Environmental Impacts of Moonstone Mining in the Ambalangoda Divisional Secretariat Division with Special Reference to Meetiyagoda and Udakerewa Grama Niladhari Divisions in Sri Lanka

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Abstract

The moonstone mining industry has experienced significant growth in recent decades, driven by increasing global demand for precious gemstones in both jewellery and ornamental markets. Moonstones are a unique and valuable kind of semi-gemstone and a specialised part of the gem mining industry. As Sri Lanka's mining industry grows rapidly, a number of effects are becoming more noticeable. The objectives of this study were to identify the environmental impacts of moonstone mining, identify the moonstone mining locations and detect the causes of environmental impacts of moonstone mining. The desired objectives were achieved using GIS analysis and chi-square test analysis. The study area of this study is the Meetiyagoda and Udakerewa Grama Niladhari Divisions in the Ambalangoda Divisional Secretariat Division. The study assesses the environmental impacts of moonstone mining, focusing on the open pits, vegetation clearance, earth subsidence, and soil changes. The data gathered from questionnaires and interviews revealed environmental impacts caused by human negligence and weaknesses in the legal proceedings. Seven active mining locations can be identified in the study area, and all active mining locations are expanded linear distribution pattern. The findings offer potential implications for sustainable mining activities in the study area.

Keywords: Moonstone, Mining Industry, Mining Locations, Environmental Impacts, Meetiyagoda & Udakerewa Grama Niladhari Divisions

INTRODUCTION

In the current global economic landscape, people are engaged in various sectors due to increasingly competitive economic conditions. Natural resources are spread on the Earth's surface as both depleting and non-depleting resources. The relationship between humans and the environment is imperative. Human existence depends significantly on the environment, while human actions also impact environmental sustainability. Human contribution to the existence of the environment is also important. With the increase in population, human needs also exceed the limit. At present, many resources are rapidly depleting, and their ability to be used has decreased. Excessive exploitation of natural resources adversely affects both humans and the environment.

Sri Lanka, a developing nation in South Asia with an area of 65,610 square kilometres, is currently transitioning from a predominantly agrarian economy to an industrial one. It is apparent that Sri Lankans, who were accustomed to an agrarian way of life, are noticing a particular affinity towards the industrial sector in the present. An industry is a group of competitors producing substitutes that are close enough that the behaviour of any firm affects each of the others either directly or indirectly (Porter M., 1979). Employment possibilities have been distributed unevenly throughout the primary sector, industrial sector, and service sector in every nation in the world. Most of the developing countries in the world are still based on primary sector employment opportunities. However, it is clear that several of the world's developed nations are focused on the industrial sector. Most developed nations only contribute to the industrial and service sectors, excluding the primary sector. An unequal distribution of employment opportunities can be identified in the primary, industrial and service sectors in the world. It is noteworthy that Sri Lanka's economy, which previously relied on employment in the primary sector, is currently leaning towards the industrial sector.

In Sri Lanka, various challenges such as land constraints, transportation issues, human resources, and raw material

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availability have led to anomalies in industrial expansion. These factors contribute to the uneven geographical distribution of industries, including those related to mining and quarrying.

The mining and quarrying sector in Sri Lanka consists of three main sub-sectors. These are: Quarrying of Stone/Granite, Sand, Clay and Soil, Mining of Gems and Other Mining and quarrying not Elsewhere Classified. Mining of Gems plays a prominent role in earning foreign exchange for the country. According to the Central Bank data (2021), mining and quarrying contributed 2.1% of Gross Domestic Product (GDP). Its growth rate represented 2.8% in 2021. Most people only know about the gem industry. In addition, the moonstone industry also exists in Sri Lanka. It is also distinctive that it is a prevalent industry mostly among foreigners. The moonstone industry in Sri Lanka was identified during the colonial period. Moonstone has a high value as it is not a common resource that is widespread in the world. Since the distribution is very less, the people who know about the moonstone industry are also few. The Central Environmental Authority (CEA), Geological Survey and Mines Bureau (GSMB) and National Gem and Jewellery Authority (NGJA) are significant government institutions in these mining activities.

Moonstone is a sub-variety of orthoclase feldspar, which is a metamorphic rock composed of sodium, potassium, aluminium, and silicate. It is known for its optical phenomenon called opalescence, which makes it highly attractive and valuable. The moonstones are currently sold at a range from one hundred rupees to ten thousand rupees (Divisional Secretariat Office, 2023). Moonstone can be found in some regions of the world. Consistent with the International Gem Society, the world's largest moonstone was discovered at Kilimanjaro in 1918. It was said to be between 300 and 450 carats in weight. The size of this moonstone may be the largest ever recorded.

Moonstones are a very attractive and relatively valuable mineral. It is known as ‘Sandakan’ in Sinhala, ‘Moonstone’ in English and ‘Chandrakantham’ in Tamil. It commands a significant share of the world market for precious and semi-precious stones. Sri Lanka is recognised as one of the leading global producers of moonstone. However, its distribution is geographically limited. In particular, Meetiyagoda and Udakerewa Grama Niladhari Divisions (GNDs) of the Ambalangoda Divisional Secretariat Division (DSD) in Galle district. This area is located about 9 kilometres from the Hikkaduwa tourist area. The moonstone mining industry has existed for more than a century in this area. These stones are called moonstone because of the belief that they are associated with the moon. It is believed that the rays of the moon fall directly on the ground in this area, and these minerals originate as a result of that impact. Initially, moonstone was discovered with kaolin clay mining and later gained the distinctive attention of foreign traders. In nature, there are blue and white coloured stones. They have a brilliant appearance and are frequently used to create silver jewellery. The value of a moonstone is determined by its weight and colour. More coloured and more weighted stones are more expensive. In this location, moonstone was found when kaolin clay was being dug out. In the past, only the kaolin deposit was recognised, and those who carried out the excavation discovered a unique kind of stone. After it was determined to be moonstone, people started paying attention to those excavations. The moonstone mining industry, which began in that way, is still active today. The Moonstone mining site is around ten feet long and five feet wide. The mining site is excavated at a rate of about three feet per day. The mining site is divided into two parts. After the excavation of the mine to a limited depth is done, cross-cutting of the dona starts. In carrying out mining activities, soil collapse occurs in the interior of the mine (Field Survey, 2023). To reduce that condition, coconut shoots, Wire Fern (Dicranopteris linearis) and Bovitia (Melastoma malabathricum) are used. Modern electric equipment is used to supply light and air inside the mining site. Specific buckets and trowels are used to bring the clay-bearing moonstone to the ground. Excavating in mines on rainy days is risky. Due to this, the minimum level of the number of employees can be seen in the current period. The majority of the mines in this region are currently owned by private owners, despite the fact that they were mostly operated by the government in the past. Despite the economic importance of moonstone mining in the study area, there is a lack of comprehensive research on the environmental impacts and the sustainability of the mining practices. The environmental impacts of moonstone mining in the study area have become a significant concern due to the rapid expansion of mining activities in recent years. While moonstone mining has been a traditional source of livelihood for local communities, its unregulated growth has led to severe environmental consequences. Open pits, vegetation clearance, occurrence of earth subsidence and soil changes are key environmental issues arising from the mining process in the study area.

