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The Effects and Impacts of Quarrying on Forest Land: the Case of Gami Quarries, Mwache Forest, Kwale County, Kenya

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Abstract
This paper highlights the effects and impacts of quarrying on Forest Land, with Mwache Forest, located in the Kwale County, whose land use is defined as conservation –as the study case. Despite the defined land-use, Gami Quarries Ltd had been given the rights of exploiting the rock out-crop in the forest to make ballast –a raw material needed in the construction industry. Ballast processing operations were initiated through blasting the rock structure using explosives inserted onto holes drilled on the rock, disseminating it into boulders that were sized into smaller rocks that were transported for processing into ballast. The explosions resulted into the generation of wave energy that weakened the rock formation and, damaged the existing neighbouring infrastructure; it produced dust and higher levels of noise. Transport of the rock material for processing into ballast, resulted in the emission of fugitive dust due to tracking on the unpaved road. This was in addition to the emission of the oxides of nitrogen and sulphur, carbon monoxide, suspended particle matter (SPM) and, volatile organic compounds (VOCs) from the poorly maintained diesel engine powered tracks. The significance of air pollution from the ballast-making operational processes was low, bearing the wind regime, which scattered and diluted the pollutants. Run-off from the quarry spoils however introduced undesirable elements in water; while lack of sanitation on-site was recipe for transmission of water borne disease. Quarrying for ballast exposed the groundwater aquifer, making it vulnerable to contamination; it at the same time led to the potential of altering the existing drainage characteristics, interfering with stream flow and aquifer recharge. Quarrying created Bad Lands, exposed the bed rock to erosion and reduced the moisture content usually experienced in forested land with impact on local ecology, arising from the destruction of the habitat. The effects of enhanced noise from the blasting operations was traced into hearing loss among the workers; the noise also disturbed wildlife and grazing animals. Fire-outbreaks were also potential due to the explosives use, it could also result from the domestic activities of the workers. Fire outbreak on dry forest could lead to severe and significant effects, including the loss of life. On occupational health and safety matters, the workers have had to do with the consequences of potential exposure to dust, potential injuries from flying blasted rock debri, from the impacts of water borne and, water related diseases and, high levels of noise. To minimize the identified effects and impacts, operating rules had been given. These offered adequate protection. However, it was recognized that the rules and procedures ought to be engraved into an Environmental Management and Monitoring Plan in order to promote sustainability of the actions. This had not been done.
Key words: quarrying, dust, noise, pollution, habitat destruction, water borne and water related diseases, cancer, operating rules and procedures

1. Introduction

Gami Quarries Ltd is a locally incorporated Kenyan Company. The company does business in the construction industry, supplying building materials that range from ballast, concrete blocks to pre-cast products. The Company has been in this business for over 20 years and, obtaining its raw materials from the Mwache Forest in the Kwale County. In its business dealings, the company has operated on short-term contract that encompassed a cycle of five-year agreements, renewable annually within the period upon meeting the conditions outlined in the individual permits and licenses. The regulatory documents, issued by the relevant government departments, specified the valid operating conditions and time at the quarry. Having invested heavily in machinery for its operations, the company sought to obtain guaranteed longer-term quarrying lease agreement periods lasting up to 50 years for the smooth running of its operations, to justify the long-term financing investment made on equipment for the stability of the business. The long term leases would, in addition give the company ample time to utilize the acquired machinery, improving on production capacity and, supporting the creation of jobs and generation of revenue.

The rationale for establishing the quarrying activity was based on a survey undertaken in 1999. The survey established that there was demand for ballast and other assorted building products for the building industry in Mombasa and its environs. The study put the demand for ballast and associated materials at about 800,000 tonnes per year, against an annual production of 500,000 tonnes, leaving a shortfall of 300,000 tonnes. The market demand and profit made from ballast attracted GAMI Holdings to venture into the business, initially targeting to producing 200,000 tonnes of ballast annually. However, as the demand for ballast in particular became particular higher, the company opted to expand its production capacity by purchasing and, installing higher capacity machinery, expanding its storage facilities, workshops and office area.

