Vol.01, Issue 02 (2022): 36-43
DOI: 10.58921/jse.01.02.028

Journal of Sustainable Environment

ISSN (p): 2710-2386, ISSN (e): 2957-9228

Published by
1885 SMI UNIVERSITY

The Double Threat: Investigating the Convergence of Pandemic and Climate Change

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Abstract

The early effects of the global climate change have been extensively studied but future effects on ecological health, human, domestic animal, and wildlife health, however, are significantly less well understood. Due to climate change, ancient bacteria and viruses that have laid asleep for thousands of years are reawakening as permafrost soils that have frozen for several thousands of years, melt. 218 of the 375 infectious diseases that humanity has faced over the planet have at some point been made worse by climatic dangers. Empirical cases showed 1,006 distinct ways that climatic risks, through various modes of transmission, led to deadly diseases. For complete societal adaptations to be effective there are too many human pathogenic diseases and modes of transmission that are exacerbated by climate hazards. This underscores the urgent need to address the root cause of the issue, which is reducing Green House Gas emissions. In addition to releasing these toxic chemicals, thawing permafrost also poses a health risk because it could release a variety of hibernating diseases, including novel and previously unidentified antibiotic-resistant bacteria, viruses, fungi, and parasites. Our immune system is underdeveloped and will need to undergo major adaptation, known as allostasis, which is also referred to as permafrost immunity. Climate change, for instance, may result in a wide range of microbiological, vector, and host reactions, while not all organisms may react in the same way or over the same amount of time. Unfortunately, our scientific community has a fairly limited grasp of the current effectors and balances for many creatures and ecosystems, making it difficult to characterize the current condition, let alone to verify predictions for the future. It is clear that improved basic systematic surveillance and research programs are required, but implementing such programs is challenging and what is done during the coming years could be crucial.

Keywords: Pandemic, Permafrost, Climate Change, Global Warming, Microorganisms

1. Introduction

The coldest part of Russia was ablazed for the 3rd summer in a row. One of the warmest and driest summers in almost a century was experienced inYakutia, in the northeastern of Siberia, with temperatures reaching 38 °C. The Guardian reports that a record-breaking 18.16 millions of hectares than four times the area of the Netherlands—was devastated by the wildfires. For the very first time in history, the smoke travelled 3000 kilometers to the North Pole, darkening the ice and snow and speeding up its melting due to greater solar heat absorption (Moscow, 2021; Roth, 2021). Summer fires are common in this area and help to maintain the ecosystem's health. However, the summer of 2021 has stood out as being particularly uncommon. The persistent heat promotes the melting of the Siberian permafrost, in part because of increased microbial activity, in addition to the fires releasing roughly 970 megatons of (CO_2) carbon dioxide into the sky, which is twice as much as was released the previous year (*Copernicus: A Summer of Wildfires Saw Devastation and Record Emissions around the Northern Hemisphere | Copernicus*, 2021; Margesin & Collins, 2019). A full zoo's worth of froze microorganisms can be found in permafrost, in addition to storing large quantities of methane and carbon that, when released, contribute to global warming (Turetsky et al., 2019). This poses the question of whether we should be concerned that the microbes kept in these frozen regions could cause the next epidemic.

1.1 Permafrost

Let's take a closer look at permafrost before we continue. According to traditional definitions, permafrost is soil that has been continuously frozen for at minimum two years, but it may also be millions of years old (Margesin & Collins, 2019). Permafrost covers about 25% of the Earth's surface (Margesin & Collins, 2019). The so-called "active layer" that lies on top of this permafrost is subjected to seasonal freeze-thaw cycle. As a result, permafrost thawing of a few centimeters to several meters is common. But as a consequence of global warming, the depths of the active layers have been rising, which has led to a decline in the amount of permanent permafrost (Jansson & Taş, 2014). Permafrost thawing causes issues in this area. Organic material, such as remains of plants and animals, has been accumulating in permafrost for a very long time. These remnants can begin to decompose when temperatures rise because previously frozen microbes might become active again. As

(CO_2) and methane (CH_4) are produced, which may speed up global warming and, consequently, the thawing of permafrost (Margesin & Collins, 2019; Revich et al., 2012). The average temperature of the top layer of Arctic permafrost grew by 3.0 °C over the past 100 years, a process known as "Arctic Amplification," whereas the average global temperature climbed by 0.7 °C during that time (Lawrence & Slater, 2005). One prediction claims that by 2100, this might result in a 90% decline in near-surface permafrost (Rogers et al., 2004). Theoretically, the melting of the permafrost might also result in the release of previously dormant pathogens that could present a concern for outbreaks in the future (El-Sayed & Kamel, 2020; BBC-Earth, 2017).

