EFFECTS OF QUARRY MINING ACTIVITIES ON THE NUTRITIONAL COMPOSITION OF EDIBLE VEGETABLES IN ISHIAGU, EBONYI STATE, NIGERIA

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KEYWORDS
- Quarry mining
- Soil quality
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- Vegetables
- Nutritional status

ABSTRACT

The study assessed the effects of quarry mining wastes on the nutritional composition of *Cucurbita pepo* (pumpkin), *Cucumis sativus* (cucumber) and *Taliferia occidentalis* (fluted pumpkin) using standard analytical methods. Nearby farmland soil receiving effluents from quarry operators were used for the study. The study covered wet and dry seasons. Water from hand dug wells in the mining area was used to irrigate farmland during the dry season. Results of study revealed a significant reduction in protein, lipid and carbohydrate content of vegetables grown in the area compared to the control (P<0.05). Further, vitamin composition of the selected vegetables significantly increased (P<0.05) in response to environmental stress compare to control. These results suggest contamination of farmlands in the study area by mine waste water and subsequent contaminant was also uptake by vegetables grown in such farmlands. Findings from this study imply that crop farming in the quarry environment and irrigation of farmlands with water from hand dug wells in the mining area should be discouraged. There is also a possibility of human ingestion of accumulated toxic contaminants such as heavy metals in vegetables if consumed.

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1 Introduction

Vegetables are the most important and widely cultivated food and income generating crops in the Eastern part of Nigeria. Quality and safety of these vegetables are of paramount importance due to their role in human health. They are included in meals mainly for their nutritional value while some are reserved for the sick and convalescent because of their medicinal properties (Thompson & Agbugba 2013).

In Ishiagu, most of the vegetable farms are located near the mining areas, thus increasing the potential of contaminant uptake by these crops and increase the risk of human intoxication. Quarry activities are well known to causes air pollution, loss of land, threatening of underground and surface water which directly impair environmental quality and ecosystems (Naik et al., 2006; Omosanya & Ajibade, 2011 Ming’ate & Mohamed, 2016). High toxic metals such as cadmium, lead, chromium, zinc and nickel content in edible plants are of considerable importance, since they might constitute a possible toxicological hazard (Ogbonna et al., 2015).

Physiological and biochemical alteration are observed in plants under stressed environmental conditions (Hasanuzzaman et al., 2013). Such changes include growth retardation, nutrients uptake, poor water balance, enzyme impairment, oxidative stress, chlorosis, necrosis and stomata destruction (Sayed et al., 1997; Dietz et al., 1998; Ogbonna et al., 2013; Otuu et al., 2015; Osuocha et al., 2016). Proximate analysis refers to the determination of the major constituents of food and is used to assess if food has normal nutritional or otherwise somehow been adulterated. This study was therefore aimed at assessing the impact of quarry activities on the nutritional composition of edible vegetables grown in Ishiagu.

2 Materials and Methods

2.1 Study area

Ishiagu is located in Ivo local Government Area of Ebonyi State, Nigeria at latitudes 5° 52’ to 5° 60’ N and longitudes 7° 30’ to 7° 37” E. The study area is located in the tropical rainforest, but due to intensive human action it is rapidly being replaced by forest savanna. Geologically, Ishiagu it is part the Cross River Basin. Ishiagu is endowed with mineral resources notably aggregates, mineral ores (lead and zinc).

Many rural dwellers in Ebonyi State are majorly peasant farmers that cultivate mainly cassava, rice, cocoyam, vegetables and yam crops as a means of livelihood and sources of income. Consequently, solid mineral exploitation and agriculture are the key activities in the study area. Poor waste management by mining operators results in the disposal of mine waste on nearby land, including farmlands. Three (3) quarry mining contaminated effluent soils sites were evaluated in this study. The sites are; (a) Crush rock industries in Ano community (b) Eza West Africa limited in Eziato community and (c) Crush stone industries in Amita village.

2.2 Planting of vegetables

The plant seeds used for this study were Cucurbita pepo (pumpkin), Taliffera occidenalis (fluted pumpkin) and Cucumis sativus (cucumber). These seeds were collected from Agricultural Development Programme (ADP) Office Umuahia, Abia State. The plant seeds were planted in situ 100m away from discharge points in each of the mining sites along the flow of the mining effluents.