Therefore, this study aims to investigate the environmental impacts of moonstone mining in the Meetiyagoda and Udakerewa GNDs of Sri Lanka. By understanding the extent of environmental degradation and exploring sustainable mining approaches, the research seeks to contribute to a more balanced and responsible utilisation of this valuable natural resource.

Objectives of the Study

Currently, mining-related activities are the main concern in Sri Lanka. There were no moonstone mining locations in Sri Lanka except Meetiyagoda and Udakerewa GNDs in Ambalangoda DSD. The main objective of this study is to identify the environmental impacts of moonstone mining in Meetiyagoda & Udakerewa GNDs in Ambalangoda DSD. The minor objectives are to identify the moonstone mining locations in Meetiyagoda & Udakerewa GNDs in Ambalangoda DSD and to detect the causes of environmental impacts of moonstone mining in Meetiyagoda & Udakerewa GNDs in Ambalangoda DSD. Some kinds of analytical techniques are used to achieve those objectives in the study.

As environmental impacts are studied mainly, it is important to take measures to minimise those negative impacts. For that, this study is important for policy formulation to minimise those effects in future. It can also be used to manage risks and raise awareness, and focus people’s attention, as the study focuses on environmental impacts.

LITERATURE REVIEW

A number of studies on mining-related activities have been carried out by local and foreign researchers, but there have not been enough studies done on moonstone mining and its environmental effects globally and Sri Lankan context. Hazen et al. (2008) conducted a comprehensive study on mineral evolution, highlighting how a combination of physical, chemical, and biological processes influences the mineralogy of terrestrial planets over geological time. Their research introduced the concept of mineral evolution as a series of stages driven by three primary mechanisms: planetary accretion and differentiation, tectonic and geochemical processes, and biological activity. Currently, over 4,300 mineral species are known on Earth, with approximately 50 new species discovered annually. The authors aimed to understand the patterns and causes behind the increasing diversity and distribution of minerals throughout Earth's history by analysing key transformations in mineral assemblages linked to planetary changes.

In a related regional study, Kaphle and Einfalt (2014) explored the prospects for mining precious and semiprecious stones in the Nepal Himalaya, an area known for gemstone occurrences spanning more than six decades. Prominent among these are ruby, sapphire, and topaz, with additional deposits of tourmaline, aquamarine, amazonite, gahnite, danburite, kyanite, garnet, epidote, amethyst, citrine, smoky quartz, agate, jasper, and transparent rock crystals (Kaphle, 2011). The study emphasises that Himalayan gemstones are in high demand in international markets, often preferred by collectors and buyers for their uniqueness. Mining operations, primarily situated in remote and underdeveloped regions, have contributed to local infrastructure development, improved living conditions, and economic contributions to Nepal's gross domestic product.

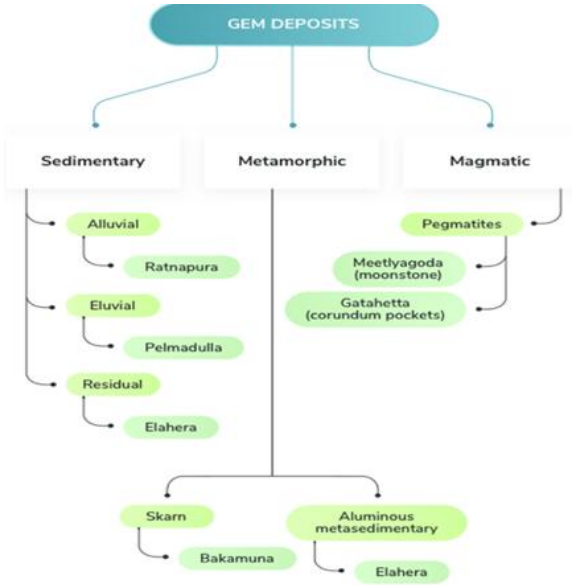
Kanazawa and Kamitani (2006) examined the global distribution and resource potential of rare earth minerals, noting their uneven geographical availability. Their study indicated that in 2003, the majority of the world's rare earth production originated from China, India, Malaysia, and Sri Lanka. The researchers identified and described key rare earth deposits, including the Bayan Obo Deposit in China, the Mountain Pass Carbonatite Deposit in the United States, the Mount Weld Carbonatite and Placer Deposits in Australia, and the Ion Adsorption Clay deposits in China. While mining activities have increased in recent years, the study also highlighted growing environmental concerns related to chemical extraction processes, necessitating a more sustainable approach to rare earth mineral exploitation.

Dissanayake and Chandrajith (1999) investigated the geological link between Sri Lanka and Madagascar within the context of the Gondwana supercontinent, providing evidence for a Pan-African mineral belt. Their research delineated three major lithotectonic units in Sri Lanka: the Highland Complex, the Vijayan Complex, and the Wanni Complex. The Highland Complex includes supracrustal rocks derived from the former Highland Series, while the Vijayan Complex to the east consists of biotite-hornblende gneisses, metasedimentary bands, and charnockitic gneisses. The Wanni Complex is characterised by amphibolite to granulite-facies rocks, pelitic to semipelitic metasediments, granitoid gneisses, and charnockitic intrusions. This study contributes to the broader understanding of the geological continuity between Sri Lanka and other Gondwanan fragments, particularly Madagascar.

Jayasinghe (2019) provided an in-depth overview of gem resources in Sri Lanka, emphasising the country's long-standing history and geological suitability for gem mining. According to the article, approximately 20% of Sri Lanka's total land area has been identified as viable for gem mining activities. This highlights the significant economic and cultural role that gem resources continue to play in the country, reinforcing Sri Lanka's reputation as one of the world's key sources of high-quality gemstones.

Sri Lanka's high-grade Precambrian metamorphic basement is separated into four major litho-tectonic units: the Highland Complex, the Vijayan Complex, the Wanni Complex, and the Kadugannawa Complex. As well as this study indicated the five major gem fields in Sri Lanka, explicitly, Ratnapura, Elehera, Bibile, Okkampitiya, and Kataragama. Tunnel mining, open-pit deep mining, open-pit shallow mining, and riverbed mining are the four types of gem mining in Sri Lanka. Dissanayake and Rupasingha (1995) proposed a classification scheme for gem deposits in Sri Lanka. It is mainly based on the general classification of three main rock types. According to the classification scheme, gems are based on the source of the deposit. The advantage of genetic classification of gem deposits lies in its predictive value. Identification of such gem features may help locate target areas for detailed exploration.