Expansion of the quarrying activities, created employment both directly and indirect and, contributed to the welfare and overall general well-being of the people. Thus, at the time of this study, the company had in its employment 40 quarry workers and, a further 30 individuals stationed at the crushing and screening sites for ballast production, leading to the operations of the company benefiting about 420 people indirectly. With the expansion plans, it was anticipated that the number of people in employment would double, increasing the number of beneficiaries. Thus, this study came about as a result of an application from M/S Zeus Quarries Ltd (herein re-named Gami Quarries Ltd) to the Director General National Environment Management Authority (NEMA), seeking for renewal of their quarrying license agreement, which in response, NEMA advised that as an on-going activity with a potential to generate impacts on the environment, then, it had to undergo the mandatory environmental audit process to identify the potential impacts on the environment and, to propose measures that minimize them.

1.1 Objectives of the Study

The specific objectives of this study were:

- To generate baseline data describing the environmental setting around the quarry;
- To describe the project activities including their environmental impact;
- To rate the significance of the impacts generated;
- To suggest measures that can minimize the impacts;
- To prepare an Environmental Management Plan, including monitoring schedules to sustain the mitigating measures.

2. Baseline Information

The Gami Quarry is found in the Mwache Forest in the coastal belt 10 km away from Moi International Airport Mombasa. Administratively, the forest is located in Mazeras Sub-location of Kasemeni Location, Samburu in the Kwale County. The forest covers a total area of 417 hectares and, is composed of lowland coastal forest vegetation with open canopy of various indigenous trees and shrubs. The vegetation is rooted on a rock stratum that extends beyond the forest boundaries.

Climatic conditions along the Kenya coast in which the forest is found are influenced by the monsoon winds, characterised by warm temperatures (mean range 23 – 32 °C) and moderately low humidity conditions (mean relative humidity range 59 – 67 %); relatively lower cloud cover (average solar radiation 20.5 – 22.7 MJ m^{-2}) occurs during the NE Monsoon period that blows from November to March. Relatively low temperatures are experienced during the SE Monsoon (mean range 21 – 29 °C), which occurs from May to September. The long rains occur in the inter-monsoonal period, beginning at the end of March and, peaking up in May when more than 60 % of the rainfall occurs. High cloud cover (relatively low radiation ranging from 17.1 – 20.5 MJ m^{-2}) and relatively higher humidity conditions (mean relative humidity range 61 – 86 %) are experienced during this season. Low temperatures prevail in June/July due to the cool winds, blowing from the south. There is a diurnal variation in the relative humidity, attaining the 60 – 70 % range during the afternoon while, rising to 92 – 94 % at night and early morning (UNEP, 1998). Short rains occur in the next transition period between October and November. The Mwache forest area on average receives a mean range of 900 to 1100 mm yr^{-1} of rainfall (Jaetzold & Schmidt, 1983).

The heating of the land surface and sea-land breeze influence the daily variation of wind speed and direction along the Kenyan coastal area. The wind strength drops at night and, early to mid-morning when the wind direction is mainly long-shore. The mid-afternoon sea-land breeze strengthens and blows in a north-westerly direction. Mean wind speeds of between 6.7 and 10.6 knots at 0900hrs and 1500 hours respectively, have been recorded. Low wind speed, blowing in a variable direction at night have been reported GOK (1975). The wind

direction from May to June, is predominantly south to south-westerly, indicating that the relatively stronger SE Monsoon are less influenced by the sea-land breeze in contrast to from December to February, which have a strong westerly to north-westerly component (UNEP, 1998; GOK, 1975). The prevailing climatic conditions play a significant role in the distribution of dust and other particulate matter in the atmosphere.