2.3 Cultural Conditions

Experimental fields were cleared from weeds and seeds of the vegetables were placed spacedly to avoid undue competition among plants. In order to ensure optimum plant growth and yield, weeds were removed on weekly intervals in both seasons. Water from hand dug wells in the mining sites was used to irrigate the farms during the dry season.

2.4 Preparation of Plant Samples for Analysis

Harvested vegetables were washed with distilled water to remove sand and dust particles. The samples were then cut to separate the roots and shoots. Plant samples were oven dried at 60°C before using them for analysis.

2.5 Physicochemical and heavy metal analysis of well water samples

Contaminated water pH, temperature, sulphate, phosphate, chloride and heavy metal concentration was determined by following the guide described by APHA (1998) while the water electrical conductivity was determined as described by UNEP (2004).

2.6 Determination of proximate composition of vegetables

Ash and moisture fiber content was determined as described by James (1995). While Crude Protein level was determined by Kjeldahl method (Chang, 2003). Further, carbohydrate content was calculated by the method prescribed by Muller & Tobin (1980) and Lipid content was analyzed by Soxhlet extraction gravimetric method of Kirk & Sawyer (1998).

2.7 Determination of vitamin composition of vegetables

Ascorbic acid and niacin content of vegetables were determined by the method given by Barakat et al. (1993) while retinol and tocopherol content of vegetables were determined by the method of AOAC (1975).
2.8 Statistical analysis of collected data

The data obtained were analyzed using Excel package and Statistical Package for Social Science (SPSS) version 20. Results of this study were expressed as mean ± SD of triplicate determinations using Excel package. One Way Analysis of Variance (ANOVA) with a Least Significant Difference (LSD) was used to identify statistical differences as described by Onuh & Igwemma, (2000) while student’s t-test was used to compare means of two seasons.

Table 1 Physicochemical parameter of well water samples used for farm irrigation during dry season.

| Sample  | Temperature (°C) | pH | Electrical Conductivity (µs/cm) | Sulphate (mg/L) | Phosphate (mg/L) | Chloride (mg/L) |
|---------|------------------|----|-------------------------------|----------------|-----------------|-----------------|
| WHO     | 25.30±0.00a      | 6.50±0.00c | 250.00±0.00c                  | 250.00±0.00c    | 5.00±0.00d      | 250.00±0.00d    |
| Sample A| 31.11±0.12b      | 6.38±0.51b | 860.79±6.47b                  | 288.33±1.73c    | 49.95±0.44a     | 541.57±3.44a    |
| Sample B| 30.83±0.49b      | 6.14±0.06c | 835.73±3.55c                  | 258.33±1.68b    | 28.39±0.54a     | 496.82±2.49b    |
| Sample C| 30.92±0.37b      | 6.30±0.83b | 552.18±1.65c                  | 261.49±1.17b    | 37.29±0.45c     | 274.57±1.05c    |
| Sample D| 29.11±0.20c      | 6.54±0.69b | 128.95±1.06d                  | 260.48±3.06a    | 41.23±2.00a     | 125.35±4.77d    |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscripts are significantly different (P<0.05). Sample A= Well water sample from Ano community, Sample B= Well water sample from Eziato community, Sample C= Well water sample from Amita community, Sample D, water used for irrigation of control vegetables.
Table 2 Level of trace metals in well water samples used for farm irrigation during dry season (mg/L).

| Sample | Lead | Cadmium | Chromium | Zinc | Nickel | Manganese |
|--------|------|---------|----------|------|--------|-----------|
| WHO    | 0.01±0.00™ | 0.03±0.00™ | 0.05±0.00™ | 3.00±0.00™ | 0.23±0.30™ | 0.50±0.00™ |
| Sample A | 3.18±0.50™ | 0.67±0.06™ | 3.53±0.76™ | 188.80±7.82™ | 2.19±0.61™ | 8.53±0.74™ |
| Sample B | 3.14±0.86™ | 0.55±0.10™ | 2.28±0.07™ | 157.42±6.81™ | 2.06±0.31™ | 6.21±0.29™ |
| Sample C | 0.87±0.10® | 0.48±0.17™ | 1.67±0.17™ | 97.53±3.61™ | 1.97±0.10™ | 1.34±0.10™ |
| Sample D | 0.49±0.71™ | 0.36±0.28™ | 1.30±0.09™ | 12.06±0.15™ | 1.17±0.06™ | 1.63±0.47™ |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscripts are significantly different (P<0.05) Sample A = Well water sample from Ano community Sample B = well water sample from Eziaio community Sample C = well water sample from Amita community Sample D = Water used for irrigation of control vegetables.