Figure 1: Gem deposits in Sri Lanka



Source: National gem and jewellery authority, 1995

Zwaan (1982) conducted a comprehensive study titled "Sri Lanka: The Gem Island," offering a valuable synthesis of geological and gemological insights on Sri Lanka, based on his field visits between 1958 and 1981. Throughout this period, he examined several major gem mining localities across the country, using firsthand observations to compile detailed data on the geology, mining practices, gem cutting techniques, and the characteristics of gem materials found in Sri Lanka.

The study aimed to provide an overarching perspective on the geological setting of the island and the distinctive nature of its gem deposits. Zwaan identified key varieties of gem-quality minerals, including blue sapphire, pink sapphire (ruby), yellow sapphire, alexandrite, cat's-eye chrysoberyl, almandine, and hessonite garnets. His research also demarcated the principal gem-bearing regions in Sri Lanka, which include:

- Sabaragamuwa Province: Ratnapura, Pelmadulla, Balangoda, Rakwana
- Central Province: Elahera
- Uva Province: Okkampitiya
- Southern Province: Tissamaharama (Amarawewa, Kochipadana), and Ambalangoda (Meetiyagoda)

Zwaan's work remains a foundational reference in Sri Lankan gemology and underscores the country's global significance in the gem trade.

Nakagawa et al. (2017) focused on the kaolin deposits of Meetiyagoda in southwestern Sri Lanka, aiming to investigate the geological environment, mineral associations, and physical properties of the kaolinite found in this region. The study utilised field investigations to collect representative clay samples, which were later analysed using X-ray Powder Diffraction (XRD) and Scanning Electron Microscopy (SEM) techniques.

The research highlighted the uniqueness of Sri Lanka's south-western coastal clay deposits, especially the kaolin (commonly referred to as China clay or ball clay), which has significant industrial value, particularly in ceramics. The study also found that the kaolinite in swampy conditions may have undergone partial recrystallisation. Notably, the research also included observations on moonstone mineralisation within the same geological setting, adding to the understanding of the area's broader mineral diversity. The findings complemented earlier works by Herath (1985) and Fernando (1986), affirming the economic and mineralogical importance of kaolin in Sri Lanka.

Mensah et al. (2015) conducted an in-depth study on the environmental impacts of mining activities in the Prestea region of western Ghana. Ghana, recognised as the second-largest gold producer in Africa, has experienced significant environmental challenges due to its mining sector. The study employed SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis to interpret the collected data.

The research identified critical environmental consequences of mining, including deterioration in water quality, ecosystem and vegetation loss, soil contamination, and degradation of land resources. The study also examined underlying factors contributing to persistent environmental degradation, such as weak regulatory enforcement and unsustainable mining practices. The authors concluded that mining, though economically beneficial, has caused widespread ecological damage in the region.

Jain (2013) investigated the environmental degradation caused by open-cast mining activities in the Bundelkhand and Gwalior regions of Madhya Pradesh, India. The study emphasised both direct and indirect environmental impacts, including land degradation, air and water pollution, noise pollution, and aesthetic deterioration.

Key issues identified include the improper disposal of quarry waste (overburden and weathered rock), which leads to land degradation and siltation in agricultural fields. Furthermore, toxic substances used in blasting operations were found to contaminate groundwater sources, rendering them unsuitable for human use. Slurry discharge from processing plants was also noted to negatively affect surface water bodies, leading to further environmental stress.

The study underscored the pressing need for environmentally responsible mining practices to mitigate the long-term ecological effects of mineral extraction.

Environmental pollution causes short-term as well as long-term damage to the ecological balance, leading to environmental pollution. Land pollution is one type of environmental pollution that occurs as a result of excessive resource use. For a long time, land pollution has degraded the Earth's surface. The amount of damage caused by mining is the same whether it is done on a large or small scale. The majority of land issues have arisen in riverine areas as a result of gem mining activities along rivers. Changes in the Earth's surface are caused by deep excavations, shallow excavations, open pit excavations, and river-bed excavations (Katupotha, 2015). Rupasinghe and Cooray (1993) have discussed the environmental damage caused by common gem mining methods. These are the methods: Morphological Damage to Land Areas, Damage to Vegetation Cover, Damage to Forests, Damage to Fauna, Damage to Stream and River Banks, Sedimentation and Water Pollution. Jayawardhana and Udawattha (2022) have studied the Environmental Repercussions of Gem Mining in Sri Lanka. Researchers aimed to identify through this study the environmental impacts of gem mining activities in Sri Lanka and to analyse the methods employed by Sri Lankan gem miners in order to ascertain the environmental impacts of gem mining and to come up with solutions to mitigate those effects. Researchers collected data from observations and discussions. A narrative analysis of qualitative research was used as a data analytical method in this study. The contamination of water, soil erosion, deforestation, loss of soil nutrients, and destruction of animal habitats environmental impacts were noted as a result of this study. The three main mining methods used in Sri Lanka for this study were used, and the impacts on the environment of each method were also determined. Through this study, it has also been deliberated on how to reduce the negative impacts on the environment due to the mining industry. Cardenas-Moller et al. studied the Sustainable Development of the Latin American Mining Industry. Their aim was to identify the social dimension of sustainable development regarding the Latin American mining industry. They divided this study into two sections. Under the first section, they discussed the sustainable issues associated with mining and the community in Latin America. Under the second section, they introduced practical approaches and solutions to identified sustainability issues, and addressed the role of mining companies and governments regarding the sustainability of the Latin American mining industry. In this study area, there have been changes in the mining activities due to different reasons. Accordingly, this study explained that the living conditions of the people around the

traditional mining areas have also changed. The Peru Royalty was initiated at a rate of 20% in 1996, and it was increased to 50% in 2001 for the mining activities. Researchers identified a large concern in relation to the economic benefits of mining in Latin America. They identified that mining companies benefited more than the local community. With the expansion of mining activities, the population of the study area also increased. With that, there were some cultural issues like a lack of adequate housing and infrastructure for migrant workers, differences between the behaviour and lifestyle patterns of migrant workers and the local community, increased prostitution and related venereal diseases and increased problems due to differences in payments between migrant workers and the local community. Under the second section of this study, researchers discussed the practical approaches and solutions. The approaches and solutions they identified were as instruments and Procedures for the Communities to exercise their Rights (including Environmental Impact Assessments, Management Plans, Remediation/Prevention Plans), used Tri-directional Dialogue, used Community Decision-Making Model, and the need for communication between mining companies, local community, and local authorities was pointed out.