2.1 Physiography and Geology

In the Mwache Forest Reserve is to be found the Mwache River. This river meanders in a deeply incised course, in the neighbourhood of Mazeras town-ship and, discharges into the Port Reitz creek. The quarry site is located in the high ground immediately to the east of the Mwache river banks. The dominant geological formations in the area are the Mazeras and Mariakani sandstones, which form part of the Duruma sandstone series that are considered to be Mesozoic of the Triassic age. The Duruma sandstone series include the Shimba Grits (grouped with the Mazeras sandstones by Gregory, 1921), Maji-ya-Chumvi beds and Taru Grits. The Duruma sandstones are of sedimentary origin deposited under lacustrine or sub-aerial conditions, with a thickness exceeding 1,000 m. The high ground along the western bank of the R. Mwache within the forest reserve is dominated by the Mariakani sandstones, dipping gently inland. On the other hand, the raised ground along the eastern river bank, where the quarry is located exhibits a predominantly Mazeras sandstone outcrop. It is recognized that the Mariakani sandstones are comparatively more suitable for use as road-metal and, ballast for other construction works and, consequently, they are the more extensively quarried in the Mazeras – Mariakani area. The Mazeras sandstones are however, similarly quarried for the same purpose.

A review of the groundwater supply from boreholes sunk in the Mazeras and Kaloleni areas (depth ranging from 68 – 131 m) revealed that the Mazeras sandstones produced relatively better quality and better yields of water than the Mariakani sandstones. Thus, the Mazeras outcrop was considered to have a better potential for the development of groundwater supplies (Caswell, 1956).

2.2 Soils and Vegetation

Soils of the Mwache forest are developed on the Mazeras sandstone series. These are composed of sandy to loamy, excessively drained to moderately well-drained shallow, very rocky and stony soils of varying texture (Jaetzold & Schmidt, 1983). The forest is found in the Cashew-nut-Cassava zone, whose environ is characterised by a medium cropping season (during the long rain season) followed by a weak and very short cropping season (during the short rain season) (GOK, 1988). Other crops that do well include mangoes, pawpaw, sisal and bixa, while coconut trees have marginal potential.

Mwache Forest is gazetted forest reserve and as such, protected from the development of human settlement. The area adjacent is sparsely populated, which in part, is explained by the marginal nature of the soils. In this marginal area, which is inhabited by the Duruma Community, mixed farming practiced at a subsistence level, with cattle being the traditional repository of wealth. The Mwache forest is therefore an important resource base to the immediate community, providing goods and services. Extractive uses of the forest include provision of poles, timber and thatching material for the construction of traditional houses, harvesting firewood for wood fuel, harvesting of fruits, essential oils, vegetables and grazing of animals. The major non-consumptive use of the forest is honey gathering. The Mwache Forest also hosts the Kaya Mtswakara shrine –a sacred grove used for worship in the tradition of the Mijikenda.

In the forest are to be found some rare and unique species of flora such as *Saintpaulia* spp. (African violet), a rich diversity of plant life, including an abundance of the large *Adansonia digitata* (Baobab), cycads, *Cynometra weberi* (mpingo) and *Luceana leucocephala*. The trees found in the forest have been utilized for medicinal purposes, construction, carving, production of fruits, etc., with some providing multiple uses. The macrofauna enriching the biodiversity of the forest ecosystem include reptiles (lizards, snakes etc.), colobus monkeys, baboons, insects (grasshoppers, crickets etc.), millipedes and centipedes.

2.3 Socio-Economics

Quarrying in the Mwache Forest has provided direct employment opportunities to adjacent residents, roping in a total of 80 individuals -40 at the quarry and, 40 at the processing site. With each employee supporting about 5 dependants in a household, the spin-offs is 400 family members, depending on the quarry activities for their livelihood.

3. Study Area and Methodology

3.1 The Study Area

The Gami Quarry is found in the Mwache Forest, approximately 24 Kilometres from Mombasa on the Mombasa-Nairobi Road. It is located 7 kilometres south west of the Mazeras Town-ship.

