IMPACTS OF QUARRYING ON LAND AND SOIL IN KAMPANI KIRIYA COMMUNITY NEAR ZUNGERU, NORTH-CENTRAL NIGERIA

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Abstract

This research was conceptualized to determine the potentially toxic elements concentrations of topsoil due to quarrying activities around Kampani Kirya and environs, near Zungeru North-Central Nigeria. Geological mapping was conducted on a scale of 1:25,000 to determine the disposition and distribution of different rock types in the area. Physical examination of impacts of quarrying on land was done. Heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn, V, Zr, Ba, Sr, Rb and Fe) were analysed in soil samples using X-Ray Fluorescence (XRF). Computation of contamination factor (Cf), Index of geoaccumulatuion (Igeo), enrichment factor (EF) were performed on concentration values of potentially toxic heavy metals to determine the extent of pollution caused by quarrying activities in the topsoil of farming and quarrying areas. The concentration values of heavy metals in soils were also compared with world average background values of heavy metals. Results showed evidence of physical impacts of the quarrying on land through land degradation and loss of top soil, dust and noise pollution. Others include destruction of vegetation cover crops rock textures and structures. The calculated contamination factors indicated that Co and Cr exhibited moderate to considerable contamination. Other heavy potentially toxic elements showed low or negligible contamination levels. However, the modified contamination factor showed that all the elements in the study area showed nil to very low degree of contamination. A considerable percentage of the samples returned Igeo class of 0 which is interpreted to be that these elements have not polluted the environment. Only chromium element exhibited Igeo classes of 1 and 2 which represents slightly to moderately polluted. It can be concluded that potentially toxic elements originate from the mining activities as indicated by contamination indices of the measured parameters. The geochemistry of rocks reflected traces of heavy metals within the mine vicinity. This study, however, allayed the fear of possible heavy metal pollution in the sediment of the study area, but there is the need for continuous monitoring of both sediment and water quality to match the potential threat from increased anthropogenic sources especially in the face of persistent mining activities in the area.

Keywords: Geoaccumulation, Geochemistry, Geological mapping, Heavy metals, Quarrying, Land degradation, Rock structures and Toxic elements

Introduction

Quarrying is the one of the major practices carried out in the world by construction industries. According to Ukpong 2012, quarrying is a form of land use method concerned with the extraction of non-fuel and non-metals minerals from rocks and it serves as a source of livelihood to the construction industry (Nduka, 2003). It is usually done by open-cast method using rock drills, explosion of dynamite and use of other methods (Lad and Samant, 2014). A quarry is a type of open-pit mine from which rock are extracted and is generally used for extracting building materials, such as dimension stone, construction aggregate, sand and gravel. The difference between mining and quarrying is that quarrying extracts industrial rocks, sand and gravel while mining excavates the site for metallic and non-metallic mineral deposits (Nartey *et al.*, 2012). Quarrying as a form of mining has negative environmental and health effects. It has a number of common stages or activities each of which has potentially adverse impacts on the environment and communities based on their proximity to operations (Kitula, 2004; Sati, 2015 and Ming'ate and Mohamed, 2016).

However, quarrying operations whether small or large-scale, are inherently disruptive to the environment, producing large quantities of waste that can have deleterious impacts for decades (Oyinloye and Ajayi, 2015). This can be in the form of chemical elements or energy such as noise, heat or light but are considered contaminants when in excess of natural levels (Ezenwa *et al.*, 2014). Apart from the physical effects on the environment, these elements accumulate in the body tissues of living organisms and their concentrations increase as they pass from lower to higher trophic levels (Aremu *et al.*, 2015). Crushed rock quarrying activities generates considerable amount of dust and wastes, which contain a number of heavy metals (Tiimub *et al.*, 2015). Heavy metals that are mobilized or dissolved into the soil can be taken up by plants or transported to surface or ground water (Sherene, 2010).

Quarrying in rural areas is a major source of livelihood in spite of the dangers it poses to the environment and other livelihood activities such as farming. Kampani Kiriya community near Zungeru, north-central Nigeria, is a farming community where varieties of crops are planted and much of these crops are sold to and consumed by the public. However, it is not yet clear the impact of the quarrying activity on the environment and the livelihood of the community. This research therefore attempts to investigate the impact of quarrying on land and soil (with reference to chemical elements) in Kampani Kiriya community near Zungeru, north-central Nigeria.

