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Study on the Geological Characteristics and Rock-Soil Erosion Effects in the Arsenic Sandstone Region

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Abstract: The arsenic sandstone region is a unique geological environment, and its geological characteristics and rock-soil erosion effects are of great significance for geological disaster prevention and ecological environmental protection. Arsenic sandstone is a sedimentary rock composed of quartz, feldspar, sandstone, and other components, with abundant harmful elements such as arsenic and sulfides. Under the influence of natural weathering and human activities, the arsenic sandstone region is prone to rock-soil erosion, leading to issues such as soil erosion, water and soil loss, and geological disasters. Through the study of the geological characteristics and rock-soil erosion effects in the arsenic sandstone region, we can better understand the formation mechanism and evolutionary laws of this special geological environment. This provides a scientific basis and technical support for geological disaster prevention and ecological environmental protection. It also has important reference value for the rational development and utilization, as well as ecological restoration, of the arsenic sandstone region.

1. Introduction

Arsenic sandstone contains a large amount of arsenic elements, and in areas with arsenic pollution, arsenic sandstone is a widely distributed rock type. Studies have shown that high concentrations of arsenic elements are often present in the soil and water of arsenic sandstone areas, posing a significant threat to the environment and human health. Therefore, in-depth research on the geological characteristics and rock-soil erosion effects of the arsenic sandstone region is of great scientific significance and practical value. The purpose of this paper is to reveal the geological characteristics of the arsenic sandstone region and analyze its rock-soil erosion effects in-depth, providing a scientific basis and technical support for arsenic pollution control.

2. Geological Characteristics of Arsenic Sandstone Region

2.1. Diverse and Complex Types

The geological characteristics of the arsenic sandstone region exhibit a diverse and complex range of types. The following are some common types of arsenic sandstone:

Clastic arsenic sandstone is formed by the accumulation of debris such as sand grains and pebbles. Its main components include quartz, feldspar, and sandstone, with a high arsenic content. Clastic arsenic sandstone typically forms in sedimentary environments like rivers and lakes, presenting good mineralization potential.

Carbonate arsenic sandstone consists of carbonate minerals and arsenic-containing substances. Common minerals found in this type include calcite and dolomite. Carbonate arsenic sandstone primarily forms in marine sedimentary environments, often associated with paleontological fossils, and holds certain mineral resource value.[1]

Sulfide arsenic sandstone is composed of sulfide minerals and arsenic minerals. Common sulfide minerals include pyrite and chalcopyrite, while arsenic minerals include arsenopyrite. Sulfide arsenic sandstone mainly forms in regions with active hydrothermal activities rich in sulfides and arsenic, displaying high arsenic content and mineral development potential.

Arsenic shale is a special rock rich in organic matter and arsenic. Its main components are clay minerals and arsenic-containing organic matter, often accompanied by coal mining activities. Arsenic shale is prone to releasing arsenic during natural weathering and human mining processes, posing certain risks to the environment and human health.

The geological characteristics of the arsenic sandstone region encompass a variety of types, each exhibiting differences in origin, composition, and distribution. Understanding these geological features is crucial for studying rock-soil erosion effects and geological disaster prevention.[2]

2.2. Severe Gully Erosion and Bedrock Erosion

The geological characteristics of the arsenic sandstone region include rock types, geological structures, and landforms. Among them, gully erosion and bedrock erosion are prominent features. The region is predominantly characterized by mountainous and hilly terrain with relatively high precipitation and frequent floods. Due to the low rock strength, the area is susceptible to erosion. Gully erosion is the primary form of surface erosion in arsenic sandstone regions. In areas with gullies, there is a dense network of ravines, high surface exposure, thin soil cover, and poor vegetation, making it prone to soil erosion and loss. Features like "sandstone forests" and "karst landforms" may also occur in gully areas due to water erosion, physical weathering, and other factors. The weak bedrock in the arsenic sandstone region is susceptible to erosion, resulting in abundant surface cavities. Surface water easily infiltrates into the bedrock, further intensifying erosion. Bedrock erosion alters soil structure and quality in the region, potentially leading to geological hazards such as surface collapse.[3]

