Analysis and Development of Current Research on Permafrost

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Abstract. In recent years, the research on permafrost is more and more in-depth. In China, with the expansion of infrastructure after China's economic reform, permafrost in high altitude areas has interfered with the construction of railways and houses. As a common resource in China, frozen soil has both advantages and disadvantages. At present, because of the existence of frozen soil layer, many infrastructure projects cannot be carried out smoothly, which has become a serious obstacle in the process of infrastructure construction. At present, the scientific community is trying to solve this problem. In fact, the existence of frozen soil layer is the most common phenomenon in nature. How to give full play to the nature of frozen soil and its value and role is a hot issue at present. The purpose of this paper is to discover the properties and problems of permafrost. Based on the research of scholars and the author's views on future trends, this paper briefly summarizes several properties of permafrost.

Keywords: Permafrost; Frozen soil; Global warming; Microorganisms.

1. Introduction

In recent years, the attention of permafrost research has gradually emerged in the world. As a widespread geological condition, a large number of engineering equipment is built on permafrost, aka frozen soil. The study shows that the distribution of frozen soil shows obvious zonal characteristics [1]. In addition, due to the unique strata structure of frozen soil, its inside properties are easily influenced by both the surrounding and global environment. These factors reduce the stability of engineering structures and cause potential safety hazards. Therefore, researchers aim to discover the mechanical behavior of permafrost and the way of improving the inside properties of frozen soil with the behavior [2]. This paper will combine various studies on the properties of permafrost and its possible effects to provide a general summary and the author's insights, including the causes of some conditions and their possible solutions [3].

At present, most of the studies point out the impact of global warming on permafrost, and most of them are evaluated by constructing permafrost vulnerability index models. Among them, the topographic aspect, altitude, type of frozen soil and topographic shelter of frozen soil impact greatly its vulnerability [4]. However, the study shows that temperature has little effect on permafrost, which seems to contradict global warming and permafrost degradation [5]. The author will discuss the causes from the perspectives of the multi-factor correlation of permafrost vulnerability and the zero-bound point of permafrost vulnerability, and provide short-term solutions according to its principles.

2. Formation of permafrost

2.1. Composition and geography

Permafrost is mainly divided into two layers: the top active layer that contains soil and thaws in summer and the bottom layer of sediment (bonding soil, gravel, and sand together by ice) frozen for at least two years, whose temperatures rarely rise above the melting point. The active layers are thin at only 10 to 15 centimeters, therefore permafrost often addresses the bottom layer (with a thickness

of 0.3 to 6 meters) [6]. Permafrost requires low temperatures to remain frozen, it is often found at the poles of the Earth or at very high altitudes in the mountains [7]. Permafrost is a significant geological structure, belonging to a part of Gelisols that lots of cold-weather towns are built upon. Moreover, as an important geological structure, China's railway extension construction is closely related to it.

2.2. Collapse and Expansion

Since the main composition and structural support of the inside soil comes from the unstable ice through very low melting and coagulation points that make the aqueous solid structure inconstant, permafrost and its surrounding soils create the unstable taxitic structure. These unstable structures caused by permafrost greatly affect the biology, chemistry, and geological conditions of the ground. Thawing permafrost raises water levels in Earth's oceans and the risk of unknown microorganisms being active. The thawing phenomenon also increases the chance of erosion since the soil inside is washed away without the ice [8]. On the other hand, because permafrost comprises a large amount of ice (generally more than 50%), easily influences the moisture at the junction between the active layer and bottom layer through temperature transfer, making this mobile moisture become unevenly frozen and therefore expanding the volume of permafrost. When the uneven formation of ice under the soil exceeds a certain threshold, the surface structure will be destroyed. Thus, the phenomenon of permafrost's expansion and its uneven characteristic also becomes the main problem of construction. Existing scientists' interpretation of the permafrost is generally chaotic and unpredictable, which creates lots of concerns about the permafrost for engineers when it comes to construction [9].

3. Strata property of permafrost

However, in response to permafrost disturbances, in 1981, Cheng Guodong, a famous permafrost scientist from the Chinese academy of sciences, noticed that the unfrozen water in both permafrost and the active layer, which had been neglected by previous scholars and thus proposed a creative hypothesis, "The mechanism of repeated-segregation for the formation of thick layered ground ice". In his article, Cheng concentrated on the "Unequal law of migration of unfrozen water", combining moisture and ice formation in freezing, frozen, and thawing soil, explaining the property of self-purification of ice. Cheng's theory reveals the nature of thick underground ice formation with the law of soil particle movement and has been graphically called the "relative theory" of permafrost [10]. His theory has become an important theoretical solution addressing permafrost's disordered structures in the international permafrost field.

4. Surrounding Microorganisms and impacts

The creatures near the frozen soil are affected by the special environment, which has produced many special places compared with those in other regions. Microorganisms in the frozen soil vary with the depth and age of the frozen soil and the content of organic matter. Microorganisms are mainly bacteria and fungi. Because of the periodic freezing and thawing of permafrost, the microbes are thus various among places [1].

