

Seawater Intrusion in Coastal Aquifers: Causes, Effects, and Solutions

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Abstract

This article provides an overview of seawater intrusion in coastal aquifers, including its causes, effects, and solutions. Seawater intrusion occurs when saltwater infiltrates freshwater aquifers, leading to a decrease in freshwater availability and quality. This can have significant environmental, economic, and societal effects, including a decrease in biodiversity, a negative impact on agricultural productivity and tourism, and conflicts over water resources. Sustainable groundwater management, land-use planning, seawater intrusion barriers, and desalination are all potential solutions to address seawater intrusion. Overall, addressing seawater intrusion is essential to ensuring the long-term availability of freshwater resources and protecting the environment, economy, and society.

Introduction

The availability of freshwater is crucial for the survival and development of human society. Groundwater has been the primary source of freshwater for human consumption and agriculture worldwide. Coastal regions rely on groundwater extracted from aquifers near the shorelines, as they are often free from pollution and saline intrusion. However, seawater intrusion is a significant threat to these coastal aquifers, as it leads to a decrease in water quality and quantity. Seawater intrusion is a natural process that occurs when saltwater infiltrates into freshwater aquifers due to various factors. In this article, we will discuss the causes, effects, and solutions to seawater intrusion in coastal aquifers.

What is Seawater Intrusion?

Seawater intrusion is a phenomenon where saline water infiltrates into freshwater aquifers, leading to an increase in the salt concentration of groundwater. This process occurs due to the natural gradient between saltwater and freshwater, which is caused by the difference in density between the two types of water. The pressure of freshwater is different than that of saltwater, which creates a gradient between the two. This gradient allows seawater to infiltrate into freshwater aquifers when the pressure of saltwater exceeds that of freshwater.

Causes of Seawater Intrusion

Seawater intrusion can be caused by various factors, including natural and human activities. Some of the primary causes of seawater intrusion are discussed below.

Natural Causes

The natural causes of seawater intrusion include geological processes and sea-level rise. The geological processes that contribute to seawater intrusion include coastal erosion, subsidence, and faults. Coastal erosion occurs when waves and tides remove sediment from the coastline,

resulting in the exposure of underlying geological formations. This process can create conduits that allow seawater to infiltrate into freshwater aquifers. Subsidence occurs when the land sinks due to natural geological processes, such as tectonic activity or compaction of sediments. This process can cause the freshwater aquifers to become shallower, allowing seawater to infiltrate more easily. Faults are geological structures that can act as pathways for seawater to infiltrate into freshwater aquifers.

Sea-level rise is another natural factor that contributes to seawater intrusion. As sea levels rise, the freshwater aquifers near the coast become shallower, making them more susceptible to seawater intrusion.

Human Activities

Human activities such as groundwater pumping, land-use changes, and saltwater intrusion barriers can also contribute to seawater intrusion.

Groundwater pumping is a major contributor to seawater intrusion. When groundwater is extracted from aquifers faster than it can be replenished, the pressure of freshwater decreases, allowing seawater to infiltrate into the aquifer. This process is exacerbated in coastal regions where the aquifers are already shallow and the natural gradient between freshwater and seawater is high.

Land-use changes such as urbanization and agriculture can also contribute to seawater intrusion. When land-use changes occur, the amount of rainfall that infiltrates into the ground decreases, leading to a decrease in freshwater recharge. This decrease in freshwater recharge can cause the pressure of freshwater to decrease, allowing seawater to infiltrate into the aquifer.

Saltwater intrusion barriers are structures designed to prevent seawater from infiltrating into freshwater aquifers. While these structures can be effective in certain cases, they can also create unintended consequences. For example, if the barrier is too close to the coastline, it can cause the freshwater aquifer to become stagnant, leading to a decrease in water quality.

Effects of Seawater Intrusion

Seawater intrusion can have significant effects on the environment, economy, and society. Some of the primary effects of seawater intrusion are discussed below.

Environmental Effects

Seawater intrusion can have a significant impact on the environment, particularly on coastal ecosystems. The increase in salt concentration can affect the vegetation and wildlife that depend on freshwater, leading to a decrease in biodiversity. The intrusion of seawater can also lead to an increase in soil salinity, which can negatively impact agricultural productivity and limit the types of crops that can be grown in the affected areas.

Economic Effects

Seawater intrusion can have a significant economic impact, particularly in coastal regions where agriculture and tourism are important industries. The decrease in freshwater

availability can lead to a decrease in agricultural productivity, which can have a ripple effect on the local economy. Similarly, the decrease in water quality can negatively impact the tourism industry, as visitors may be deterred by the poor water quality.

Societal Effects

Seawater intrusion can have significant societal effects, particularly in areas where access to freshwater is already limited. The decrease in freshwater availability can lead to conflicts over water resources and exacerbate existing social and economic inequalities. Additionally, the decrease in water quality can lead to health problems for individuals who rely on groundwater as their primary source of drinking water.

Solutions to Seawater Intrusion

Seawater intrusion is a complex issue that requires a multifaceted approach to address. Some of the primary solutions to seawater intrusion are discussed below.

Sustainable Groundwater Management

Sustainable groundwater management is essential to addressing seawater intrusion. This involves managing groundwater resources in a way that ensures their long-term availability while also preventing seawater intrusion. This can be achieved through a combination of measures, such as reducing groundwater pumping rates, increasing the use of alternative water sources, and implementing groundwater recharge projects.

Land-Use Planning

Land-use planning is another important solution to seawater intrusion. This involves managing land use in a way that reduces the impact on groundwater resources. For example, limiting urbanization in areas with shallow aquifers can reduce the demand for groundwater and prevent seawater intrusion. Similarly, implementing sustainable agricultural practices can reduce water use and limit the impact of land-use changes on groundwater resources.

Seawater Intrusion Barriers

Seawater intrusion barriers can be an effective solution to prevent seawater intrusion. These structures can be designed to prevent seawater from infiltrating into freshwater aquifers while also allowing freshwater to flow freely. However, it is important to ensure that these structures are designed and implemented in a way that does not create unintended consequences, such as stagnant water or a decrease in water quality.

Desalination

Desalination is a technology that can be used to treat seawater and make it suitable for human consumption and agricultural use. While desalination can be expensive, it can be an important solution in areas where freshwater resources are limited and seawater intrusion is a significant problem.

Conclusion

Seawater intrusion is a significant threat to coastal aquifers worldwide. It is a complex issue that requires a multifaceted approach to address, including sustainable groundwater management, land-use planning, seawater intrusion barriers, and desalination. Addressing seawater intrusion is essential to ensuring the long-term availability of freshwater resources and protecting the environment, economy, and society.