Table 3 Effect of wet and dry seasons on proximate compositions of *Cucurbita pepo* (pumpkin) cultivated in quarry mining effluent discharge soils.

| Location | Moisture (%) W | Moisture (%) D | Fibre (%) W | Fibre (%) D | Protein (%) W | Protein (%) D | Lipid (%) W | Lipid (%) D | Ash (%) W | Ash (%) D | Carbohydrate (%) W | Carbohydrate (%) D |
|----------|----------------|----------------|-------------|-------------|---------------|---------------|-------------|-------------|-----------|-----------|------------------|-------------------|
| Control  | 7.04±0.00™ | 6.77±0.00™ | 0.38±0.00™ | 0.83±0.00™ | 3.11±0.00™ | 2.89±0.00™ | 1.19±0.00™ | 0.96±0.00™ | 6.22±0.00™ | 7.61±0.00™ | 82.06±0.00™ | 80.94±0.00™ |
| Ezza     | 12.39±0.33™ | 10.17±0.06™ | 0.56±0.10™ | 1.61±0.02™ | 1.91±0.67™ | 1.07±0.10™ | 0.31±0.10™ | 0.27±0.02™ | 8.14±1.03™ | 10.91±0.32™ | 76.69±1.10™ | 75.97±1.49™ |
| Crushrock | 13.15±0.67™ | 12.65±0.26™ | 0.86±0.10™ | 0.25±0.01™ | 1.22±0.06™ | 0.98±0.11™ | 0.22±0.10™ | 0.12±0.06™ | 9.75±1.13™ | 12.52±1.17™ | 74.80±3.12™ | 73.48±4.17™ |
| Crushstone | 11.78±0.10™ | 9.28±0.32™ | 0.81±0.12™ | 1.28±0.01™ | 1.85±0.67™ | 0.77±0.03™ | 0.37±0.06™ | 0.22±0.25™ | 7.91±0.13™ | 12.42±0.11™ | 77.28±0.54™ | 76.03±0.07™ |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscripts are significantly different (P<0.05). W=wet season, D=dry season.

Table 4 Comparative assessment of proximate composition of *Cucumis sativus* grown in quarry mining effluent discharge soils in wet and dry seasons.

| Location | Moisture (%) W | Moisture (%) D | Fibre (%) W | Fibre (%) D | Protein (%) W | Protein (%) D | Lipid (%) W | Lipid (%) D | Ash (%) W | Ash (%) D | Carbohydrate (%) W | Carbohydrate (%) D |
|----------|----------------|----------------|-------------|-------------|---------------|---------------|-------------|-------------|-----------|-----------|------------------|-------------------|
| Control  | 5.15±0.00™ | 5.08±0.00™ | 0.27±0.00™ | 0.49±0.00™ | 4.76±0.00™ | 4.16±0.00™ | 0.35±0.00™ | 0.26±0.00™ | 4.47±0.00™ | 7.58±0.00™ | 85.00±0.00™ | 82.43±0.00™ |
| Ezaa     | 10.73±0.15™ | 9.97±0.15™ | 0.43±0.01™ | 1.92±0.15™ | 1.21±0.11™ | 0.97±1.22™ | 0.16±0.15™ | 0.11±0.12™ | 10.48±0.39™ | 12.93±0.03™ | 76.99±1.10™ | 74.10±1.20™ |
| Crushrock | 10.06±0.26™ | 8.18±0.57™ | 0.32±0.02™ | 0.53±0.10™ | 1.18±0.16™ | 0.86±0.06™ | 0.18±0.01™ | 0.14±0.01™ | 8.43±1.01™ | 10.55±0.15™ | 80.22±5.76™ | 79.94±3.18™ |
| Crushstone | 9.06±0.01™ | 6.6±0.46™ | 0.33±0.01™ | 0.36±0.10™ | 1.36±0.21™ | 0.81±0.59™ | 0.18±0.05™ | 0.18±0.15™ | 8.03±0.20™ | 12.55±0.02™ | 81.07±1.55™ | 79.50±0.05™ |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscript are significantly different (P<0.05). W=wet season, D=dry season.
Table 5 Comparative assessment of proximate composition of *Taliferia occidentalis* grown in quarry mining effluent discharge soils.

