine?
- Have you been sick in the last year? What were your main symptoms?
- Do you think the extraction in the mine has brought diseases to the community? (digestive, respiratoy, skin, miscarriages, genetic deformities)
- Have you noticed people in the community with skin diseases? Do you think they are caused by the mine?
- Have your children been sick? What symptoms have they had?
- Have you been treated for a serious illness in the last year?
- If someone needs treatment or medical attention, where do you go?
- Do you use alternative treatments, medicinal plants? What medicinal plants do you use most often?
- Did many people get sick with COVID?
- What diseases has the mine brought to the animals (fish, cows, chickens, dogs)?
- What diseases or effects has the mine brought to the plants or trees?
- Do you think it has affected women differently?
- Have they done health studies in the community? How? When? What happened? Were they useful? What do you need most? Who participated? Do you know anyone who participated? Explain.

Social/political:

- Are these activities in the mine legal or illegal? Explain

- How has your community responded to the mine?
- What resistances have there been against the mine? What have been the moments of resistance? (Timeline of high points of resistance)
- What was the participation of women, youth, and children in the resistance?
- Did other communities participate in the resistance in Olopa? How has the solidarity of surrounding communities been?
- How has the mine responded to the resistance?
- How have the local authorities responded and acted towards the resistance and the mine?
- What has been the role or participation of other authorities (COCODES, government) in relation to the mine?

Perceptions:

- The mine says it brings development to the communities. Do you think mining is development? What would be a better type of development?
- What did the mine offer to the communities? Did they follow through with what they offered? (infrastructure, health, employment)
- How often do you think about problems related to the mine?
- Psychological? How does it make you feel? Do you worry? Does it make you angry? Has it affected your sleep? Headaches?

Community Mapping

Elements to map:

- Home: Where do you live on this map?
- Children: Where do the children play? Where do they go to school?
- Water: Where does your water come from?
- Crops: Where do you grow your food?
- What areas of the community do you perceive as healthy? Why?
- Unhealthy? Why?
- Safe? Why? Dangerous? Why?
- Clean? Dirty?
- Special?
- Where is your favorite place? Why?
- Are there places you avoid? Why?
- Where are the rivers? What do you think of the rivers?
- The mine?
- Other specific places (determined once in community)?

Syndemic:

- Who is most affected by these problems?
- How do these problems affect women specifically? Children? The elderly? Disabled people?
- What does the combination of all of these problems mean for your community? For you?
- What do you think needs to be done or changed?

Interview Script Spanish

Meghan Albritton #22-142
Korine Kolivras (PI)
Ch'orti' Perceptions of Environmental Risks in Chiquimula, Guatemala
Interview Guidelines

*Las entrevistas se adaptarán a personas y situaciones específicas en colaboración con las comunidades que participan en la investigación.
*Las preguntas de la entrevista se traducirán al español y, según sea necesario, a los idiomas indígenas

<u>Demografía:</u>

- ¿Hace cuánto vives en Olopa?
- ¿Cuántos años tienes?
- ¿Qué nivel de educación o estudio tiene?
- ¿Cuántas personas viven en tu casa?
- ¿Cuáles son sus principales oficios? ¿Usted trabaja por temporadas, qué trabajos hay en las distintas temporadas ? ¿Qué trabajos hay que duran todo el año?
- ¿A qué lugares te mueves para trabajar?
- ¿Tiene familiares migrantes ? ¿Recibe remesas de alguno de ellos?
- ¿Cuántos hijos tienen? ¿Ha perdido algún embarazo?
- ¿Tiene acceso a tierra para poder sembrar?
- ¿Cuántas tareas de tierra tiene ? ¿Qué tipo de cultivos trabaja?
- ¿Usted compra semilla o guarda de su cosecha? ¿Compra en algún agroservicio ¿Compra o intercambia en la comunidad?
- ¿Recolecta algunos alimentos del bosque, quebradas u otros sitios?
- ¿En qué consiste su comida diaria o qué alimentos consume diariamente? ¿Qué otros alimentos incorpora en su dieta de forma irregular (eventuales, quincenales, mensuales)?
- ¿Cuál es el principal mercado que visita? ¿En qué otros lugares consigues comida?
-

<u>Minería en la comunidad:</u>

- ¿De qué manera se relacionaban con el espacio en donde está la mina? ¿Tenían algún tipo de relación con el cerro que explotaron? ¿Era terreno era comunal?
- ¿Desde cuándo han explotado el lugar conocido como "la mina"?
- ¿Cómo inició la explotación minera en la comunidad? ¿Quienes han explotado la mina? (Tiene fotos antiguas de la mina o de la comunidad)
- ¿Cómo se siente tener una mina en ese lugar?
- ¿Que están minando/sacando? ¿Cómo lo hicieron? ¿Adónde se llevan lo que sacaron?
- ¿Cómo se ha comportado la minera y sus empleados en la comunidad?
    - [¿Qué han dicho? ¿qué han hecho? [solo para probing]
- ¿Hay personas de la comunidad que han trabajado en la mina?
- ¿Cuáles son los cambios más grandes en la comunidad desde que vino la mina? (en el entorno, en las familias, en la comunidad?)
- ¿La instalación de la mina ha afectado la unidad de la comunidad?

- ¿De qué manera afecta la actividad minera a la agricultura, los ríos, los animales, los árboles? ¿Por qué lo relaciona con la mina?
- ¿Desde la llegada del proyecto minero, usted siente que se ha limitado la movilidad ha perdido la libertad, la confianza de transitar en el territorio? ¿De qué forma?