2.3. Human Activities Intensify Erosion

Human activities, such as large-scale agriculture, forestry, and urbanization, can lead to land exposure and vegetation destruction, increasing the risk of soil erosion. Accelerated soil erosion enhances the erosion processes of rocks and soil. Construction of reservoirs and water resource development in arsenic sandstone regions may alter the original hydrogeological conditions, increasing water flow velocity and exacerbating erosion. Some arsenic sandstone areas may be rich in mineral resources such as gold and silver. During mineral extraction, operations like excavation and blasting may cause surface damage and soil erosion. Large-scale infrastructure projects, including roads, bridges, and buildings, may involve earthworks that disturb the original surface cover, exposing arsenic sandstone and elevating erosion risks. It is essential to note that the impact of human activities on erosion is multifaceted and extends beyond arsenic sandstone regions. The specific degree of impact depends on the comprehensive interaction of geological, climatic, hydrological, and other natural factors. Therefore, when developing and utilizing arsenic sandstone regions, scientific environmental protection measures should be implemented to mitigate adverse impacts of human activities on geological characteristics, ensuring the preservation of ecological environments and geological resources.[4]

3. Hazards Caused by Rock-Soil Erosion in Arsenic Sandstone Regions

In arsenic sandstone regions, the hazards brought about by the complexity of geological features and the enrichment of arsenic elements make rock-soil erosion particularly severe. High concentrations of arsenic elements are often present in the soil and water of arsenic sandstone areas. These elements, along with eroded materials, spread through soil and water, resulting in environmental arsenic pollution. This not only jeopardizes the ecological environment and affects natural landscapes but also poses health risks to humans and animals.

The soil in arsenic sandstone regions is relatively infertile, with limited resources such as water, nutrients, and soil. Rock-soil erosion leads to further land erosion, diminishing soil fertility and water retention capacity, exacerbating land degradation. Additionally, rock-soil erosion can trigger geological disasters, especially in areas where river and slope erosion intensify. For instance, accumulated eroded materials on slopes may cause landslides and collapses, resulting in casualties and property losses. Trees and vegetation in arsenic sandstone regions play vital roles in soil retention, erosion prevention, and maintaining surface microclimates. Increased rock-soil erosion results in sparse vegetation, ecological imbalance, and subsequent impacts on local ecosystems and biodiversity.[5]

4. Basic Characteristics of Soil Erosion in Arsenic Sandstone Regions

4.1. Non-Rainfall Soil Erosion

Non-rainfall soil erosion primarily involves slope erosion, where water flow on the slope scours and transports soil particles. This erosion typically occurs in areas with steep slopes, especially on exposed or poorly vegetated land. The process of non-rainfall soil erosion can be divided into three stages: erosion, transport, and deposition. Rainfall impact causes soil particles to loosen, forming small rills. Subsequently, water flow transports the eroded soil particles, leading to soil particle migration. Finally, in areas where water flow velocity decreases, soil particles gradually settle, forming sediment. The occurrence of non-rainfall soil erosion is influenced by various factors, including rainfall amount, intensity, distribution, soil type, slope, and slope length. Vegetation cover plays a crucial protective role, with richer vegetation associated with lower levels of non-rainfall soil erosion.

Non-rainfall soil erosion has certain effects on soil quality and the environment. The loss of soil particles, rich in nutrients and organic matter, contributes to soil quality decline, reduced soil fertility, water source pollution, riverbed siltation, and decreased biodiversity. To mitigate the impact of non-rainfall soil erosion, protective measures should be implemented, such as strengthening vegetation protection, increasing vegetation cover, and adopting conservation practices in agriculture.

4.2. Surface Soil Erosion

Surface soil erosion refers to the phenomenon where the surface layer of soil is scoured, worn, and eroded under the influence of rainfall and surface water flow. In arsenic sandstone regions, the surface layer of soil is relatively fragile, with loose soil texture and weak vegetation cover, making it susceptible to the scouring force of rainfall and surface water flow. When rainfall occurs, water quickly infiltrates the surface layer of the soil, and surface water flow forms on sloped terrain. This flowing water exerts high-speed impact on the surface layer of the soil, carrying away soil particles. Consequently, the surface layer of the soil is gradually scoured and eroded, leading to soil loss.