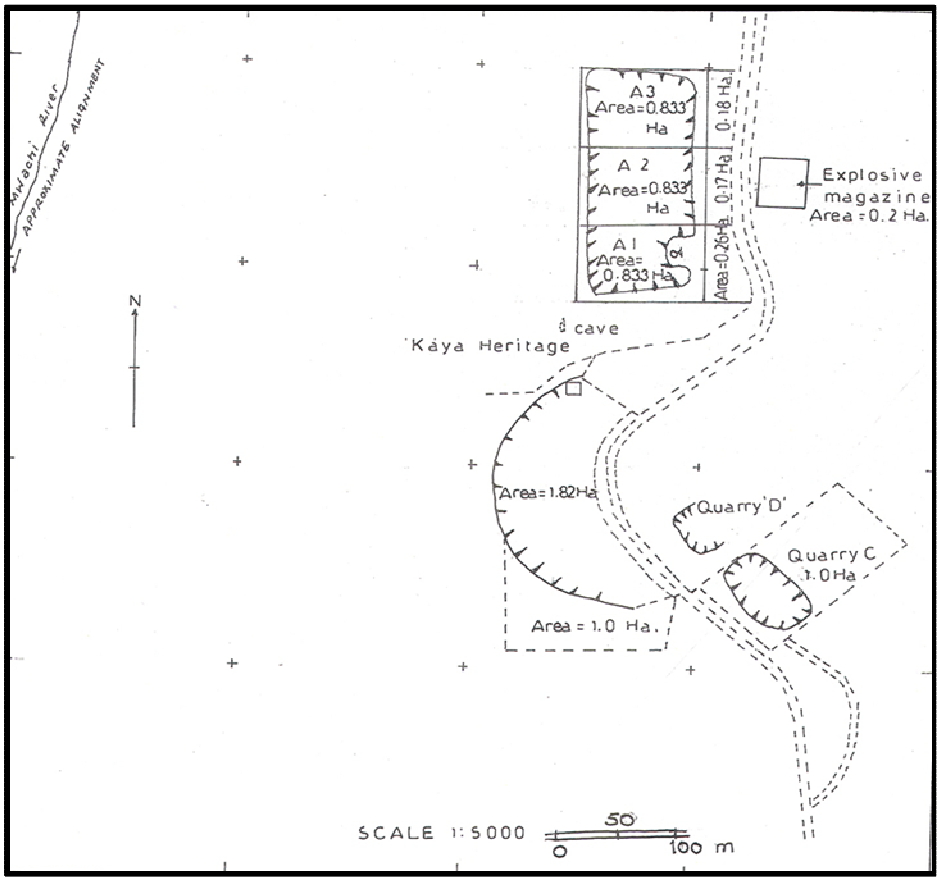

Fig. 1: Location of the Gami Forest

The quarry is divided into three portions and allocated to three licensees. The quarry occupies the high ground on the eastern side of the river embankments. The portion of the quarry allocated to Gami Quarries Ltd is identified as A2 on the map (Fig. 1). It occupies a surface area of 1.0 Ha and has an average height of 20 m. The excavating area is 0.833 Ha with a frontage of 0.22 Ha. It is planned to produce 200,000 tonnes of ballast per year. The company has also been allocated an additional frontage area for the storage of explosives, which it has fenced. Two caves traverse the quarry area with tunnels that are said to reach out into the sea. This cave-tunnel system is held sacred by the Mijikenda tribes of Coastal Kenya and, are used as places of worship and offerings in times of distress. The depth of the quarries which averages about 20 m (Fig. 2) was limited by the preservation of the tunnels, running under the bedrock. Mijikenda elders have no problem with the quarrying activity amidst their shrines as long as their cave system is protected.

Fig. 2: A view of the quarry with baobab trees in the background

3.2 Quarrying Operations

The quarrying equipment at the site includes a compressor for drilling, explosives and blasting equipment. There are six tipper Lorries for transporting the sized boulder rock to the crushing facility located at Mkomani, approximately 30 km away. At the crushing site is a Pegson Jaw crushing machine and screening equipment. The mining process comprised drilling and blasting; removal of the boulders; sizing of the boulders manually to small rock sizes, and; transportation of the sized rocks to the crushing and screening site to produce the several sizes ballast stones required. The Company was licenced to store blasting explosives of classes III and VI, Divisions I, II, and III, including ammonia nitrate for porous drilled, blasting, plain and electrical detonators, safety fuses and igniters of various amounts and lengths in a steel portable magazine of approved design for use in its operations.