Iamsupa et al. (2016) conducted a comprehensive study titled "Gemological Characteristics of Moonstone from Sri Lanka", with the primary objective of examining the gemological properties, spectroscopic features, and chemical composition of Ceylon moonstone. Additionally, the study aimed to understand the structural features responsible for the optical phenomenon of adularescence. Samples were collected from the study area and subjected to a range of analytical techniques.

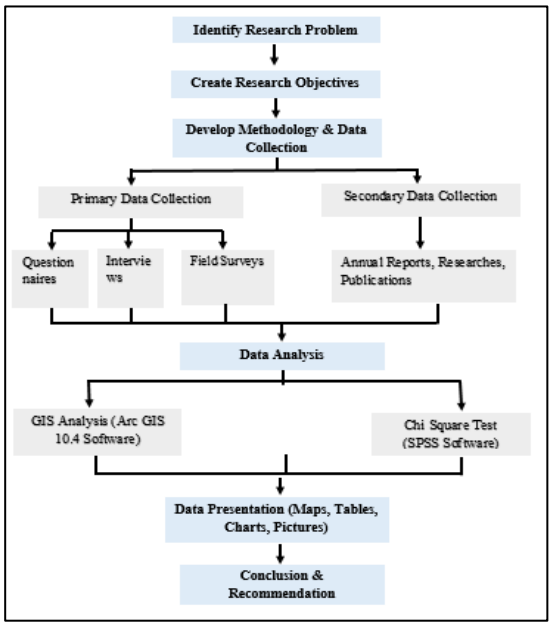
Petrographic analysis and scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) were employed to investigate the submicroscopic features, including the nature of perthite. Chemical composition was determined through X-ray fluorescence (XRF) analysis, providing insights into the elemental makeup of the samples. The findings highlighted key gemological properties and clarified the role of perthitic structures in generating adularescence.

In contrast, Kitula (2004) examined the environmental and socio-economic impacts of mining on local livelihoods in Tanzania, focusing on the Geita district. Using a mixed-method approach, the study collected both primary and secondary data. Primary data collection techniques included participatory rural appraisal (PRA), participant observation, and formal and informal surveys. Data analysis involved statistical tools such as analysis of variance (ANOWA) and Chi-square tests, supplemented by field investigations. This research emphasised the socio-economic consequences of mining activities, highlighting implications for sustainable development.

The growing demand for moonstones in the global jewellery market has brought increased attention to the moonstone mining industry. However, research on this sector remains limited, particularly regarding the challenges and opportunities associated with sustainable practices. Existing studies have not sufficiently explored technological innovations such as automated mining or environmentally responsible extraction methods that could mitigate ecological damage. Additionally, issues such as market volatility, supply chain transparency, and ethical sourcing remain understudied. Although Sri Lanka is renowned for its gem mining heritage, there is a notable gap in the literature specifically addressing moonstone mining in regions like Meetiyagoda and Udakerewa GNDs. Future research focusing on sustainable technologies and supply chain governance is critical for enhancing the long-term viability and ethical standards of this industry.

MATERIALS AND METHODS

Figure 2: Methodology chart



Source: Developed by author, 2023

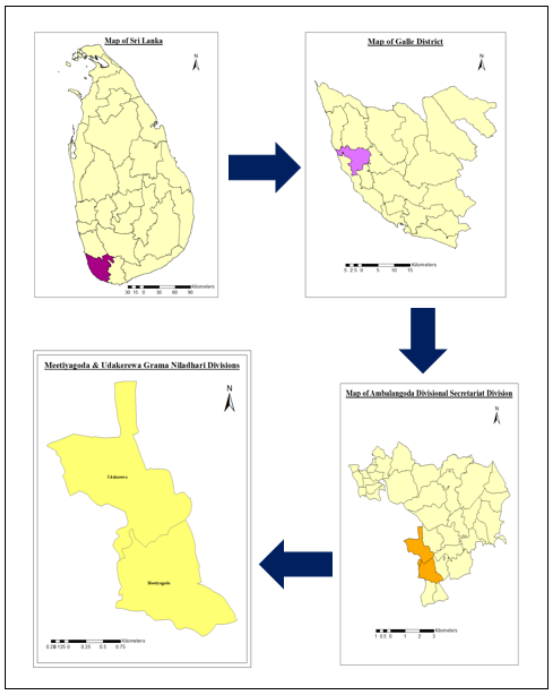
Study Area

Ambalangoda is one of the major towns of the Galle District in the Southern Province. 3.5% of the total land area of the Galle district belongs to the Ambalangoda DSD, and it consists of 5200.1 hectares and 36 GNDs (Divisional Secretariat Office, 2023). The relative location of the Ambalangoda area borders Balapitiya DS from the north, Karandeniya and Baddegama DS from the east, Gonapinuwala DS from the south-east and the Indian Ocean from the south and west. The absolute location of the Ambalangoda DSD is between 6° 03`N to 6° 14`N latitude and between 80° 03`E to 80° 10`E longitude. The total area of the study is 366.6 hectares. 171.1 hectares belong to Meetiyagoda GND, and 195.5 hectares belong to Udakerewa GND (Divisional Secretariat Office, 2023).

Only the central part of the Ambalangoda DSD is slightly elevated, and all other zones are plain. The highest zone of the division is not more than 300 feet. The entire region covers a total of 0.8% slopes. Based on the existing land condition in the area, physical as well as human activities have been well spread. The study area belongs to the lowland wet zone. Hence, there is significant rainfall throughout the year. The expected rainfall is 1,575 mm. The probability of rainfall of this amount is higher than 75%. The geological survey of the entire region reveals that it is composed of prehistoric Cambrian rocks. That is about 600 million years ago. Red Lateritic soil and Quartz Red Yellow Podsol soil are prevalent throughout the area. This soil

covers about 60% of the total land area. Thereafter, mainly Half Bog soils and Bog with Alluvial mixed soil cover 33% of the land area (Divisional Secretariat Office, 2023). Although these are widely distributed, other categories do not represent such an important distribution. In terms of mineral resources, two types that are endemic to both GNDs can be identified: Kaolin Clay & Moonstone Rocks. Blue and white moonstones can be found in this area. Those are a rare species of gem. These moonstones contain three minerals that are Silicon, Calcium and Phosphorus.