Surface soil erosion results in reduced soil quality, accelerated soil erosion rates, and the loss of nutrients and organic matter from eroded soil particles. This nutrient and organic matter loss causes soil infertility, affecting agricultural productivity and plant growth. The decline in soil quality further intensifies the rate and degree of soil erosion, creating a vicious cycle. Surface soil erosion also leads to land degradation and ecosystem disruption. Exposed rock or secondary soil, resulting from eroded surface soil, has poor soil quality, lacks nutrients and moisture, hinders plant root growth, and impedes ecosystem recovery. Therefore, an in-depth study of the characteristics of surface soil erosion in arsenic sandstone regions is crucial for soil erosion prevention and land conservation.

4.3. Ravine Formation

One of the soil erosion characteristics in arsenic sandstone regions is the prevalence of ravines, where a complex network of intertwined ravines forms a distinctive landscape. The formation of ravines is closely related to the geological features and environmental conditions of arsenic sandstone regions. The topography in these regions is mainly composed of mountains and hills, with relatively high precipitation and frequent floods. The low strength of arsenic sandstone rocks makes them susceptible to erosion by water flow. Under rainfall, water flow creates numerous ravines on the surface of arsenic sandstone regions. Due to the brittle nature of arsenic sandstone rocks, prone to erosion by water flow, an intricate network of ravines develops over time, resulting in the unique landscape of ravines crisscrossing the arsenic sandstone region.

The existence of ravines not only accelerates soil erosion but also leads to significant soil loss. The presence of ravines exposes the surface soil, making it susceptible to water flow erosion and intensifying the speed and degree of soil erosion. Soil loss not only depletes the fertility of farmland but also causes soil shrinkage, further exacerbating land degradation. The characteristics of ravines pose challenges to water resource management and flood control. Water flow in ravines quickly gathers and forms floods, increasing the risk of flood disasters. The ravine system in arsenic sandstone regions also impacts the planning and layout of land use and agricultural production, limiting the utilization of farmland. Therefore, an in-depth study of the characteristics of ravine formation in arsenic sandstone regions is essential for soil erosion prevention and land management.

5. Strategies for Mitigating Rock-Soil Erosion in Arsenic Sandstone Regions

5.1. Vegetation Restoration

Rock-soil erosion in arsenic sandstone regions causes severe damage to soil resources and the ecological environment. Therefore, effective strategies are needed to reduce the impact of erosion. Vegetation restoration is a crucial measure to slow down the rate of rock-soil erosion by enhancing and restoring vegetation cover. In arsenic sandstone areas, the root systems of vegetation help stabilize the soil, preventing it from being washed away or eroded by water flow. Vegetative cover disperses the impact force of rainfall, slowing down the destructive effects on the soil. Thus, vegetation restoration enhances soil retention, reduces soil erosion, improves soil structure and texture, and increases organic matter content through plant growth and decomposition. Organic matter enhances soil fertility, water retention capacity, and erosion resistance. Additionally, plant roots penetrate the soil, increasing its porosity and improving water permeability, thereby reducing water accumulation and erosion.

Furthermore, vegetation restoration decreases water flow velocity and erosion force. Canopies and leaves of vegetation reduce the impact force of rainfall, slowing down water flow by breaking rainfall into smaller droplets. Plant stems and leaves also act as a barrier, reducing the direct impact of erosion on the soil. Therefore, vegetation restoration is instrumental in reducing water flow velocity and erosion force, contributing to the deceleration of rock-soil erosion. Vegetation restoration in arsenic sandstone regions provides habitats and food sources, promoting the recovery of biodiversity. The root systems and foliage of vegetation stabilize the soil, protect water sources, and maintain ecosystem stability. Vegetation also absorbs carbon dioxide from the atmosphere through photosynthesis.

