International Journal of Mining and Mineral Engineering

ISSN online: 1754-8918 - ISSN print: 1754-890X
https://www.inderscience.com/ijmme

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DOI: 10.1504/IJMME.2023.10056431

Article History:

Received:	12 October 2022
Last revised:	22 January 2023
Accepted:	01 February 2023
Published online:	20 June 2023

Effect of seasonal variations on quarry operations in Southwest Nigeria

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Abstract: This study assessed the seasonal effects on quarry operations and productivity in South-Western, Nigeria. Data were collected through oral interview, supplemented with well structured pre-tested questionnaires. The findings show that seasonal changes had effect on all quarry operations. The results revealed that aggregate production was higher during the dry season across all the quarries with Samchaze quarry having the highest production of 54,460–64,000 tons attributing to reduced downtime from rainfall and higher aggregate demand due to increased engineering projects rate in the dry season. With regards to sales, the findings showed a decrease in aggregate sales in the wet season in all the quarries with Western quarry making the lowest sales of 2,700–6,000 tons while Samchaze quarry made the highest sales of 11,000–15,000 tons. Health challenges like respiratory infections and heat stress were greater in the dry season while common cold, malaria and typhoid, cough and catarrh were common during the wet season. Eye infections, chest and hearing problems were felt in all the seasons. Appropriate recommendations were made to mitigate these seasonal changes impacts.

Keywords: quarry; seasonal variation; drilling; blasting; crushing; productivity; Nigeria.

Reference to this paper should be made as follows: Afeni, T.B., Adebayo, B. and Ogundayo, A.A. (2023) 'Effect of seasonal variations on quarry operations in Southwest Nigeria', *Int. J. Mining and Mineral Engineering*, Vol. 14, No. 1, pp.27–40.

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1 Introduction

Nigeria as a country is blessed with about fifty different solid minerals discovered in various locations. These minerals and ore deposit include gold, silver, limestone, coal, bitumen, iron ore, tin, columbite, lead, zinc, gemstones, granite, marble, gypsum, talc, lithium etc. Mining is carried out across the federation even though not all the minerals are available in commercially viable quantities. Also, before the exploration of oil started commercially in the Niger Delta, ore deposits were the major foreign exchange source and contributed enormously to the economy and the development of Nigeria. The mining and metals sector plays a crucial role in driving economic growth of any nation (Roland and Benjamin, 2015). Mineral resources development is a pillar of many national economics, both in terms of contribution to gross domestic product (GDP) and tax revenue. The extraction and processing of minerals/metals had brought numerous benefits to society. These minerals are essential commodities used in the construction of communication and transportation networks, consumer electronics, vehicles, buildings, and many other items that serve as foundation for society's material quality of life (USUG, 2019). The mining and metals sector faces several sustainable development challenges, including the impact of seasonal variations. Our season is not constant, as evidenced by observations of rise in rainfall and dryness (IPCC, 2007a, 2007b). As a result of seasonal variations, we will experience further changes in average temperature, precipitation, sea level and extreme events.

Nigeria, like the rest of West Africa and other tropical regions, has only two seasons. These are the dry season and the rainy season. The dry season (from November to March) is accompanied by a dust laden air mass from the Sahara Desert, locally known as Harmattan, or by its main name the tropical continental (CT) air mass, while the rainy season in Nigeria on the coast lasts for seven months (from the end of March to the end of October) is heavily influenced by an air mass originating from the south Atlantic Ocean, locally known as the south western wind, or by its main name, the tropical maritime (MT) air mass. Nigeria's location in the tropics has given her a tropical hot climate. Temperatures in Nigeria vary according to the seasons of the year as with other

lands found in the tropics. Nigeria's seasons are determined by rainfall with rainy season and dry season being the major seasons in Nigeria (Geography of Nigeria, 2021).