The quarrying activities were being carried out subject to the following conditions:

- Quarrying activity to continue subject to the availability of materials in the licensing area;
- Payment of royalties to the government based on the total quantity of material extracted;
- Operate on an annual renewable licensing agreement;
- Conform in all aspects to the provisions of the law, rules, or by-laws applicable to working in quarries;
- Pay land occupancy fees in advance in accordance with the Forest Department General Order in force;
- Provide to the District Forest Officer, Kwale, monthly returns of persons residing in the forest area, showing full identification details;
- Provide guards to man the quarry entrance area on 24 hr. basis;

- Provide the registration numbers and carrying capacity of each vehicle removing stone from the licence area;

Fig. 3: The manual breaking of boulders to small sized stones

- The Licence Agreement was not be assigned, transferred, mortgaged or sub-let without written permission from the Chief Conservator of Forests;
- Adherence to the designated times of operations in the quarry, which are given as from 6.00 am to 6.00 pm;
- Payment of surety bond to the government as security for due fulfilment of conditions of licence by Licensee.

3.3 The Audit Methodology

The Government of Kenya has accorded high priority to the protection and restoration of the environment in its entire development agenda and, the Environmental Management and Co-ordination Act (EMCA), 1999 made it mandatory for all on-going projects whose activities were deemed to potentially generate negative impacts on the environment to be audited annually to ensure that their operations are in compliance with the law. It was also to ensure that an Environmental Management and Monitoring Plan (EMMP) would be developed to ensure sustainability of the mitigation measures that protect the environment, human health and safety. The EMCA (EIA/Audit) Regulations, 2003 provided the guidelines for conducting the environmental audit.

The approach used to conduct this audit included an introductory meeting, site visit and tour, information gathering, initial assessment of evidence, and an exit meeting, which provided preliminary findings; a final assessment of evidence followed and, this enabled drafting and finalization of the report. The first meeting was used to introduce the audit team and site representatives, review the purpose, scope and methodology of the audit, schedule interviews and other meetings as necessary and, discuss health and safety risks at the site. In this meeting :operating licenses and permits, monitoring data, operational drawings and blueprints, procedure manuals, accident reports, organizational charts, site maps, and site history were reviewed. An audit protocol –to guide the auditing team during interviews, site inspection and document reviews was prepared and, and agreement made on the auditing dates. The audit logistics including –transport arrangements, and audit schedule were discussed and also agreed upon. A site tour around the quarry was then carried out to identify areas

requiring detailed inspections and, to assess the amount of effort required to complete the work in order to determine the whether the planned audit activity schedule was achievable. The site tour familiarized the audit team with the health and safety issues and standards of operations at the quarry.

Information gathering started through site inspections, using the prepared checklists and protocols; review of environmental monitoring data and summary reports and; conducting structured interviews with selected facility personnel. Collected data was reviewed for information and preparation of a preliminary summary report of the audit findings, focusing on the facility's practices, or conditions, where specified operational standards were not met. The preliminary audit summary report findings were shared with the site representatives with a rider that these report findings, were un-official until the final report was delivered. The exit meeting with the site representatives was therefore undertaken to provide an overview of how the audit went on, and comments it generated on the nature of the preliminary audit findings, with reviews accepted, ensured that the audit findings were based on correct information. At this same moment, opportunity was taken to discuss the preparation of the draft audit report and its action plan. The final assessment of evidence was done through a thorough review of the findings to ensure that they were accurate and backed by supporting evidence before the draft report was prepared and released for comments and finalization.

4. The Impact of Quarrying Activities

In carrying out the environmental audit, the study aimed at identifying and evaluating the impacts the quarrying activity could generate to a degree, sufficient enough for informed decision-making as to either permit or halt the activity. The nature and level of the investigations therefore include evaluation of the likely extent and scale of the impacts in order to determine their severity and significance. Thus, the impacts of the activity on the major ecological systems, including air quality, demand on surface and groundwater resources and quality, land use and; noise, fire-outbreaks and, on human health and safety were evaluated. Such findings are as presented in the sections that follow.