Agua:

- ¿Cuenta con servicio de agua potable en su casa?
- ¿De dónde proviene su agua potable? (Preguntar si es ojo de agua, nacimiento, municipio, proyecto comunitario y si pueden que te digan el nombre)
- ¿Cada cuánto llega el agua a su hogar? ¿Por cuántas horas llega el agua ?
- ¿Puedes describir esta agua? ¿Gusto? ¿Olor? ¿Color?
- ¿Filtra o hierve el agua antes de beberla?
- ¿Crees que es seguro beber?
- Si no, ¿por qué?
- ¿Ha notado algún cambio en el agua?
- ¿Tiene cultivos que usan riego? ¿Con qué agua los riego?
- ¿Cree que la mina ha afectado la calidad del agua? ¿Cómo?
- ¿Han desaparecido nacimientos? ¿Dónde? ¿Ha disminuido la cantidad de agua?
- ¿Hay problemas con el agua en la comunidad? Si es así, ¿Cuáles son?
- Tiene alternativas o cuáles son las alternativas para abastecerse de agua

Salud:

- ¿Cuáles son las principales enfermedades o problemas de salud en la comunidad? ¿Sabes por qué existen estos problemas?
- ¿Les ha dicho algo el centro de salud sobre los brotes de enfermedades ¿Las vinculan con la mina?
- ¿Ha estado enfermo en el último año? ¿Cuáles fueron sus principales síntomas?
- ¿Cree que la explotación minera ha traído enfermedades a la comunidad? (Digestivas, respiratorias, piel, abortos, malformaciones genéticas)
- ¿Han notado que las personas tienen enfermedades en la piel ? ¿Cree que son efectos de la mina?
- ¿Tus hijos han estado enfermos? ¿Qué síntomas han tenido?
- ¿Ha sido tratado por una enfermedad grave en el último año?
- Si necesita tratamiento o atención médica, ¿a dónde va?
- ¿Ustedes utilizan tratamientos alternativos, usan plantas medicinales? ¿Qué plantas medicinales utilizan más?
- ¿Se enfermaron muchas personas de la comunidad con COVID?
- ¿Qué enfermedades ha traído la mina a los animales (peces, vacas, gallinas, perros)?
- ¿Qué enfermedades o afectaciones ha traído la mina a las plantas o árboles?
- ¿Cree que ha habido un impacto diferenciado en las mujeres?
- ¿Se han hecho estudios de salud en la comunidad? ¿Cómo? ¿Cuándo? ¿Qué sucedió? ¿Fue útil? ¿Qué más se necesita? ¿Usted participó? ¿Conoce a alguien que participó? Explique.

Sociales/políticos:

- ¿Estas actividades en la mina son legales o ilegales? Explique
- ¿Cómo ha respondido su comunidad a la mina?
- ¿Qué resistencias han habido en contra de la minería?¿Cuáles han sido los momentos de resistencia? (Cronología de momentos álgidos de resistencia)
- ¿Cómo fue la participación de mujeres, jóvenes y niños en la resistencia?
- ¿Otras comunidades han participado en la resistencia en Olopa? ¿Cómo ha sido la solidaridad con comunidades alrededor?
- ¿Cómo ha respondido la mina a la resistencia?
- ¿Cómo han respondido y actuado las autoridades locales frente a la resistencia y frente a la minería?
- ¿Cuál ha sido el papel o participación de otras autoridades (cocode, gobernación) frente a la minería?
- ¿Cuál fue el rol de las iglesias frente a la minería?

Percepciones:

- La mina dice que trae desarrollo a las comunidades ¿Cree que es desarrollo la minería? ¿Qué sería un mejor desarrollo para usted?
- ¿Qué ofrecimientos hizo la empresa a las comunidades? ¿Cumplieron con alguno de estos ofrecimientos? (infraestructura, salud, empleos)
- ¿Qué tan seguido piensas en problemas relacionados a la mina?
- ¿Psicológico? ¿Cómo te hace sentir la mina? ¿Te preocupas? ¿Te hace enojar? ¿Ha afectado tu sueño? ¿Dolor de cabeza?

Mapeo comunitario

Elementos a mapear

- Vivienda: ¿Dónde vives en este mapa?
- Niños y Niñas: ¿Dónde juegan los niños? ¿A dónde van a la escuela?
- Agua: ¿De dónde viene tu agua?
- Cultivos: ¿Dónde cultivas tus alimentos?
- ¿Qué áreas de la comunidad percibe como saludables? ¿Por qué?
- ¿Insalubre? ¿Por qué?
- ¿Seguros? ¿Por qué? ¿Peligroso? ¿Por qué?
- ¿Limpio? ¿Sucio?
- ¿Especial?
- ¿Cuál es tu lugar favorito? ¿Por qué?
- ¿Hay lugares que evitas? ¿Por qué?
- ¿Cuáles son los principales ríos?¿Qué opinas del río?
- ¿La mina?
- ¿Otros lugares específicos (determinados una vez en comunidad)?

Sindémico:

- ¿Quiénes son los más afectados por estos problemas?

- ¿Cómo afectan estos problemas específicamente a las mujeres? ¿Niños? ¿Los ancianos? ¿Personas discapacitadas?
- ¿Qué significa la combinación de todos estos problemas para su comunidad? ¿Para usted?
- ¿Qué crees que se debe hacer o cambiar?