Study Area Description and Drainage

The study area is part of Zungeru Sheet 163 NE and is located in Wushishi, Wushishi Local Government of Niger State, North central Nigeria (Figure 1). It is underlain by crystalline rocks of the basement complex of Nigeria (Figure 2). It is located between latitudes 9°45′00″ to 9°48′ 00″ N and longitudes 6°08′ 00″ to 6°11′ 00″ E. It covers an area extent of 30 km^2. It can be accessed through Minna-Zungeru road and other minor roads and footpaths. The drainage pattern of the mapped area is largely dependent on the topography of the area.

The study area is drained by a number of streams and channels which are tributaries of the major River Kaduna (Apata *et al.*, 2016). The numerous tributaries all originate from the hilly areas and they flow north to south to connect with the River Kaduna, thus most stream channels were dry. The drainage pattern shows the resistance of the underlying basement rock and their structural features and also describes the fracturing pattern of the rocks.

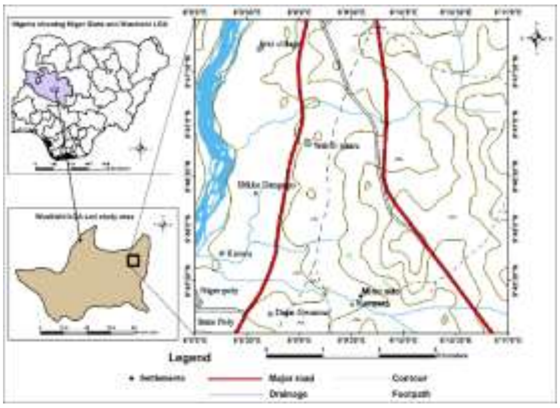

Figure 1: Map of the Kampani Kiriya and its Environs, Wushishi Local Government Area of Niger State, Nigeria

Geology of the Study Area

The study area lies within the North-central portion of the Nigerian Basement Complex, which is characterized by three lithofacies: the migmatite gneiss complex, the low-grade schist belt and the older granites (Olarewaju, *et al*., 1996; Olasehinde, 1999.
(Figure 2)

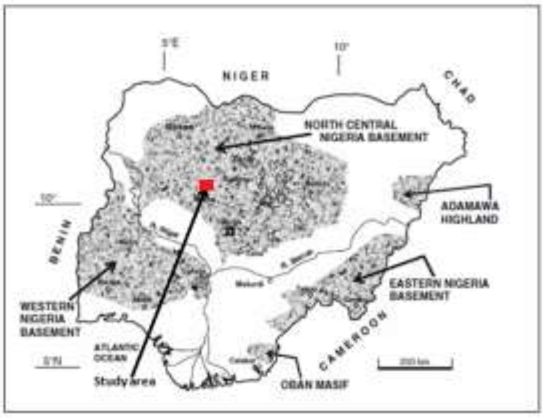

Figure 2: Regional geological map of Nigeria with areas occupied by crystalline basement rocks (modified after Obaje, 2009).

Materials and Methods

Geological mapping was carried out in the study, to determine the rock types, distribution, textures, mineralogy and structures. A total of 17 soil samples were collected, 15 of them were randomly collected around the quarry sites and at increasing distances away from the quarrying site at a depth of 0 – 15 cm using a digger and shovel. While 2 soil samples were collected 2 km away from the quarry site, in an undisturbed area to act as control. Four samples of the rock being quarried collected in the field were used for thin section preparation at the laboratory of Nigerian Geological Survey Agency, Kaduna, Nigeria. The resulting thin sections were used to determine the mineralogical composition of the rock using a petrological microscope. This served as a guide in inferring the source of the trace elements that may contaminate the soil as minerals are constituents of two or more elements. Also, Energy Dispersive X-ray fluorescence (EDXRF) spectrometer of model "Minipal 4" was used for the sediments and rock samples analysis in the laboratory.

Results and Discussions

Field Aspect

Geological field mapping shows that the study area consists of schist which has been intruded by large bodies of granitic rocks as shown on the geological map (Figure 3). The schist occupies more than 80% of the study area and occurs as low-lying rock units. It is dark grey in colour, medium to coarse grained, highly foliated and consists of feldspar, quartz and mica (Plate I). In some locations, the schist has been greatly deformed and tilted and dips up to 50º while in others they have been greatly weathered displaying remnants of previously more extensive assemblages. Granitic rocks of the Older Granite suite account for less than 20 % of the study area and occur as batholiths which are massive, hilly and elongated acidic rocks (Plate II) containing a lot of quartz veins. The rocks are dark grey in colour, fine to medium grained, weakly foliated, consist of light and dark coloured minerals, and form fairly prominent topographic features which resemble the schist ridges.