Figure 3: Location of the study area



Source: Developed by author based on 1:50000 digital data, Survey Department of Sri Lanka, 2018

Data Collection Methods

Both primary and secondary data collection methods were used to collect data in the study. This study also used both qualitative and quantitative data. This study is mostly based on primary data. There has been no proper institutional data update on moonstone mining in the country. The data required for the study are collected based on the respective industry in this area and the Ambalangoda DSD. In order to obtain the primary data, three main methods, questionnaires, interviews and field surveys were carried out. All primary data collection methods were used to prove the environmental impacts of moonstone mining in the study area. Field surveys, points of GPS locations data and 1:50000 digital data were used to identify the factors affecting the locations of moonstone mining. Questionnaires and interviews were used to identify relevant causes of the environmental impacts of moonstone mining.

100 people were selected as the sample for intentional, and the sample is divided into 45 each for both GNDs and 10 for relevant government officials. The 10 government officials are used to get details, including two GN officers, two Development Officers (DO), two officers of the NGJA and four officers of the DS office, including the planning unit and land unit. Out of 100 people in the sample, 40 people representing both GNDs were used to get the data by using the questionnaire. The researcher gave 25 questions per questionnaire to one person in the sample for 40 questionnaires. 60 interviews were conducted here. There, 30 people from Meetiyagoda GND, 20 people from Udakerewa GND and 10 people representing government officials were interviewed. Informal discussion was used as the interview method to collect data. This sample was randomly selected. Field surveys were more important to verify the accuracy of the collected primary data. The participatory field survey method was directly used here. Since this study primarily aimed at environmental impacts, it was more appropriate to use field surveys. 1:50000 digital data from the Survey Department of Sri Lanka in 2018 was used to create the maps in this study. Previous research, annual reports and publications were used to collect secondary data. Environmental impacts, locations of moonstone mining and industry and government regulations were identified through secondary data.

Data Analytical Techniques

The data which were collected from both primary and secondary methods were analysed using the ArcGIS 10.4 software, SPSS software and MS Excel 2013 office package. GIS visualisations were done using ArcGIS 10.4 software. GIS and GPS were used to create the study area map and the map of mining locations in the study area. A map of mining locations was created based on the GPS points obtained in the moonstone mining sites during the field surveys. GIS visualisation was used to identify the factors affecting the locations of moonstone mining. Descriptive statistics analysis can be described as a method used to analyse the primary data obtained. SPSS software is used to execute this analysis. The chi-square test method is used to show whether there is a relationship/or no relationship between mining activities and environmental impacts in the study area. The study is based on the Pearson chi-square test. This analytical technique was used to prove how the moonstone mining impacts the environment in the study area. For chi chi-square test to be proven, the P value must be less than the Chi value. The following hypotheses were formulated, and the objectives were achieved relevant to this study.

- There is no relationship between moonstone mining activities and their environmental impacts.
- There is a relationship between moonstone mining activities and their environmental impacts.

Maps, tables and charts were used to present the data, which was analysed. Maps were used to illustrate the study area and the location of the moonstone mining. Tables were used to present the data in a concise and easily understood manner. Graphs were used to visually represent the data obtained from interviews and questionnaires. The data obtained from the community knowledge was represented through charts. Images were used to present data obtained from field surveys.

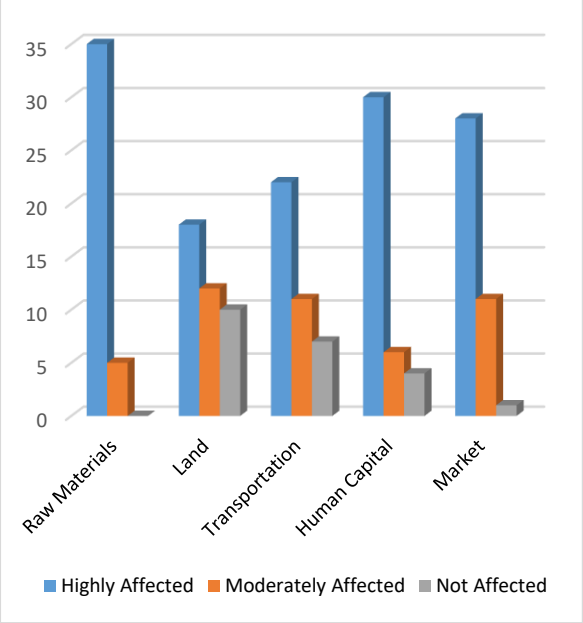
RESULTS AND DISCUSSION

Factors Affecting the Location of the Moonstone Mining Industry

There were some factors that determined the location of the industry, according to the interviews and questionnaire survey carried out to collect data regarding factors affecting the location of the moonstone mining industry in this area.

The factors that have the greatest influence on where the moonstone mining industry is located are: availability of raw materials, land, transportation, human capital and market. Based on the questionnaire, findings revealed that 87.5% of the participants identified the availability of raw materials as a significant factor influencing the expansion moonstone industry in the study area. 75% of respondents emphasised the importance of human capital, 70% highlighted the role of the market, 55% highlighted transportation as a factor, and 45% acknowledged the influence of land on the expansion of the moonstone industry. The data show that the main driving forces behind where an industry is located are raw materials, human capital, and the market.

Figure 4: Factors affecting moonstone mining in the study area



Source: Questionnaire survey, 2023

Mining industries are definitely based on raw materials. Therefore, it is a crucial factor in determining the location of the mining industry. The mining industry must extract the materials from the mining site. Only stones are not extracted in this industry; instead, clay with stones is mined together in a systematic way to obtain moonstones. Moonstones are not widely spread in the world, but only a few locations allow for the identification of certain moonstone types. The uniqueness of this study area is that it is the only location in the world where moonstones are excavated from Sri Lanka. This is the main reason this industry is limited to this area.

In particular, for the mining industry, human capital is a crucial consideration when choosing an industrial location. Because of this, this industry needed a labour force. Any industry that is situated in a region with low labour power will undoubtedly fail. For the moonstone mining industry, a better understanding and awareness are essential. It is common to inherit that knowledge. In addition to moonstone mining and the jewellery manufacturing sector also needs human capital. Even if only a small amount of machinery is used, it still requires labour to operate. Transportation is one of the major infrastructure elements that determines where an industry is located. The study area has a developed transportation system. Additionally, there has been a significant improvement to the road system. Due to easy access to moonstone jewellery showrooms, its market is also strong. The distance between the study area and the Hikkaduwa tourist area is about 10 kilometres. Additionally, being able to quickly reach the Kurundugaha and Baddegama interchanges of the Southern Expressway has assisted in promoting the moonstone mining industry. Another important factor is the market. Especially, this industry is aimed at the international market. In here, there are no specific international buyers. Interview data revealed that almost every tourist who comes to witness this industry in this area brings some kind of jewellery. There are almost no market opportunities for this industry in Sri Lanka. Supply must meet demand, and demand must meet supply, both of which are essential for any industry. The market for the moonstone industry is virtuous. In the foreign market, there is a large demand for moonstone jewellery. The market for this industry experiences little disruption because foreign tourists frequently travel to the southern tourist areas, including Hikkaduwa, making it simple to keep it at a steady level.