| Location    | Moisture (%) W | Moisture (%) D | Fibre (%) W | Fibre (%) D | Protein (%) W | Protein (%) D | Lipid (%) W | Lipid (%) D | Ash (%) W | Ash (%) D | Carbohydrate (%) W | Carbohydrate (%) D |
|-------------|----------------|----------------|-------------|-------------|----------------|----------------|--------------|--------------|------------|------------|---------------------|-------------------|
| Control     | 6.10±0.00      | 4.86±0.00      | 0.22±0.00   | 0.51±0.00   | 5.18±0.00      | 4.22±0.00      | 0.47±0.00   | 0.38±0.00   | 6.44±0.00  | 9.66±0.00  | 81.59±0.00         | 80.37±0.00        |
| Ezza        | 9.33±0.06      | 5.75±0.18      | 0.25±0.25   | 0.77±0.01   | 2.32±0.41      | 1.67±0.30      | 0.26±0.10   | 0.23±0.13   | 7.93±0.66  | 12.87±0.56 | 79.91±0.15         | 78.71±0.20        |
| Crushrock   | 10.21±0.61     | 5.91±0.25      | 0.27±0.17   | 0.93±0.26   | 2.50±0.19      | 1.82±0.25      | 0.26±0.01   | 0.21±0.17   | 7.68±0.08  | 12.19±0.44 | 79.08±0.05         | 78.94±0.13        |
| Crushstone  | 10.06±0.58     | 5.99±0.95      | 0.35±0.10   | 0.97±0.28   | 1.35±0.10      | 0.92±0.25      | 0.20±0.27   | 0.18±0.20   | 8.12±1.00  | 12.97±0.93 | 79.92±0.55         | 78.97±0.23        |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscript are significantly different (P<0.05). W=wet season, D=dry season.

Table 6 Comparative assessment of vitamin content of *Cucurbita pepo* vegetable grown in quarry mining effluent discharge soil in wet and dry seasons (mg/100g).

| Location    | Retinol W | Retinol D | Tocopherol W | Tocopherol D | Niacin W | Niacin D | Ascorbic acid W | Ascorbic acid D |
|-------------|-----------|-----------|--------------|--------------|----------|----------|----------------|----------------|
| Control     | 0.04±0.00⁵ | 2.07±0.00⁵ | 0.91±0.00⁵   | 1.37±0.00⁵   | 1.25±0.00⁵ | 6.5±0.00⁵ | 1.31±0.00⁵     | 2.96±0.00⁵     |
| Ezza        | 0.14±0.10⁹ | 4.60±0.06⁹ | 1.04±0.01⁹   | 4.66±0.13⁹   | 2.13±0.20⁹ | 10.13±0.23⁹ | 2.03±0.35⁹    | 3.20±0.10⁹     |
| Crushrock   | 0.07±0.03⁹ | 2.62±0.38⁹ | 1.20±0.06⁹   | 1.56±0.23⁹   | 5.15±0.15⁹ | 12.93±0.12⁹ | 2.73±0.55⁹    | 3.18±0.15⁹     |
| Crushstone  | 0.08±0.01⁹ | 3.24±0.45⁹ | 1.24±0.06⁹   | 1.75±0.36⁹   | 4.82±0.35⁹ | 8.27±0.55⁹ | 1.41±0.26⁹    | 1.86±0.03⁹     |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscript are significantly different (P<0.05). W=wet season, D=dry season.