Thin Section Analysis

Petrographic examination of thin sections of the granite revealed that it consists of plagioclase (45%), quartz (32%), biotite (15%), hornblende (5%), and microcline (3%) (Plate III)

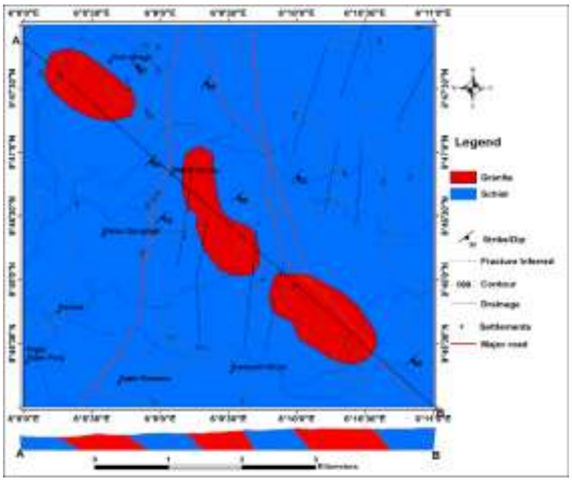

Figure 3: Geological map of the study area.

Plate I: Highly foliated dark-grey schist with medium-coarse grained texture

Plate II: A massive, hilly, elongated and exfoliated granitic rock with quartz vein cutting across

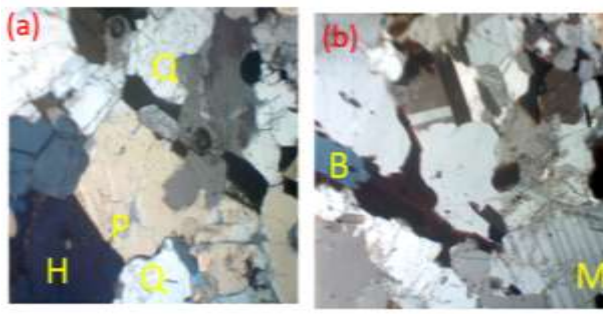

Plate III: Photomicrographs of granite with hornblende (H), plagioclase (P), quartz (Q), microcline (M) and biotite (B) as its mineral constituents.

Physicochemical Properties of Sediments

The quarry site soil texture of the sub-samples is the sandy loam type. The particle size distribution of which is observed high percentage of sand fractions such as coarse with 13-16%, medium with 12-14% and fine with 11-16% respectively, in the sieve analysis process. The porosity of the silt and clay soil showed that in the range of 0.97 - 1.11 for the sampled areas of granite different points way from the quarry site. Two agricultural soils however have more porosity (0.97) than granite quarry site samples and agricultural soils near the quarry site. The representative soil sub-samples of sampled areas showed an alkaline pH (5.98 - 6.85), the quarry site soils are more alkaline than agricultural soils, an electrical conductivity and high total dissolved salts (TDS) were in the range of 105.65 - 124.20 µs/ppm and 109.72 - 201.31ms/ppm respectively.

Index of Geoaccumulation

The computation of the index for geoaccumulation is presented in Table 3. A considerable percentage of the samples returned Igeo class of 0 which is interpreted to be that these elements have not polluted the environment (Muller, 1979). Only chromium element exhibited Igeo classes of 1 and 2 which represents slightly polluted to moderately polluted (Muller, 1979).

Contamination factor

The contamination factors in Table 5 indicated that Co and Cr ranges from 2.3 to 5.7 which interpreted by Hakanson, 1980 (Table 2) exhibited moderate to considerable contamination. Other heavy elements or potentially toxic elements such as Cu, Mn, Ni, Pb, Zn, V, Zr, Ba, Sr and Rb showed low or negligible contamination levels. However, the modified contamination factor showed that all the elements in the study area showed nil to very low degree of contamination (Hakanson, 1980). This result point to the fact that the activities in the quarry as at the moment, has very little effect in the environment. This should not be neglected because the result shows that the effect is active. Hence, measures must be taken to prevent further exacerbation.