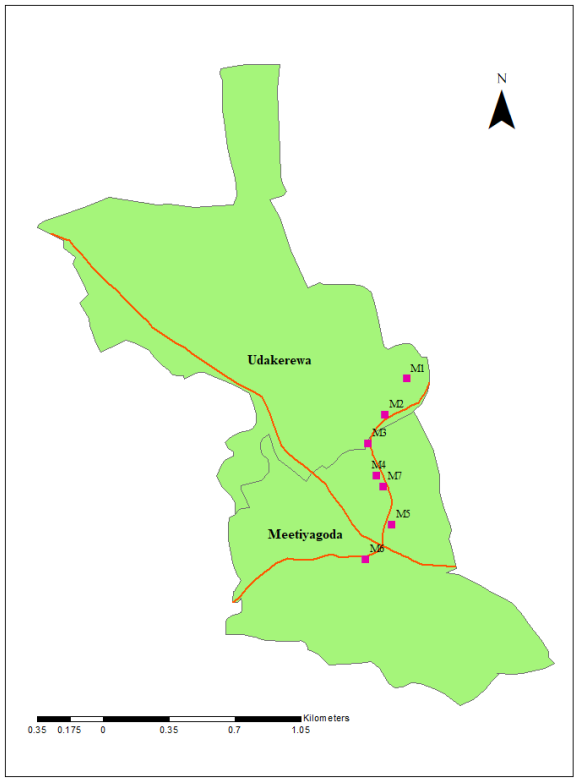
According to the questionnaire and interview surveys, there were currently no illegal mining pits, and all of the ones that were there were legal in the study area. An average depth mine is around 80 feet (Interview and Field Survey, 2023). There were some abandoned mining pits that could be found in this area. But Figure 03 represents the active mining pits in the study area. This area contains seven moonstone mining pits. The map was created based on the data obtained by GPS coordinates during the field surveys. Along with those mining pits, a jewellery store has been established nearby. A unique pattern can be seen that almost all the mining pits in the study area are located on both sides of the main road in this area. Five mining locations were located in Meetiyagoda GND, and two mining locations were located in Udakerewa GND. A linear distribution pattern can be detected in the study area.

Table 1: GPS values in the moonstone mining locations

Name	Latitude	Longitude
M1	6° 11` 53"N	80° 5` 52"E
M2	6° 11` 47"N	80° 5` 48"E
M3	6° 11` 42"N	80° 5` 45"E
M4	6° 11` 36"N	80° 5` 47"E
M5	6° 11` 28"N	80° 5` 49"E
M6	6° 11` 22"N	80° 5` 45"E
M7	6° 11` 35"N	80° 5` 48"E

Source: Field surveys, 2023

Figure 5: Moonstone mining locations (active) in the study area

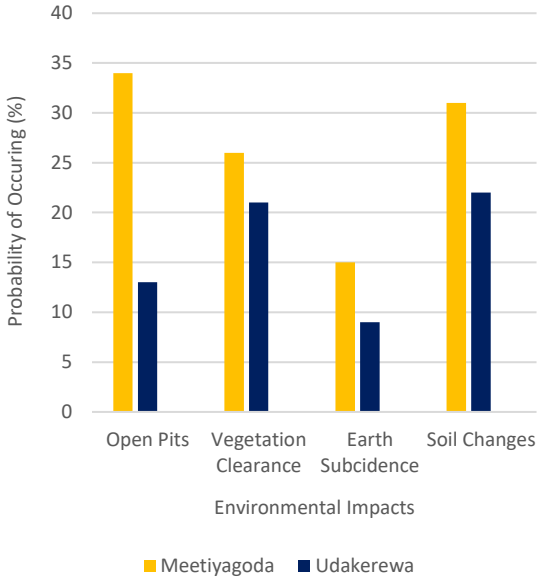


Source: Developed by author - Survey Department of Sri Lanka, 2018 & field surveys, 2023

Environmental Impacts of Moonstone Mining

The global implications of mining on the environment are a significant issue of concern. Mining affects water, soil, air, wildlife, human habitat, agricultural land, water courses, forest land, and recreational land. Mining creates noise pollution, dust, disturbance due to truck traffic, sedimentation and erosion, land subsidence, and vibration from blasting (Sengupta, 2021). Environmental Impacts of Mining: Mining and the Environment. The need to use more resources has increased along with human needs. Although moonstone can be found in some areas in the world, orthoclase-type moonstone can only be found in the study area of the world, which makes it unique. Since the moonstone industry has existed in this area for a long time, its influence is also growing. Moonstones do not recur, so they are not a renewable resource. Some claim that it has almost entirely vanished at this time. 70% of the respondents reported moonstone depreciation at this time. Because there was a greater need than there is moonstone, mining continues. This had a number of negative effects on the environment. Moonstone mining makes a number of environmental impacts, such as the problem of open pits, vegetation clearance, and the occurrence of earth subsidence and soil changes. Based on the informal discussions, 78% of respondents reported that they were at risk of open pits and vegetation clearance each, 40% of respondents reported that they were at risk of earth subsidence, and 88% of respondents reported that they were at risk of soil changes in both GNDs.

Figure 5: Environmental impacts due to the moonstone mining industry



Source: Questionnaire survey and interview, 2023

Open Pits

H_0 – There is no relationship between the occurrence of open pits and the moonstone mining industry.

H_1 - There is a relationship between the occurrence of open pits and the moonstone mining industry.

Table 2: Chi square test: impact of open pits

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-Square	8.473[a]	3	.037
Likelihood Ratio	6.171	3	.104
Linear-by-Linear Association	4.616	1	.032
N of Valid Cases	100		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .77.

Source: Sample survey, 2023

Decision - Since the P value (.037) is less than the Chi value (0.05), the H_0 hypothesis can be rejected and the H_1 hypothesis can be accepted. Accordingly, the moonstone mining industry has an impact on the occurrence of open pits in the study area.