Table 7 Comparative assessment of vitamin composition of *Cucumis sativus* grown in quarry mining effluent discharge soils in wet and dry seasons (mg/100g).

| Location    | Retinol W | Retinol D | Tocopherol W | Tocopherol D | Niacin W | Niacin D | Ascorbic acid W | Ascorbic acid D |
|-------------|-----------|-----------|--------------|--------------|----------|----------|----------------|----------------|
| Control     | 0.019±0.00⁶ | 0.51±0.00⁶ | 0.19±0.00⁶   | 1.22±0.00⁶   | 1.39±0.00⁶ | 1.10±0.00⁶ | 1.12±0.00⁶     | 2.08±0.00⁶     |
| Ezza        | 0.075±0.03⁸ | 4.56±0.53⁸ | 0.21±0.01⁸   | 1.69±0.10⁸   | 5.02±0.23⁸ | 9.73±0.39⁸ | 2.15±0.12⁸    | 3.91±0.78⁸     |
| Crushrock   | 0.057±0.01⁸ | 2.71±0.21⁸ | 0.70±0.02¹   | 1.69±0.21¹   | 0.03±0.57¹ | 1.82±0.36¹ | 1.68±0.26¹    | 2.98±0.20¹     |
| Crushstone  | 0.14±0.01¹ | 1.10±0.73¹ | 0.25±0.03¹   | 1.33±0.10³   | 2.62±0.16³ | 7.18±0.20³ | 1.53±0.36³    | 2.64±0.42³     |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscript are significantly different (P<0.05). W=wet season, D=dry season.

Table 8 Comparative assessment of vitamin content of *Taliferia occidentalis* grown in quarry mining effluent discharge soils in wet and dry season (mg/100g).

| Location    | Retinol W | Retinol D | Tocopherol W | Tocopherol D | Niacin W | Niacin D | Ascorbic acid W | Ascorbic acid D |
|-------------|-----------|-----------|--------------|--------------|----------|----------|----------------|----------------|
| Control     | 0.006±0.00⁸ | 1.01±0.00⁸ | 0.11±0.00⁸   | 1.31±0.00⁸   | 1.14±0.00⁸ | 1.70±0.00⁸ | 1.27±0.00⁸     | 1.01±0.00⁸     |
| Ezza        | 0.007±0.02¹ | 2.82±0.26¹ | 0.15±0.02¹   | 1.48±0.21¹   | 1.77±0.38¹ | 3.25±0.30¹ | 2.22±0.25¹     | 2.43±0.15¹     |
| Crushrock   | 0.029±0.17¹ | 1.41±0.32¹ | 0.19±0.05¹   | 3.46±0.26¹   | 1.83±0.27¹ | 2.77±0.35¹ | 1.92±0.17¹     | 2.31±0.15¹     |
| Crushstone  | 0.044±0.03¹ | 1.59±0.0¹   | 0.15±0.00⁸   | 1.85±0.21¹   | 1.84±0.46¹ | 4.31±0.70¹ | 1.40±0.52¹     | 2.18±0.17¹     |

Values are mean of triplicate determination ± standard deviation. Means down the column having different superscript are significantly different (P<0.05). W=wet season, D=dry season.

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3 Results and Discussion

Results of physicochemical analysis and trace metal content of mining well water samples are presented in Tables 1 and 2 respectively. For physicochemical properties of well water samples, significant increase in electrical conductivity values were found compared to WHO (2001) standard (P<0.05). The increase in electrical conductivity values in well water samples obtained from this study is an indication of the degree of dissolved metal constituents in well water. Findings also showed significant increase in phosphate and sulphate concentration of well water samples compared to WHO (2001) standard (P<0.05). This increase could be due to runoff water which carries dissolved salts into waterways. These findings are in conformity with the reports of Claassens et al. (2005) and Baath et al. (2005) that washing down of particles brings sulphate and phosphate into pits.

Table 2 showed increase level of trace metals in well water used for farm irrigation in dry season compared to WHO standard (P<0.05). Water samples from the quarry mining sites had higher concentration of metals which were above WHO (2001) permissible limits. This could be as a result of the mining activities in Ishiagu which has been observed to occur mainly in the hill and elevated sites, increasing contaminant load of runoff into shallow wells. Suspended particulate matter particles can also get into these wells.