1.2 Beneath The Frozen Soil

The permafrost will melt more as the planet warms. Under typical conditions, summertime melting occurs in 50 cm-deep surface permafrost layers. But as the climate warms, older permafrost layers are being gradually revealed. For bacteria to live for incredibly prolonged periods of time, possibly up to a million years, frozen permafrost soil provides the ideal environment. Therefore, ice melting might possibly unleash a host of diseases. Three times quicker than the rest of the world, the Arctic Circle's temperature is rising quickly. Viruses and other pathogenic agents could be discharged as the ice as well as permafrost melt. Because it is cold, devoid of oxygen, and dark, permafrost is a particularly effective preserver of bacteria and viruses, claims evolutionary biologist Mr. Jean-Michel Claverie of the French university of Aix-Marseille. Older permafrost levels may contain pathogenic viruses that really can infect either humans or animals, including ones that have already caused pandemics. Over a million reindeer perished from anthrax in the first decade of the 20th century alone. Since it is difficult to excavate deep graves, the majority of these corpses are strewn throughout 7,000 cemeteries across northern Russia, close to the surface. The main concern is what else might be hiding beneath the frozen ground.

According to a 2011 study by Boris Revich & Marina Podolnaya, "the vectors of lethal infections of the 19th and 18th centuries may come back as a result of permafrost melting, right near the cemeteries where victims of these viruses were buried.

In a 2005 study, scientists of NASA successfully resurrected bacteria that had lain dormant for 32,000 years in a frozen pond in Alaska. Since the Pleistocene epoch, when mammoths still roamed the Earth, the microorganisms, known as Carnobacterium pleistocenium, had remained frozen. They started swimming around once the ice thawed, seemingly unfazed. Two years later, in the Mullins and Beacon valleys of Antarctica, scientists discovered an 8-million-year-old bacterium dormant in ice beneath the surface of a glacier. Bacteria were also recovered from ice that was more than 100,000 years old in the same study.

Two viruses that had been preserved t for 30,000 years in Siberian permafrost were brought back to life in a 2014 study by a group led by Claverie. They are called "giant viruses"; Mollivirus sibericum and Pithovirus sibericum, because, unlike other viruses, they are so large that they can be seen under a standard microscope. They were found 100 feet underground in tundra along the shore. The viruses immediately spread once they were revived. Luckily for us, these specific viruses only affect amoebas with a single cell. However, the research raises the possibility that additional viruses that may infect humans could be revived in a similar manner (D'Amico et al., 2006).

1.3 Surviving the cold

Any organism becoming alive after being frozen for thousands of years seems to be quite implausible. Microorganisms can live in temperature below 0 °C due to a variety of tactics that they have developed. One of these is for the cell to go into a dormant state, when there is minimal metabolic activity and the creation of specialized proteins aids in cell survival (Katayama et al., 2007). In 2007, scientists discovered microorganisms that could last 25,000 years of being frozen (Legendre et al., 2014). Another most recent example is the study that employed an Acanthamoeba as "bait" to extract a sizable, live DNA virus from a permafrost layer that was 30,000 years old (Rivkina et al., 2000). The bacteria not only endure, but it has been demonstrated that they are metabolically active and proliferate at temperatures as low as –20 °C (Bidle et al., 2007). Even in the oldest glacial layers on Earth, which are thought to be 34 million years old, metabolically active bacteria that had lived for around 8 million years were discovered (Mardanov et al., 2012). Additionally, elderly diseases are lazing around within the guts of extinct mammoths (Goodwin et al., 2012). New microbes are always being added to the ice by humans. A study upon the Kahiltna Glacier in the Alaska, a well-known climbing location, estimated that climbers created almost two megatons of human excrement per year (El-Sayed & Kamel, 2020). The bacteria in the fecal matter turned out to be capable of surviving for a prolonged period of time yet were anticipated to travel through glacier, resurfacing at lower, quite accessible elevations creating extremely unhygienic conditions that caused diahorrea for almost a third of all the 132 climbers interviewed (El-Sayed & Kamel, 2020). Thus, permafrost contains both ancient and modern microbes.