4.1 Impact on Air Quality

Drilling, blasting and transportation of materials have effects on air quality. Drilling and blasting introduces dust into the atmosphere, while diesel powered trucks transporting sized rocks on unpaved road, in addition to dust – introduce exhaust emissions composed of particulate matter, sulphur dioxide, nitrogen oxides, carbon monoxide and volatile organic compounds such as polycyclic aromatic hydrocarbons, some of which are known to be carcinogenic. The estimated contribution of quarrying activities and trucking to air pollution in the area is presented in Table 3.

Table 3: Engine exhaust emissions and fugitive dust generation, Source of emission factors, WHO, 1989

Source	Unit	Annual estimate	Pollutants#									
			SPM		SO_2		NOx		CO		VOC	
			kg/unit	tn/yr	kg/unit	kg/yr	kg/unit	kg/yr	kg/unit	kg/yr	kg/unit	kg/yr
Engine emissions Diesel Trucks >3.5 tons	1000 km	1804 km	2.0	0.003	$3.9*S^{\alpha}$	2.8	14	25.3	51	92	3.7	6.7
Fugitive dust Open quarry Blasting	tn	1234§	0.08	0.10								
Transport 6 wheeler Trucks	1000 km	1804 km	$1.80*f^{\beta}$	15.3								

# SPM = suspended particulate matter, SO_2 = sulphur dioxide, NOx = nitrogenous gases,
CO = carbon monoxide, VOC = volatile organic compounds.
§ Annual production of quarrying activity.
α S = sulphur % by weight, average of 0.4% for diesel.
β f = 473068, is a factor of average speed, weight and number of wheels of vehicles (WHO, 1989).

The significance of the impact from exhaust emissions and the fugitive dust generated on the ambient air quality around the forest area can be assessed by considering the atmospheric stability and its influence on transport and dispersion of the pollutants (WHO, 1989) as represented by solar radiation and wind speed in the area. The solar radiation ranges from strong to moderate (solar altitude 35 – 60 ºC with clear skies) during a better part of the day and, slightly strong (solar altitude 15 – 35 ºC with clear skies) in the early part of the day to late afternoon. The daily average radiation (which varies according to the season), is another important factor. Its minimum occurs during the SE Monsoon season. The wind speed on average, ranges from as low of 4 knots at 0900hrs to as high of 12 knots at 1500hrs. The solar radiation and wind speed depict atmospheric weather conditions that range from extreme to slight instability, predominating the daytime. Such conditions encourage the vertical transport and diffusion of airborne pollutants (Gupta, 1992). The strong winds usually experienced in the area are thus capable of dispersing the air contaminants generated at the quarry and the truck road well beyond the forest boundaries. This has minimized localized concentration of the pollutants in the air, making the impact one of little significance.

4.2 Impact on Water Resources and Quality

River Mwache is a major source of potable water supply for the residents and, so is the availability of significant quantities of good quality groundwater in the area, Caswell (1956). Quarrying being dry processes, places no demand on water resources and, as such, no impact to water resources is caused. Concerns however, abound on water quality, both chemically and microbiologically as run-off from the quarrying spoils, could introduce undesirable elements in the water; while the potential for microbiological pollution could originate from the workers and the resident population in view the absence of suitable sanitation systems for both. Vegetation could filter and attenuate the contaminants in the run-off, however, quarrying has removed this cover in some areas, promoting surface run-off, but undermining the natural attenuation defence mechanism to minimize the amount of pollutants entering the water bodies. Quarrying also had the potential to modify the existing drainage characteristics, interfering with stream flow and aquifer recharge. In addition, quarrying has the potential to expose the groundwater aquifer, increasing its vulnerability to pollution.