Results indicate that the concentration of trace metals in sample A was significantly higher compared to other well water samples (P<0.05). This increase could be attributed to nearness of this hand dug well to crush rock quarry mining site. This observation agrees with the findings of Nagajyoti et al. (2010) who reported high concentration of metals in well waters near quarry mining sites. High level of trace metals such as cadmium, lead, chromium, aluminum, copper, iron and zinc in well waters in Ishiagu have also been reported Akubugwo et al. (2012) and Onwumesi et al. (2011). Several researchers have also reported high level of trace metals in water samples in Ishiagu area (Onwumesi et al., 2011; Nwaugo et al., 2011). This high level of heavy metals may contribute to increased metal concentration in soils and vegetables irrigated with hand well water near Ishiagu quarry mining sites. Similar reports were opined by Liu et al. (2005) that metal contaminated water used for farm irrigation may contribute to high concentration of trace metals in vegetables planted in agricultural soils near mine sites.

Results of proximate analysis showed significant difference in percentage composition of carbohydrate, fats and protein, ash, fiber and moisture (P<0.05). Findings of the present study showed increase in ash and fibre content of vegetables grown in quarry mining effluent discharge soils compared to control (P<0.05). Comparative analysis of ash and fibre content of vegetables showed significant increase in dry season compared to wet season (P<0.05). This increase could be due to increased level of metal accumulation as reported by Osuocha et al. (2016) and increased synthesis of lignin leading to woody texture in the vegetables. Similar reports have been reported by Winkel-Shirley (2002). Results of this study showed a decrease in protein content of vegetables grown in mining effluent impacted soils compared to their control counterparts (P<0.05). This may be due to inhibition of protein synthesis as reported by Reddy & Prasad (1992). Other possible reasons are the unavailability of essential components of amino acids and inhibition of amino acid mobilization to the site of protein synthesis.

Comparative analysis also showed a decrease in protein content of vegetables grown in dry season compared to wet season (P<0.05). This may be due to interaction of trace metals with thiol residues of proteins and its replacement with trace metals in metalloproteins. Impaired protein synthesis has been reported in plants under heavy metal stress (Abdussalam et al., 2015). The increase in moisture content of vegetables in wet season compared to dry season is expected due to increased rainfall events and the predisposition of the area under study.

Analysis of percentage carbohydrate composition of the vegetables shows decrease in carbohydrate content of vegetables grown in quarry mining effluent discharge soils compared to their control counterparts (P<0.05). This decrease in carbohydrate content may be a metabolic signal in response to trace metal stress. Generally proximate results of the present study showed significant increase in percentage (%) carbohydrate, protein and lipid content of vegetables in wet season compared to dry season. This values were significantly lower compared to control (P<0.05).

In humans, vitamins play a vital role in cellular defense against oxidative stress (Zengin & Munzuroglu, 2005). Findings of study revealed a significant increase in vitamin composition of vegetables grown in the mining effluent discharge soils compared to control (P<0.05). The results also indicate significant increase in the concentration of tocopherol, ascorbic acid, retinol and niacin composition of the vegetables grown on quarry mining effluent contaminated soils in dry season compared to wet season (P<0.05).

This may be due to increased oxidative stress leading to increased biosynthesis of the vitamins as the serve as free radical scavenger. These results agree with the findings of Zengin & Munzuroglu (2005) who reported an increase in retinol, tocopherol and ascorbic acid content in vegetables due to exposure to heavy metals. Several researchers have reported a significant increase in the content of ascorbic acid which was activated by following the exposure of vegetables to heavy metal stress (Cui & Zhao, 2011; Kleckerova et al., 2011; Ivanov et al., 2012).

Further, Hegazy et al. (2013) reported an increase in vitamin C content of bean plant with increased accumulation of uranium and thorium. Increase in the level of vitamins in dry could be due to its antioxidant based function in plant metabolism.
Conclusion

This study indicated that well water samples near Ishiagu quarry mining sites are contaminated with heavy metals. Findings from the study also suggested negative impact on nutritional composition of vegetables grown on soils receiving waste water irrigated with well water samples, particularly during the dry season. There was also observable increase in vitamin composition of the vegetables which could be due to its antioxidant role in response to environmental stress. This study implies that rock mining in the study area have negative impacts on different environmental media including plants.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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