Enrichment Factor

The enrichment factor which is presented in Table 6 indicates that different elements exhibited different enrichment levels. According to Zhang and Liu 2002, enrichment factor values of $0.5 \leq EF \leq 1.5$ suggest that the trace metal concentration may come entirely from natural weathering processes. However, an EF>1.5 indicates that a significant portion of the trace metals was delivered from non-crustal materials so, these trace metals were delivered by other sources, like point and non-point pollution and biota. The Enrichment factor (EF) of the analyzed soil samples in the study area, range from minimal enrichment to significant enrichments from the values obtained (Barbieri, 2016).

Physical impact of quarrying on land in the study area

Destruction of landscape and loss of topsoil: The activities of quarrying in the study area, have led to the destruction of the natural landscape (Plate IV). Clearance of vegetation also led to soil erosion down the slopes. Several gullies and trenches had been created along the roads linking the quarry sites as a result of persistent and sustained removal of the top soil. No measures have been put in place by the quarrying company to reclaim the degraded lands as a result of their activities.

Dust: From observations made during the field survey, another negative environmental effect associated with quarrying was the excessive emission of dust into the atmosphere, which tends to affect local air quality. Dust emission into the atmosphere was primarily caused by excavation, drilling, blasting and the crushing of rock products into their respective aggregate sizes. The dust particle in effect does not only affect the quality of local air, but results in serious respiratory disorders like cancer, tuberculosis and silicosis. In terms of dust emissions, the workers at the quarrying sites were the most vulnerable since they had no protective clothing like nose masks to reduce the inhalation of these dust particles.

Destruction of Vegetation Cover and Crops: Quarrying activities in the study area have resulted in the destruction of the vegetation cover as well as destruction of crops. This destruction is caused primarily by excavation works that involves the removal of plants and vegetation to expose the burden rock for subsequent exploitation by the quarrying companies. The blasting process also results in the emission of excessive dust that with serious repercussion on food crops cultivated in the area. It was evident from the survey that several crops cultivated were stunted in growth as a result of the quarrying. Thus, when dust particles settle on the plants, it affects the ability of the crops to manufacture their own food, through the natural process of photosynthesis. The gradual and uncontrolled rate of vegetation destruction is leading to deforestation, hence resulting in desertification.

Accumulation of Water in Abandoned Pits: The accumulation of water in these abandoned pits could have both positive and negative outcomes. On the positive front, after a quarry is abandoned, the basin or base of the pit serves as a good reservoir for surface water that is trapped. Community residents and stone workers can use this water to undertake domestic household activities and for other industrial purposes. It is however important to subject such water to careful treatment before using them to undertake domestic chores. Also, the accumulation of water in the abandoned pits can be tapped on to facilitate local agriculture production. Thus, water accumulated in the pits can be exploited and used to irrigate crops in the catchment area to enhance all year farming, thus improving food security and stability in the region. Conversely, the accumulated water in the abandoned pits can also have negative outcomes. Thus, water accumulated in the pits can serve as breeding grounds for mosquitoes. This essentially results in an increase in the prevalence of diseases like malaria and fever. Also the water contained in the abandoned pits can trap community residents and stone workers, which can result in the loss of lives.

Conclusion

Quarrying activities have led to a lot of negative physical environmental impacts on land in the study area. These impacts include land degradation due to destruction of the natural landscape, formation of large pits, destruction of rocks texture and structure, soil erosion and destruction of vegetation.

The contamination factors indicates that Co and Cr exhibited moderate to considerable contamination. Other heavy elements or potentially toxic elements showed low or negligible contamination levels. However, the modified contamination factor showed that all the elements in the study area showed nil to very low degree of contamination. It can be concluded that potentially toxic elements originate from the mining activities as indicated by contamination indices of the measured parameters. The geochemistry of rocks reflected traces of heavy metals within the mine vicinity. Anthropogenic influences and weathering activities may induce the disintegration of rocks and ultimately show high concentration of these metals in soil. As a result of water rock interaction, weathering, leaching and erosion, surface water and shallow hand dug wells may be contaminated.

The contamination is likely to remain confined to mining areas and may likely follow the groundwater flow paths. This implies that those living downstream the mining site areas are prone to contamination of measured parameters.

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Table 1: The mean and range of some physical and chemical properties of soils in the vicinity of the granite quarry.