4.3 Impact on land use

The designated land use for Mwache Forest is maintenance of the natural forest by the Forest Department. The department at the same time however, allowed controlled quarrying to ensure that the forest cover is maintained. As the quarrying was being carried out on a rock outcrop, no significant changes were observed on the forest. However, the excavation activities have the created Bad Lands, with impact on the aesthetic value the forest, provides. Similarly, the loss of vegetation cover, although localised, had exposed the bedrock to agents of erosion, reducing the moisture retention capacity of the forest, affecting its moderating influence on local climate. The loss of the forest habitat on the quarried areas also has adverse, but less significant impacts on local flora and fauna.

4.4 Impact Associated with Noise

During the blasting operations, the noise levels were very high. This noise occurred occasional as a one-off event spread among the different operators. Otherwise for all intent and purpose, the noise was bearable. It however, constituted of occupational hazard among the workers in light of them not using ear-muffs provided. Blasting activities have also had significant negative impacts on infrastructure, causing cracks to walls of the Forest Department offices. The noise also potentially disturbed the wildlife.

4.5 Impacts of Fire Out-break

Potential fire out-breaks were considered to be of major concern in the forest environment, particularly during the dry period, where the vegetation could catch fire with adverse impacts on the forest and its wildlife. The two sources that could cause fire-outbreaks –included blasting operations and the domestic activities of the workers. Fire out-break from these activities could raze down the forest with the loss of forest services. Such impact be adverse with long term, significant consequences.

4.6 Occupational Health and Safety Impacts

The quarrying activities exposed the workers to dust and high levels of noise. Dust is associated with breathing problems, while noise could impair hearing senses –effects that gradually lead to slow, but permanent health damage. A spot check, indicated the prevalence of respiratory problems and hearing loss among the quarry workers. In addition, workers could suffer injuries from flying debris caused by the blasting operations. There was potential outbreak of malaria from a forest environment infested with mosquitoes; there was potential for

workers to suffer from water borne disease as a result of contamination of drinking water by faecal matter since the workers lacked sanitation facilities. The use of explosives is another source of bad injuries.

5. Measures to minimize the Impacts of the Quarrying Activities

5.1 Impact on Air Quality

Drilling and blasting operations dislodged different sized rock materials and, also produced dust. The dust had impact on air quality. Tracking on unpaved road to deliver the quarried material for ballast making, away from the quarry site, produced fugitive dust. Similarly, the use of old diesel powered tracks, injected suspended particulate matter, the oxides of nitrogen and sulphur, carbon monoxide, and volatile organic compounds – components that lowered the air quality, yet, their management was too, not addressed. Overall, there were no intervention measures to protect the air quality from the quarry activities.

5.2 Impact on Water Resources and Quality

Quarrying operations do not require the utilization of water. As such, it has no impact on water resources. However, it could pose potential impacts on water quality. Quarrying could exposure and render groundwater aquifers vulnerable to pollution. Surface run-off on quarry spoils could cause diffuse pollution, while lack of on-site sanitation facilities to serve the workers had the potential to introduce pathogens into the water sources. Caswell groundwater surveys, (1956), reported that in the Mazeras area, quarrying should not be allowed beyond the allowed 20metres depth.

5.3 Impact on Land Use

Quarrying for ballast production had created open lands, damaging the landscape –a situation that should not have arisen because the strategy adopted was to progressively rehabilitate excavated areas through tree planting, as the quarrying operations moved to new areas Though this was attempted, (Fig. 5), it was not sustained.

Fig. 5: Rehabilitation of quarried land by reforestation

In the strategy, the quarried were to be levelled and spread with top soil spread ready for tree planting. Tree seedlings were availed by the Forest Department, which maintained a tree nursery in the forest with support from Gami Quarries Ltd and other licensees, which was part of the licensing conditions for undertaking the quarrying activity in the forest. Unfortunately, at the time of the study, the trees planted had weathered partly as a result of the drought, but more so due to the insufficient amount of the top soil spread on the rock basement. Tree planting if properly instituted, could restore the landscape, promoting re-establishment of the local climate and repopulation of the area by flora and fauna.