2. Is the threat real?

In reality, a significant anthrax epidemic in the Arctic Russian Siberia in 2016 was brought on by hazardous, living bacteria (Stella et al., 2020). Over 2000 reindeer died prematurely as a result of this, along with 20 people being hospitalized and ultimately the terrible loss of a 12-year-old child. Bacillus anthraces spores that had been kept under frozen soil for more than 75 years caused the victims' infections (Stella et al., 2020). According to experts, spores were liberated from frozen burial sites of sick carcasses that appeared as a result of rapid thawing (Steffan et al., 2020). Because of the 13,885 livestock burial grounds that have been created in Russia alone as a result of anthrax outbreaks, resurgent anthrax poses a serious threat to individuals who live nearby (Thèves et al., 2014). According to this theory, outbreaks caused by other powerful viruses could also happen. The smallpox-causing variola virus could be one of the more notorious contenders. It is claimed that before this terrible disease was eliminated in 1980, it was responsible for 10% of all total deaths over the previous millennium (Meyer et al., 2020). Since smallpox vaccination programs were discontinued decades ago, a growing number of people worldwide lack smallpox protection. When this combines with the increase of people who are immune-suppressed, smallpox suddenly reemerges as a serious concern (Stone, 2002). When a tomb containing 19th-century smallpox victims was discovered in 1991, the Russian government was already concerned that floods might spread the infection to populated areas (Biagini et al., 2012). When Russian and French researchers discovered a wooden grave in the permafrost that contained five mummies in 2004, they discovered a similar burial site (Reardon, 2014). Samples from this strange discovery showed that variola infection was most likely the cause of death. The researchers were able to connect this strain to smallpox pandemic that occurred more than 300 years earlier, in 1714 (Reardon, 2014; Ushida et al., 2010). The possibility that permafrost could serve as a gene repository for antibiotic resistance poses an additional threat. Researchers have discovered tetracycline and beta-lactam resistance genes using PCR techniques. These genes may have been transferred to these regions by migratory birds and airborne germs (Edwards, 2015; World Health Organization, 2019). Such a reservoir regularly releasing resistance genes could become troublesome in a society where resistance to antibiotics is one of the top 10 global health issues (Edwards et al., 2020). Some scientists argue that the freeze-thaw cycles required to integrate microorganisms in the permafrost along with the following thaw and discharge are likely to render microorganisms inactive (Hueffer et al., 2020; Sköld, 1996). Additionally, the soil under permafrost is typically acidic, which limits survivability (World Health Organization, 2019; Sköld, 1996). Even the previously reported Siberian anthrax outbreak, which is frequently used to highlight the threats of frozen pathogens, is no longer believed to be solely the result of permafrost thawing; instead, it is likely that decreased reindeer vaccinations and an increase in the number of reindeer played a role (Sköld, 1996).

2.1 Melting of Permafrost and the Release of Infectious Diseases

Infectious diseases predominated the high death rate in the Arctic nations two centuries ago. Between 1750 to 1800, smallpox killed over 300,000 individuals in Sweden, a nation of only 2 million people. Smallpox mortality dropped significantly when the vaccine was developed in the early 1800s, and that in 1976 the (WHO) World Health Organization proclaimed that the illness had been completely eradicated from the planet. This was the initial infectious disease that was actively eradicated through human health prevention (Mamelund et al., 2013). Between 1918 and 1920, there was a global influenza pandemic that claimed 50 to 100 million lives. Indigenous peoples in the Arctic, in particular, were severely affected. Up about 90% of the population perished in Alaskan rural towns as a result of the sickness (Schwartz, 2009). Anthrax is a bacterial infection that was first referenced in the Bible as a disease of herbivores. It continued to be a leading cause of animal mortality worldwide until the end of the 19th century, occasionally contaminating humans on a large scale. More than 90% of patients who are left untreated for the illness die (Margesin & Collins, 2019).