There are several main features of the microorganism in permafrost environment. Microorganisms have strong vitality and high cold resistance; even the microorganisms in the ice layer thousands of years ago are still active. They spend most of their time dormant, metabolizing only in small areas with short periods. Microbes in frozen ice are less able to synthesize DNA and proteins [11]. This is due to the surrounding temperature that causes freeze: the freezing process will dehydrate the cells. Due to the dehydration of the cells, the cytoplasm will gradually condense or even exit to the west, the nucleus will shrink and the fluidity of the cell membrane will decrease, and the cell wall will be damaged. Cell activity of microorganisms is largely determined by the rate at which the frozen soil freezes, with a fast process having little effect and vice versa.

In recent years, scientists have had a big worry about microbes that live near permafrost, that they will release large amounts of greenhouse gases, and carbon dioxide, affecting the GIF environment and the environment of the entire planet. In the past decades, climate warming has caused extensive permafrost melting, enhanced microbial activity, and accelerated the decomposition of soil organic carbon [12]. The huge carbon pool has become an important carbon source due to the melting of permafrost and the emission of greenhouse gases such as carbon dioxide and methane into the atmosphere, which may have positive feedback on climate warming. Considering that soil microorganisms play a key role in controlling microorganisms in permafrost regions, their response to permafrost melting determines the fate of carbon release in deeply frozen soil under the background of climate warming.

Therefore, it is very important to study the microbial response and its relationship with soil carbon release during the process of permafrost thawing to better understand the direction and intensity of permafrost carbon-climate feedback [13].

5. The effects of Global Warming

The Northern hemisphere is currently the focus of most permafrost research. Since the 1980s, nearly a century ago, the international community has been very concerned about global warming. In general, China's climate change trend is similar. According to studies, China has experienced the most significant warming since the 1980s in the context of global warming. The winter temperature increase is most noticeable in the northern region. A type of soil known as permafrost is unstable and temperature-sensitive. The relationship between the permafrost sphere and global climate change has garnered a lot of attention in the context of global warming [3].

According to the statistics, the Global average surface temperature has been climbing since 1990 and 1996 with the release of 0.3 ~ 0.6 ℃, 0.4 ~ 0.8 ℃ in 2001, 0.56 ~ 0.92 ℃ in 2007, and 0.65 ~ 1.06 ℃ in 2013.

Although the temperature continues to rise, under the current warming level, climate factors change only indirectly affects the vulnerability of frozen soil through the reception and redistribution of water and heat by topography and the change of frozen soil type. Based on the prediction of the vulnerability of glaciers and the research results of influencing factors, we speculate that, with the further increase of warming in the 2030s and 2050, the impact of climate factors on the vulnerability of frozen soil will emerge and become one of the main factors influencing the vulnerability of frozen soil. There is a critical increase in the vulnerability of not only glaciers but also multi-year frozen soils due to climate change. Within this range of warming, the impact of climate factor change on vulnerability is not obvious or relatively small. When it exceeds this critical range of warming, the impact of climate factor change will be obvious. Whether our inference is correct remains to be confirmed by future research.

Anisimov and Nelson found that a 2°C increase in the Northern Hemisphere would result in a 25–44% decrease in the amount of permafrost. Researchers Wan et al. and Dufresne et al. found that an increase in temperature would accelerate the decomposition of soil organic matter, improve respiration, and increase greenhouse gas emissions. This means that a significant amount of the greenhouse gases trapped in permafrost may be released as a result of the permafrost melting [5].

The primary trend of recent permafrost changes is permafrost degradation brought on by global warming. When Jorgenson et al. examined the permafrost distribution in Tanana Flats in Central Alaska, the United States, they discovered that between 1994 and 1998, the rate of permafrost degradation was extremely rapid. And from Birch Forests to Fens and BOGs, ecosystems have changed. The accumulation and decomposition of organic carbon in permafrost are influenced by the symbiotic relationship between marsh wetlands and permafrost. The freeze-thaw disturbance on the burial depth of organic carbon and the anaerobic Peatlands have been found to be significant long-term sources of atmospheric CO_2 uptake, which may help to slow the pace of global warming. The storage of atmospheric CO_2 by peatlands over the past 10,000 years is thought to have lowered global

temperatures by 1.5–2.5°C. environment of frozen soil, and the low-temperature environment of saturated water in the active layer, and all of these factors prevent the decomposition of organic matter.

The two main soil states that will be left behind by the permafrost thawing brought on by global warming are aerobic and anaerobic. Fires may result in increased CO_2 (aerobic) and CH_4 (anaerobic) GHG emissions, which could affect the carbon balance in permafrost regions when coupled with ecosystem changes.

6. Conclusion

This article set out to discuss the properties of permafrost and its possible effects, including possible solutions to some extent of problems. This thesis has provided a deeper insight into the causes of permafrost formation and the habitat and migration habits of microorganisms based on their nature.

In addition, this paper makes scholars' conjecture about the degradation of the ecosystem and the release of greenhouse gasses, though there is not enough evidence to prove that the threshold of climate warming will change the effect of temperature on permafrost. The formation of permafrost and the properties of the surrounding strata are determined, including the morphological changes and causes of permafrost. In terms of its impact, the study suggests that the melting of permafrost and the degradation of the surrounding ecosystem may increase greenhouse gas emissions, thus accelerating the process of global warming. However, as mentioned above, there is not enough evidence to support our prediction of the threshold of climate warming, and this argument needs to be supported by more data in the future.

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