Soil Texture Analysis		Mean	Range
Gravel (>2.00 nm) (%)		25.32	16.48 - 33.95
Sand	Coarse (1.00 - 2.00 nm) (%)	14.38	12.96 - 15.89
	Medium (1.00 - 0.525 nm) (%)	13.17	12.15 - 14.05
	Fine (0.525 - 0.0075 nm) (%)	13.35	11.07 - 15.87
Silt (0.0075 - 0.002 nm) (%)		24.83	14.41 - 31.36
Clay (<0.002 nm) (%)		14.77	11.03 - 18.71
pH		6.45	5.98 – 6.85
Electrical conductivity (µs/ppm)		115.87	105.65 - 124.20
TDS (ms/ppm)		153.04	109.72 - 201.31
Organic matter (%)		1.55	0.82 - 2.50

Table 2: Index of geoaccumulation classes (Muller, 1979)

Igeo value	Igeo class	Level
Igeo ≤0	0	Unpolluted
0<Igeo ≤1	1	Slightly Polluted
1<Igeo ≤2	2	Moderately Polluted
2<Igeo ≤3	3	Moderately Severely Polluted
3<Igeo ≤4	4	Severely Polluted
4<Igeo ≤5	5	Severely Extremely Polluted
≥5	6	Extremely Polluted

Table 3: Index of geoaccumulation for sediment samples in the study area.

Sample ID	Co	Cr	Cu	Mn	Ni	Pb	Zn	V	Zr	Ba	Sr	Rb
1	0.55	1.04	-1.52	-1.59	-0.58	-8.58	-2.06	-8.01	-8.89	-8.24	-7.91	-9.59
2	0.44	0.85	-1.60	-1.78	-0.77	-8.11	-1.43	-7.85	-9.17	-8.90	-7.83	-9.57
3	0.83	0.81	-2.24	-1.51	-0.86	-8.41	-2.46	-7.77	-8.79	-8.21	-7.83	-8.52
4	0.61	0.84	-2.16	-1.87	-0.49	-8.19	-1.81	-7.63	-9.02	-9.34	-7.89	-9.48
5	0.91	0.79	-2.14	-1.73	-1.06	-9.31	-1.68	-7.63	-9.05	-8.96	-7.84	-9.23
6	0.87	1.25	-1.53	-1.39	-0.90	-9.14	-1.75	-7.74	-8.32	-8.62	-8.00	-8.55
7	0.85	1.34	-2.11	-1.66	-0.68	-8.09	-1.69	-7.82	-9.20	-7.94	-7.88	-8.46
8	0.49	1.08	-1.34	-1.82	-0.50	-8.33	-2.23	-7.84	-8.50	-8.98	-7.97	-8.49
9	0.72	1.19	-1.42	-1.49	-0.53	-8.08	-2.44	-8.12	-8.72	-7.82	-7.89	-8.39
10	0.62	1.26	-1.38	-1.42	-0.59	-8.47	-1.54	-7.96	-9.34	-8.12	-7.92	-8.55
11	0.83	1.31	-1.73	-1.43	-0.91	-8.24	-1.58	-7.51	-8.74	-9.16	-7.99	-8.69
12	0.87	1.10	-2.07	-1.74	-1.06	-9.27	-2.06	-8.44	-8.93	-8.04	-7.85	-8.88
13	0.53	0.99	-2.04	-1.85	-0.78	-8.13	-1.99	-7.61	-10.02	-7.78	-7.93	-8.43
14	0.91	1.00	-1.35	-1.90	-0.75	-8.10	-1.48	-7.73	-9.40	-9.00	-7.97	-8.82
15	0.46	0.79	-1.38	-1.67	-0.82	-8.51	-2.53	-7.67	-8.35	-8.45	-7.96	-8.80

Table 4: Contamination factor classes and level of contamination (Hakanson 1980)

Cf Class	Level of Contamination
$C^i_f<1$	Low Contamination
$1\leq C^i_f<3$	Moderate Contamination
$3\leq C^i_f<6$	Considerable Contamination
$C^i_f\geq 6$	Very high Contamination

Table 5: Contamination factor and modified contamination for sediments in the study area