5.4 Impact Associated with Noise

The main source of noise at the quarry is during blasting of the rock structure using explosives. If the companies undertook this activity simultaneously, then, the noise levels would have been very high and unbearable. It would scare the wild life to a greater scale and also increase the occupational impacts it causes among the workers, leading to long-term hearing defects. To reduce the noise level and minimize its impacts, the companies quarrying in the forest have put in place a scheduled arrangement for blasting by each firm. Under this arrangement, no two firms can carry out the blasting activity at the same time. Similarly, the activity is restricted to day hours only. This arrangement controls the noise level, confining it to allocated times. The arrangement works well.

5.5 Contingency for Combating Fire Outbreaks

The intervention measures that had been put in place to reduce the likelihood of fire outbreaks included:

- Accepted liability for damage to government property within the forest that could occur as a result of the activities of their agents, workers or servants, costs incurred in containing fire outbreaks;
- Provide material needs, trained human resource and transport to fight fires under the guidance of the Forest Department;
- Kept the quarry workers alert through regular notices from the forest department on the possible occurrence of fire-outbreaks with the dry seasons; such alertness demanded that the workers were to be available at all such times and, prepared to fight the fires;
- Maintain the unpaved road to provide unhindered access to the quarry.

5.6 Maintaining Occupational Health and Safety

Aware of occupational hazards at the quarry, the Company provided its workers with appropriate clothing and gear to ensure safety. Such included provision of overalls, boots, helmets, goggles, dust masks, and ear muffs. Awareness campaigns were held to inform the workers the dangers associated with flying objects during blasting operations. The importance of wearing eye goggles was emphasized. Explosives were placed in secure storage area measuring 50 m X 50 m, which was manned 24 hours a day. To guard against malaria in the forest environment, the workers were educated on the need to prevent formation of stagnant water ponds, and to the drainage systems remained free of blockages.

6. Conclusions and Recommendations

The Regulations provided by the Forestry Department, the Mines and Geology Department and, those of the Ministry of labour as defined by the Directorate of Occupational Safety and Health have enabled Gami Quarries Ltd to mitigate against the negative impacts of the quarrying operations. The annual renewal of the operating licence was proof of continued compliance to the regulations. However, quarrying had created Bad Lands and the strategy of reclaiming the same through re-vegetation on the quarried areas proved unsuccessful. To be

successful in tree planting, the Company should move adequate amounts of topsoil into the quarried areas to aid germination and growth of the tree seedlings. Rigorous supervision by the forest Department is crucial to the success of this initiative. Re-vegetation, shall minimize erosion in the quarried areas and attenuate contaminant movement into the water bodies. The high noise level posed an occupational health threat to the workers who routinely avoided wearing protective gears. They should be made to adorn them. The noise from explosives was also strong enough to damage infrastructure as seen from the cracked walls of the Forest's Dept. Offices. Explosives will continue to be used in the quarry operations and, as such, future infrastructure development near the quarry should be avoided. The impacts on air quality was largely localised and, its effects were occupational. Such were addressed through provision of protective gears. The impact from fugitive dust and vehicular emissions from trucking along the gravel road encompassed the wider Mwache Forest route and, was subject to transport and dispersion by winds. The terrain in Mwache and the thick forest cover helped to trap some of the dust generated and, contained it within. Vehicular emissions also contributed to air pollution, however, it is concluded that the wind regime scattered and diluted this contamination. Cleaner emissions from the vehicles could be assured by regular and proper maintenance of truck engines and, this apart from decreasing the amount of emissions, addressing the air pollution problem, improved fuel efficiency and, minimized running costs. Paving the road could also be considered as another strategy for minimizing pollution of air from dust. Workers lacked sanitation facilities and, these should be provided to avoid the potential contamination water with faecal matter, to avoid impact on human health from water borne diseases. The risk of malaria infection from mosquitoes in the forest environment was real. To minimize this, the formation of stagnant water ponds was to be avoided. Drainage channels were to be maintained. The potential for fire hazards was also real and, the fire drills that were organized periodically should be made, taking into consideration the personnel turn-over in the work station. On occupationally health and safety, the workers should be informed of benefits of following the code of work practice to ensure they adhere to occupational health and safety rules and regulations.

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