2.2 New and emerging zoonotic diseases

There are Proofs that increase in air temperatures is causing an increase in disease transmission. In some locations that previously did not support the survival of vectors and diseases, rising temperatures and variations in rainfall have produced favorable conditions for their survival. The earth's cryosphere, which is made up of glacier, permafrost, icebergs, frozen lakes, and seas, is extremely sensitive to global warming (Dobricic & Pozzoli, 2019). Through environmental pathways, pathogens can spread by using contaminated surfaces and melting water as a medium of transfer. Currently, circumpolar permafrost covers 37% of northern hemisphere (Oliva & Fritz, 2021). Inhabitants of these permafrost zones number 35 million (Biskaborn et al., 2019). By 2100, it is possible to anticipate a 60% thaw due to global warming (Stella et al., 2020). Microbes that have been long-term ice-buried can be released by glacial melt and thawing permafrost. The risks to animal and human health posed by such melting ice stores of microbes are serious. Thawing might facilitate transmission by bringing the host (which could include people and animals) close to the disease. Essentially, two scenarios are possible: the first is the re-emergence of well-known pathogens like Bacillus anthracis, which recently caused an outbreak in humans and reindeer herds in Siberia (Okamoto et al., 2017). The other is the resurgence of viruses that were previously undiscovered, such the enormous virus Pithovirus sibericum, whose infectivity is unknown and was identified from a 30,000-year-old ice block (Reid et al., 1999). Despite being less noticeable, these disease hotspots are becoming more significant for global health.

2.3 Viral threats

Viruses are powerful pathogens that have the potential to cause widespread pandemics. The virus currently termed as the Severe Acute Respiratory Syndrome Coronavirus 2 is what caused the COVID-19 pandemic, which is covered in more detail later in the chapter (SARS-CoV-2). In 1918, the Spanish Influenza (H1N1A) claimed the lives of up to 40 million people globally. Exhumed for analysis in a recent study were victims of the 1918 Spanish flu who had been interred in a mass burial in Alaskan permafrost (Sommer et al., 2015). From their bodies, the virus's positive RNA could be extracted. This discovery paints a grim picture: that melting ice permafrost can uncover bodies that are home to such deadly viruses. The likelihood of viral transmission and infection can be increased by increased anthropogenic activities in these areas. Similar to how a 300-year-old body mummified in Siberian permafrost yielded the DNA of the smallpox virus Variola major (Segawa et al., 2012). The influenza virus can also spread by migratory birds and arctic penguins into frozen lakes, which serve as reservoirs for the virus when they defrost (Segawa et al., 2012).

2.4 Bacterial threats

Cold habitats were once thought to as ideal conditions. Studies utilizing soil and ice samples have shown genes that are resistant to antibiotics (Rafiq et al., 2017). The frequency with which melt away waters are sampled for Escherichia coli & Streptococcus fecalis raises the possibility of fecal-oral transmission amongst polar tourists and climbers (Rafiq et al., 2017). A well-known pandemic that is climate-sensitive and has a high rate of mortality is cholera. Meanwhile, the Indian subcontinent faces a particularly unique hazard as a result of the discovery of several antibiotic-resistant bacteria in the Siachen glacier (Githeko et al., 2000.). It has been hypothesized that migratory birds, increased human activity, and airborne transmission are the main causes of disease emergence. These frozen regions may serve as breeding grounds for bacteria resistant to harmful drugs, thwarting efforts to control the spread of antibiotic resistance on a worldwide scale. Another potential is the accidental release of deadly germs like the previously mentioned Bacillus anthraces into populations of people and animals, which would have fatal effects.