Sample ID	Cf Co	Cf Cr	Cf Cu	Cf Mn	Cf Ni	Cf Pb	Cf Zn	Cf V	Cf Zr	Cf Ba	Cf Sr	Cf Rb	mCd
1	2.5927	4.2640	0.3284	0.3072	0.8383	0.0003	0.1918	0.0005	0.0002	0.0004	0.0006	0.0001	0.71
2	2.3340	3.5186	0.3017	0.2535	0.6940	0.0005	0.3607	0.0006	0.0002	0.0002	0.0006	0.0001	0.62
3	3.4277	3.3567	0.1590	0.3307	0.6372	0.0003	0.1280	0.0006	0.0002	0.0004	0.0006	0.0003	0.67
4	2.7646	3.4858	0.1724	0.2321	0.9183	0.0004	0.2453	0.0007	0.0002	0.0001	0.0006	0.0001	0.65
5	3.7094	3.3112	0.1769	0.2662	0.5183	0.0001	0.2809	0.0007	0.0002	0.0002	0.0006	0.0001	0.69
6	3.5842	5.2324	0.3259	0.3728	0.6112	0.0002	0.2611	0.0007	0.0004	0.0003	0.0005	0.0003	0.87
7	3.5060	5.7358	0.1810	0.2863	0.7618	0.0005	0.2772	0.0006	0.0002	0.0005	0.0006	0.0003	0.90
8	2.4520	4.4317	0.3940	0.2425	0.9110	0.0004	0.1605	0.0006	0.0003	0.0002	0.0005	0.0003	0.72
9	3.0667	4.9234	0.3622	0.3389	0.8809	0.0005	0.1309	0.0004	0.0002	0.0006	0.0006	0.0003	0.81
10	2.7975	5.2870	0.3764	0.3640	0.8319	0.0003	0.3212	0.0005	0.0001	0.0004	0.0005	0.0003	0.83
11	3.4265	5.5415	0.2659	0.3596	0.6054	0.0004	0.3093	0.0008	0.0002	0.0002	0.0005	0.0003	0.88
12	3.5917	4.4873	0.1891	0.2622	0.5179	0.0001	0.1920	0.0003	0.0002	0.0005	0.0006	0.0002	0.77
13	2.5599	4.0440	0.1953	0.2358	0.6892	0.0004	0.2059	0.0007	0.0001	0.0006	0.0005	0.0003	0.66
14	3.7430	4.0856	0.3872	0.2246	0.7089	0.0005	0.3400	0.0007	0.0001	0.0002	0.0005	0.0002	0.79
15	2.3763	3.3107	0.3760	0.2823	0.6629	0.0003	0.1190	0.0007	0.0004	0.0003	0.0005	0.0002	0.59

Table 6: Enrichment factor for the sediment samples in the Kampani Kiriya Community

Sample ID	Co	Cr	Cu	Mn	Ni	Pb	Zn	V	Zr	Ba	Sr	Rb
1	1.800	3.468	0.912	1.387	1.408	0.002	0.732	0.003	0.001	0.004	0.001	0.001
2	3.132	5.531	1.619	2.211	2.253	0.006	2.658	0.006	0.002	0.004	0.002	0.002
3	1.980	2.271	0.367	1.242	0.890	0.002	0.406	0.003	0.001	0.004	0.001	0.003
4	0.543	0.802	0.135	0.296	0.436	0.001	0.265	0.001	0.000	0.000	0.000	0.000
5	0.770	0.805	0.147	0.359	0.260	0.000	0.320	0.001	0.000	0.001	0.000	0.000
6	0.648	1.108	0.236	0.438	0.267	0.000	0.259	0.001	0.001	0.001	0.000	0.001
7	1.519	2.910	0.314	0.806	0.798	0.002	0.659	0.002	0.001	0.004	0.001	0.002
8	1.453	3.077	0.934	0.934	1.306	0.002	0.523	0.003	0.002	0.002	0.001	0.003
9	2.416	4.544	1.141	1.736	1.679	0.003	0.566	0.003	0.002	0.007	0.001	0.004
10	8.039	17.797	4.326	6.799	5.783	0.009	5.070	0.011	0.003	0.020	0.004	0.013
11	1.195	2.264	0.371	0.815	0.511	0.001	0.593	0.002	0.001	0.001	0.001	0.001
12	2.174	3.182	0.458	1.032	0.758	0.001	0.639	0.001	0.001	0.004	0.001	0.002
13	2.102	3.890	0.642	1.259	1.369	0.003	0.929	0.004	0.001	0.008	0.001	0.004
14	1.442	1.843	0.597	0.562	0.661	0.002	0.719	0.002	0.000	0.001	0.001	0.001
15	2.655	4.334	1.680	2.051	1.792	0.003	0.731	0.006	0.004	0.005	0.002	0.004

Plate IV: Destruction of natural landscape due to quarrying activities at Kampani Kiriya