5.2. Soil and Water Conservation

Soil and water conservation measures help reduce water flow velocity and erosion force, particularly in arsenic sandstone regions characterized by heavy rainfall and intense rainstorms. Constructing soil and water conservation structures such as terraces, contour channels, and ditches can divert water flow into multiple smaller streams, slowing down flow velocity and reducing erosion force. Effective channel measures, such as reinforcement, dredging, and the installation of grooves, can control and utilize water flow more efficiently, reducing scouring and erosion. Given the loose texture and vulnerability of soils in arsenic sandstone areas, these measures also help maintain soil moisture by minimizing surface water evaporation and protecting against rainfall scouring and erosion.

Measures such as building terraces, protective materials, and promoting vegetation cover protect slopes and soils from erosion, preventing the development of gullies. Properly designed channels and grooves guide and control water flow, preventing gully formation and expansion. These measures collectively mitigate soil loss and gully development, safeguarding soil and water resources in arsenic sandstone regions. Soil and water conservation not only facilitate vegetation recovery but also enhance habitat provision and food sources, fostering biodiversity. The stabilization of soil through root systems and increased vegetation cover improves soil fertility and ecosystem health.

5.3. Land Management

Land management involves improving soil structure and quality to reduce the impact of rock-soil erosion. In arsenic sandstone regions, where soils are often loose and susceptible to erosion, adding organic matter, lime, and organic fertilizers can enhance soil structure and stability. This reduces soil loss and erosion. Implementing appropriate cultivation practices, such as deep plowing and planting, improves soil water retention and permeability, enhancing soil resistance to erosion. Land management, by promoting vegetation recovery, ensures that the root systems of plants stabilize the soil, reducing the risk of soil erosion due to water flow. Through effective planting and management, vegetation cover increases, enhancing soil erosion resistance and slowing down erosion rates.

Land management can also incorporate soil and water conservation engineering to prevent rock-soil erosion. Measures like terracing, contour channels, ditches, and dams help slow down water flow, reducing erosion force. By selecting suitable materials and reinforcing channels and grooves, soil erosion and gully formation can be prevented. Land management authorities need to strengthen planning, approval, and supervision of land use, implementing policies and measures for sustainable land governance. Monitoring and law enforcement ensure legal, scientific, and sustainable land utilization.

5.4. Construction of Protective Measures

Building protective measures on slopes in arsenic sandstone regions, such as constructing retaining walls, helps reduce water flow velocity and soil erosion. Retaining walls can be made of materials like stone strips, concrete, or other suitable materials based on the slope's characteristics. In transportation projects, like highways and railways in arsenic sandstone regions, reinforcing embankments can be employed to minimize soil erosion. Methods such as thickening embankments, installing drainage facilities, and using protective nets can be employed. In hilly and mountainous areas of arsenic sandstone regions, rain interception facilities, like shallow and deep ditches and catchment pits, can be implemented to reduce rainfall scouring and erosion. Scientific planning, considering local topography, climate, and soil conditions, is essential before implementing protective measures. Choosing locally available materials, such as stones and cement, for constructing retaining walls reduces transportation costs and enhances protective effects.

During the implementation of protective measures, a series of technical measures, including enhanced monitoring and regular maintenance, are necessary to ensure their effectiveness and longevity. Constructing protective measures effectively slows down soil erosion rates and scales, safeguarding soil resources and the ecological environment. For instance, reinforcing embankments in highway projects can reduce the occurrence of landslides and collapses, improving safety and reliability. Protective measures, like retaining walls, decrease soil and water loss, protect vegetation, and enhance soil retention. Implementing rain interception facilities reduces the impact of rainfall on soil scouring and erosion, improving soil stability and retention.

6. Conclusion

In summary, the geological characteristics and rock-soil erosion effects in arsenic sandstone regions constitute a crucial research topic with significant implications for preserving soil resources and the ecological environment. Through this study, strategies for mitigating rock-soil erosion in arsenic sandstone regions were explored, encompassing vegetation restoration, soil and water conservation, land management, and protective measures. These strategies aim to decelerate the rate of rock-soil erosion, safeguard soil and water resources, and promote the recovery and protection of ecosystems. It is hoped that these measures will contribute to the sustainable development and ecological well-being of arsenic sandstone regions.

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