2.5 Fungal threats

Environmental fungi like Cryptococcus are well-known pathogens for the immuno-compromised (including people living with AIDS/HIV, those with liver and kidney diseases, those receiving organ or stem cell transplants, and those receiving cancer therapy), as well as, to a lesser extent, for the general population. Due to its resistance, Aureobasidium pullulans is yet another environmental fungus that has adapted to the cold and is significant in medicine (Segawa et al., 2012). The developing superfungus Candida auris is similar in that it exhibits multi - drug resistance and serves as a significant pathogen in hospitals intensive care units. As an outcome of global warming, fungal colonies stored in ice have "adapted" to hotter temperatures. They can strategically overcome human thermal barriers thanks to this (Edwards, 2015). The El Nino oscillation has been connected to the spread of the Rift Valley fever, West Nile virus, and Dengue fever in new geographic areas (*Prioritizing Zoonotic Diseases for Multisectoral, One Health Collaboration in the United States Workshop Summary CS29887A*, 2021.). Whereas new viruses like HIV, Ebola hemorrhagic fever, and Rift Valley fever emerged in Africa, the Zika virus increased in South America. The zoonotic illnesses of salmonellosis, influenza, plague, West Nile virus, emerging corona viruses, brucellosis, rabies, and Lyme disease have been mentioned as those of greatest concern in North America, particularly the US (VOROU et al., 2007). In Asia, the H5N1, SARS, and Nipah viruses first surfaced. Tularemia, hemorrhagic fever along with renal syndrome, mad cow disease, tick-borne encephalitis, and West Nile fever cases increased in Europe (Dauphin, 2015). Rabies, brucellosis, cysticercosis, toxoplasmosis, echinococcosis, leptospirosis, Japanese encephalitis (JE), Scrub typhus, Kyasanur forest disease (KFD), Nipah, and Crimean-Congo hemorrhagic fever are the main zoonotic illnesses affecting humans in India. When it comes to zoonotic viruses, influenza has caused the most epidemics and even pandemics. Animals and people both carry influenza viruses. The influenza A, B, C, and D viruses come in four different varieties. Seasonal epidemics as well as pandemics have both been brought on by influenza A, but seasonal epidemics are the only thing influenza B brings on. A new pandemic influenza strain may evolve as a result of climate changes that affect wild waterbird habitats, migratory patterns, and resting places. These changes may also have an impact on the spread of avian virus agents globally. By their very nature, influenza viruses are continually changing throughout a wide range of genetic and antigenic groupings and species. Even though location and timing are undetermined, there is a good chance that there will be influenza pandemic in the future. In the past, there have been four pandemics caused by influenza viruses (Kuriakose et al., 2013). The (WHO) World Health Organization, the World Organization for the Animal Health and the (FAO) Food and Agriculture Organization collaborate through a variety of established response and detection mechanisms in order to identify a possible pandemic influenza strain. The corona viruses are a different family of viruses that have contributed to epidemics including the most recent pandemic. A class of viruses known as corona viruses is responsible for illnesses in both people and animals. It is thought that a wide variety of bird and bat species serve as their natural hosts. They frequently move around with animals like pigs, cats, cows, camels, and others. There are now seven coronaviruses that can harm people. Three (SARS, MERS, and COVID-19) reportedly caused serious sickness, but 4 are endemic and typically cause moderate disease (frequently found as well as responsible for roughly 10-15% of common colds). Like SARS in the year 2002, COVID-19's pandemic was caused by a brand-new coronavirus called SARS-CoV-2, which likewise originated in China (WHO, 2019). It turned out to be a very contagious illness that spread quickly over the world and caused unprecedented devastation in several countries. Lockdown measures taken by many nations to contain the virus resulted in the closure of schools, offices, businesses, and factories as well as travel restrictions and protracted aircraft cancellations. The disaster spread around the world, bringing enormous suffering and an economic collapse.

2.6 Overlaps between pandemics and climate change in terms of impact and responses

There are many similarities between a COVID-19 pandemic and climate change, despite the fact that the former poses significant difficulties. Both pandemics and the impacts of climate change have no geographical bounds. Both have global issues with local effects, thus finding effective solutions that can be adopted locally, nationally, regionally, and worldwide is necessary. Their effects on people's health and the economy are clear-cut and catastrophic. Both are connected to how people behave. It is obvious that quick action on the both can save lives, and that any delay in action can significantly increase the costs to both the human race and the economy. Both pandemics & climate change fundamentally affects every aspect of society, necessitating coordinated effort that involves the "whole of society" in the solution. The impoverished, the elderly, the young, and those with little or no access to health care are the groups that are disproportionately affected by pandemics and climate change. Both impose protection-related obligations on authorities and other parties.