Mining is the main activity associated with the moonstone mining industry. In that case, it is essential to get permission from the NGJA in Sri Lanka to start the excavation in a mine. Although the institution responsible for mining activities is the GSMB, since moonstone is a semi-gem, all its activities are under the control of the NGJA. Only after taking into account every requirement of the owner and the concerned area is a mining license granted. To the owner who is concerned that permission has been granted to dig a mine, a legal license is issued. An average moonstone mine is only used for about 5–6 years, compared to a mine's maximum useful life of about 7-8 years. The rotted wood that was used in the mine is the primary cause of this. After using the mine, the owner must refill the old mine before beginning the new

one. Without such closure, the NGJA will not get permission to start mining again, and the license will not be issued.

But there were currently a number of issues with the moonstone mines. The main problem was not to fill the mine again. As a result, some unfilled mines can be found in the study area (Interview, 2023). Due to this, mine owners have stopped investing in this sector of the economy, and there aren't enough raw materials to fill the mine. The fact that only 35–40% of a dug hole can be filled using the leftover materials from the clay extracted during moonstone excavation is a problem (Divisional Secretariat Office, 2023). The fact that these excavations' open pits were never filled in causes long-term issues. Those open pits in the area eventually turn into inland freshwater ponds. Furthermore, the accumulation of water for an extended period of time due to non-use poses a risk of disease transmission. The risk of diseases like dengue is also increased by the presence of open pits (Questionnaire Survey, 2023). The mine has been refilled, and the surrounding area forested as well. In some cases, it was impossible to tell that an open pit had been abandoned as a result. There were also risks to life, according to the community of the area. Due to depletion of resources and insufficient technical knowledge, some industry owners were already gradually leaving the industry at present (Interview, 2023). They do not fill the previous mining pit because they do not need to apply for a license once more. It developed into an open pit nearby.

Vegetation Clearance

H_0 – There is no relationship between the vegetation clearance and the moonstone mining industry.

H_1 - There is a relationship between the vegetation clearance and the moonstone mining industry.

Table 3: Chi-Square Test - impact of vegetation clearance

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.202[a]	3	.017
Likelihood Ratio	7.754	3	.051
Linear-by-Linear Association	4.948	1	.026
N of Valid Cases	100		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .64.

Source: Sample survey, 2023

Decision - Since the P value (.017) is less than the Chi value (0.05), the H_0 hypothesis can be rejected and the H_1 hypothesis can be accepted. Accordingly, the moonstone mining industry has an impact on the vegetation clearance in the study area.

According to the data obtained from the research sample, it was identified that the impacts on the vegetation cover of the study area due to the moonstone mining industry were increasing. The impact on the vegetation cover has been through several dimensions. Paddy, coconut and cinnamon cultivations were the main agricultural products of the study area.

Vegetation clearance changes were also related to population and development activities in the area. Among these, the main reasons were the use of tree raw materials like Coconut (Cocos Nucifera) wood and Fern leaves (Tracheophyta). in the excavation of a new mine, the clearing of the land for the construction of moonstone jewelry showrooms, the clearing of the land due to settlement of some people who came for work in this area (Questionnaire Survey and Interviews, 2023). Vegetation clearing had an impact on habitat loss and ecosystem processes. Coconut rafters were used to prevent collapses that occur inside the moonstone mine after digging. There, the trunks of the coconut trees were separated into parts and used for that. At least 5-7 coconut trees were used for one mine.

Occurrence of Earth Subsidence

H_0 – There is no relationship between the occurrence of earth subsidence and the moonstone mining industry.

H_1 - There is a relationship between the occurrence of earth subsidence and the moonstone mining industry.

Table 4: Chi-square test - impact of earth subsidence

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-Square	8.190[a]	3	.042
Likelihood Ratio	8.343	3	.039
Linear-by-Linear Association	3.606	1	.058
N of Valid Cases	100		

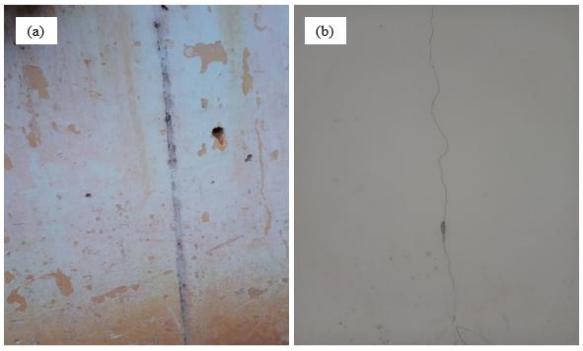
a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 2.40.

Source: Sample survey, 2023

Decision - Since the P value (.042) is less than the Chi value (0.05), the H_0 hypothesis can be rejected and the H_1 hypothesis can be accepted. Accordingly, the moonstone mining industry has an impact on the occurrence of earth subsidence in the study area.

About 30 to 40 feet into the earth, there are moonstones that must be mined. To prevent the mines from exploding, a variety of strategies are used. Many of these techniques are both traditional and specific to the industry. The community of the area believed that the land in the study area may sink in the future as a result of excavations done inside the earth. They claim that as the soil layers in the interior go through different changes, such conditions will start to appear. The Earth's surface received a lot of thrust in locations where mining activities are carried out using large machinery. It influences alterations in the internal conditions of the Earth. Various changes occur inside a mine over the course of the five or six years that excavation activities are conducted there. Although the impact of these cannot be observed from the outside, they can be demonstrated scientifically.

Exhibit 1: Wall cracks of the house in the study area, (a) wall crack of Meetiyagoda GND and (b) wall crack of Udakerewa GND



Source: Field observation, 2023

The walls of some homes in the study area had scratches on them, as observed during the field surveys. One of them stands out for being recently constructed. These cracks were present in some of the houses in the area, according to the data from the interviews. There were 1083 houses in the entire study area, 617 in Meetiyagoda GND and 466 in Udakerewa GND (Divisional Secretariat Office, 2023). This area has a number of structures, including public spaces, businesses, and more. Both property damage and a significant loss of life will result from the future submersion of this area. This circumstance cannot be anticipated to occur anytime soon due to the low probability of earthquakes in Sri Lanka. Since this industry has been operating for a considerable amount of time, it is impossible to make a precise prediction.

Soil Changes

H_0 – There is no relationship between the soil changes and the moonstone mining industry.

H_1 - There is a relationship between the soil changes and the moonstone mining industry.

Table 5: Chi-square test - impact of soil changes

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-Square	11.913[a]	3	.008
Likelihood Ratio	11.013	3	.012
Linear-by-Linear Association	6.936	1	.008
N of Valid Cases	100		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is 2.24.

Source: Sample survey, 2023

Decision - Since the P value (.008) is less than the Chi value (0.05), the H_0 hypothesis can be rejected and the H_1 hypothesis can be accepted. According, the moonstone mining industry has an impact on the soil changes in the study area.

Soil conditions have changed significantly as a result of moonstone mining activities. During the study, a number of conditions, including deterioration of soil structures, instability of soil moisture, decline in soil fertility, and ongoing changes in the soil's top layer, could be found (Questionnaire and Field Survey, 2023). The structure, texture, density, acidity, salinity, and other characteristics of the soil changed as the soil's fertility declined. Mining for moonstone in this area is similar to mining for kaolin clay. These two sectors of the economy have helped make this area more well-known. However, due to the kaolin clay's depletion, there are currently very few kaolin mining activities. There was also a problem with the use of large machines for excavation work in both of these sectors. The use of heavy machinery, such as excavator machines, has also had a major impact on the soil. There was no approval for these mechanical mining activities for every mine, and the NGJA has given permission for mining activities using machines only for the purpose of reducing the risk to lives in the community.

As well as, it was mentioned above that there was a relationship between the clearing of vegetation and the moonstone mining industry. The removal of vegetation had a direct impact on how the soil changed. Circumstances like soil erosion and soil degradation were exacerbated when soil is directly exposed to the air and has no vegetation to protect it in the surrounding areas of Meetiyagoda junction. Despite the fact that mining activities will affect the soil, landslides will not be a risk in this area because it is a plain area.

Exhibit 2: Soil extracted from a mine

Source: Field observations, 2023

Causes of Environmental Impacts of Moonstone Mining

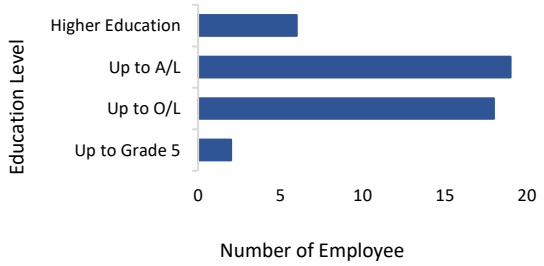
The development of the industry in the study area and the ensuing effects on the environment has been influenced by a number of factors. All mining sites and areas related to mining share these causes. The effects of these causes can be reduced by using proper management.

The moonstone mining industry is governed by a legal framework. It is possible to see that, in some situations, the way that the law is applied has some failings. The primary institution in charge of the mining of gems and semi-gems is the NGJA. The Sri Lanka Police is another responsible institution when it comes to the gem industry in Sri Lanka, but that is unimportant in this situation. This is not the case, as shown by the fact that there are no illegal mining pits in the study area. Mining licenses should be issued by and under the supervision of the NGJA. However, information gathered from interviews indicated that there were times when mining activities were not conducted in accordance with the terms of mining licenses. These are incredibly uncommon cases, in their opinion. It is obvious that there was insufficient legal action taken against excavations that

were carried out in violation of the license's rules and regulations. Responsible government institutions should regularly monitor mining activities and conduct on-site inspections.

The way people act has a direct impact on the moonstone mining industry affects the environment. This is not due to industry participants' ignorance; instead, the impacts are due to their lack of concern. They are unaware that certain circumstances have an impact on the environment, despite knowing this. Because they are not engaged in the industry at present, some people have abandoned the mining pits. It significantly affects the study area. However, the information from the interviews showed that despite their awareness of the impact, they do not give a damn about it. This means that even though the populace is unconcerned with the negative effects of the moonstone mining industry, their level of education is generally high. About twenty-five workers work in one mine. People are reluctant to work in mines because of the risks of the job (Interview, 2023). Those who are employed in the industry are educated to some extent, despite the fact that the education level has no direct bearing on these related employments. Out of 100 samples, 45 people were engaged in industry-related employment. The figure below shows their education level. 4% of people were educated up to grade five, 40% of people were educated up to O/L, 42% of people were educated up to A/L, and rest of 13% of people had completed their higher education.

Figure 7: Education level of people engaged in the moonstone mining industry



Source: Questionnaire survey and interview, 2023

CONCLUSION

This research provides an exploration of the environmental impacts of moonstone mining in Ambalangoda DSD, focusing especially on Meetiyagoda and Udakerewa GNDs. The moonstone mining industry has a significant economic impact, but it also has environmental consequences that need to be controlled. For that, a variety of management strategies could be used, and some actions have already been taken. However, the data obtained from the interviews showed that they have some weaknesses that prevent them from operating effectively. As a result, while some strategies can be applied at the community level, others require direct institutional involvement. A unique feature of this area's moonstone type is that it can only be found in this study area in the entire world. Moonstone is a type of feldspar. It belongs to the orthoclase subtype of feldspar. As a result, there is a significant industry and a high level of demand for this mineral. The finding reveals seven active mining pits that are all licensed legally and are also present in the area. There is a unique pattern to the mine's location in the area. The only locations of the mining pits in the study area are on either side of the main road, all of which are close to the main town in the study area. Additionally, everyone involved in the manufacture of jewellery has a thorough understanding of technical knowledge. The sample surveys indicate that the moonstone mining industry is directly responsible for the negative effects on the environment. The study's findings revealed that it was possible to find open pits, vegetation clearance, risk of earth subsidence, and changes in the soil in the study area. These environmental effects have been caused by the creation of open pits as a result of the mine not being filled in again, the clearing of vegetation due to various industry-related activities, earth subsidence as a result of mining activities being carried out deep to the earth, and the direct impact on the existence of the soil layers. After mining is complete in a legal mine, the mine must be refilled. However, occasionally the mine is not refilled once more. In the study area, the mine is frequently not refilled or rehabilitated, which has had an impact. After a license is granted, a new license is given after the previous mine has been refilled. By focusing deep understanding of the moonstone mining industry in Sri Lanka, the government can develop strategies to navigate the consequences and challenges posed by moonstone mining.

Recommendations

After mining activities, abandoned open pits can become the source of life-threatening situations and the spread of diseases like dengue. Freshwater fish culture ponds can be created in open pits. By doing this, a new auxiliary industry will be established in the area, and by allowing the people of the study area to participate in it, a new source of income will be made available. Reforestation projects can be implemented, and the community of the area should be encouraged to do so in order to stop the destruction of the vegetation cover. At the level of the mining firms in the study area, it is also possible to give the necessary instructions for carrying out those projects. People can also be aware of soil conservation techniques simultaneously with these reforestation programs. It is obvious that the buildings were constructed close to the exciting mines. Building construction should be restricted or avoided for a specific distance away from the mining activities due to the risk of earth subsidence. It is possible that the buildings should be located 150 meters away from the mining pits. A proper implementation of the institutional process relating to mining activities is required. For mining activities, there is a specific legal framework, but it has some weaknesses. Continuous monitoring by the responsible government institutions should be carried out from the start of a mine's excavation to the time it is stopped. Aside from that, it is necessary to update existing rules and regulations or introduce new rules and regulations.

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