Nations are just as strong as their weak health system when confronted with global public health risks like COVID-19 or climate change. In order to safeguard the population from both immediate and long-term health risks, equitable and universal health coverage are necessary. By taking action and altering behaviour in response to COVID-19, the international community demonstrated its capacity to address a crisis. Multilateralism is the sole strategy that can address the complex effects of COVID-19 & climate change. It calls not only for political commitment and the application of science in legislation, but also for everyone to come together as an one global community and act in concert. Countries need extensive and long-lasting multisectoral response and preparedness plans that lay out their policies, strategies, and operations for handling these calamities because pandemics as well as climate change influence many different facets of society. To help mitigate the risks and effects of climate and weather extremes upon the most vulnerable individuals, social safety net programs are currently in place (Gilligan, 2020). Through monetary transfers to disadvantaged households, the following has been implemented in drought-affected areas. Similar social welfare programs have been utilized successfully to mitigate the COVID-19's simultaneous health and economic shocks (*Liselotte Lindgren*, 2015.).

3. Effects of Climate Change on the Emergence of Infectious Diseases

In the following years and decades, climate change may have an impact on the distribution, incidence, and severity of infectious diseases throughout Canada. High water velocity from more precipitation will cause more turbidity in the water. Additionally, quick melting leads to a rise in occurrences of digestive disorders. The danger of water-borne transmission of infectious diseases will rise as a result of both the high precipitation and the quick melting, which will mix and spread additional pathogens into water sources (Parkinson & Evengård, 2009). Temperature increases will lead to an increase in food-borne illnesses, food spoiling, and the spread of disease organisms. The conventional techniques of food preservation, such as canning, fermenting, and outdoor food storage, will be disrupted by melting permafrost, especially in the Arctic. Due to climate change and rising temperatures, air-drying meat will amplify the danger of exposure to infections (Taubenberger et al., 2012). This may lead to more cases of food-borne illnesses such botulism, campylobacteriosis, salmonella, and others (Taubenberger et al., 2012). The habitat range for animal hosts travelling farther north will be expanded as a result of climate change warming. This will lead to a rise in the number of animal hosts and the spread of zoonotic diseases.

3.1 Resurrecting viruses

Scientists creating new viruses from stored viral genomic material might pose a greater risk. For instance, scientists previously succeeded in recovering the whole viral genome in the year 1918 of Spanish flu, which caused more than 50 million fatalities (Ng et al., 2014). There are risks associated with this, even though it does offer crucial knowledge on topics like future pandemic prevention and control, which is relevant of obvious reasons. In 2014, scientists discovered the viral genomes of two unidentified viruses in 700-year-old caribou feces, of which one could infect plants in a lab (Christie, 2021). Since little is known about the infectiousness of these viruses, this type of research needs to be carried out with great caution in order to prevent "pathogens escaping from the lab" scenarios (World Health Organization, 2019).

4. Conclusion

Conclusively, pandemics are not anticipated to be one of the main issues associated with the thawing of permafrost. There are a number of other concerns regarding the warming and defrosting of permafrost soil, such as an increase in the intensity and frequency of wildfires, infrastructure failure because of damage to roads, buildings, pipelines, and homes, pole ward disease-vector spread of, coastal erosion and flooding, for instance, ticks, and also that glacial ice stores up to 1580 billion megatonne of organic carbon, almost double in addition to present in the entire atmosphere (Revich et al., 2012; Hueffer et al., 2020; Sköld, 1996). More investigation is required to ascertain whether bacteria in permafrost are genuinely viable and capable of causing an outbreak on release because we just do not yet understand the full scope of the hazard. The surveillance and monitoring of the permafrost as well as its microorganisms is not easy particularly in light of the fact that climate change, tourism, and increased gas, oil, and mineral extraction with in Arctic circle lead to greater levels of direct contact of human with thawing permafrost (Yarzábal et al., 2021; Sachal et al., 2019) As the world is already trying to deal with the one pandemic, introduction of Infectious diseases will only have a negative impact on future generations' health. Infectious diseases that are sensitive to climate change should be better monitored. Indigenous peoples' input can help identify culturally acceptable adaptation and mitigation methods to combat newly developing infectious illnesses in a global context (Sachal et al., 2019).

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