Seasonal changes present great risks to mining operations because these mining industries are often located in challenging geographical regions and they depend on fixed asset with long lifetimes, involve global supply chains, manage seasonal sensitive operations, and balance the interests of various stakeholders. Increasingly, external stakeholders are tasking mining companies with identifying, disclosing, and planning for the risks and opportunities posed by varying seasonal conditions. By taking steps to adapt to these risks, mining companies can also achieve complementary sustainable development goals related to local community engagement, social development, biodiversity enhancement, protection of sensitive ecosystems and natural resources stewardship (SustaiNet, 2018). The exact nature of seasonal change impacts will be location-specific and dependent on regional characteristics and ecosystems, it is possible to come to some broad conclusions regarding seasonal change related risks and opportunities in the mining industry. Transportation and hauling routes and mining infrastructure are susceptible to structural weakening and failure due to increased frequency and severity of extreme weather events and seasonal variability (Adebayo and Taiwo, 2011). Depending on the nature and where a mine is located, containment facilities, buildings, energy sources, and mine site drainage may be immensely affected by rising average temperature, stronger winds, changing water levels and ice composition, and greater intensity and frequency of precipitation. Geographically, these changes could be particularly problematic, weakening structural integrity and safety of roads, bridges, pipelines (Instanes et al., 2005). Furthermore, the walls of open pit mines and containment structures may not safely withstand melting and exposed permafrost (Altiti et al., 2021). Seasonal variations are expected to affect mineral processing operations (Brown et al., 2006). Given that some mine processes are highly water dependent, e.g., sodium sulphate mining, increased water scarcity could impact production rates, dust suppression efforts, mine drainage, and the covering of tailings (Pearce et al., 2011).

Seasonal variation presents quarries with wide range of risks and opportunities. Higher temperatures and sea levels, shifting patterns of precipitation and water levels, and increased frequency and intensity of extreme weather events will create site-specific risk, as well as risk to the broader network within which quarries functions (Estela, 2015). Seasonal variation also poses physical risks to quarries value chain, including risks to production inputs, the workforce and market demand for goods. Finally, the broader economy or infrastructure (e.g., third-party energy or water services, supply chains, government services and market access) will experience seasonal variation impacts (Freed and Sussman, 2008).

1.1 The study areas

This study selected quarries from three States which are located within south-western part of Nigeria. The quarries chosen for the study are in Ondo, Ogun and Oyo States as shown in Table 1 and Figures 1 to 3 respectively.

Table 1 Location of study areas

Study area	*Longitude*	*Latitude*	*Location*
Samchaze quarry	5.1591°E	7.2249°N	The quarry is located along Itaogbolu-Akure road, Itaogbolu in Akure North Local Government Area of Ondo State, Nigeria
Western quarry	3.5290°E	7.2331°N	The quarry location is at Kemta Logemo Village via Odeda, Odeda Local Government, Abeokuta, Ogun State, Nigeria
ENL quarry	3.9470°E	7.5503°N	The quarry located along Aba-Aje, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria

The objective of the study is to assess the impact of seasons on quarry operations and to suggest possible ways to mitigate seasonal variation impacts on quarry operations.

Figure 1 Map of Ondo State showing Akure North Local Government (see online version for colours)

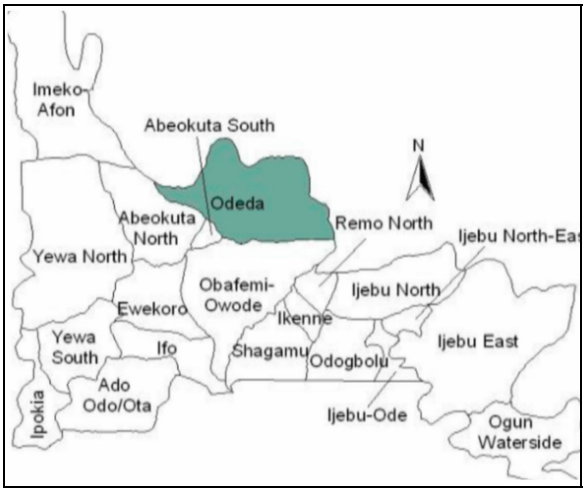
Source: Akinsami et al. (2016)

2 Materials and methods

The study areas of this work are narrowed to quarries in southwest states of Nigeria. The rocks in the study areas cover the Precambrian basement complex rocks. It is a crystalline rock comprising minerals such as quartz, feldspar, and mica. It is usually fine grained and relatively light coloured. Its hardness varies according to composition and principally the

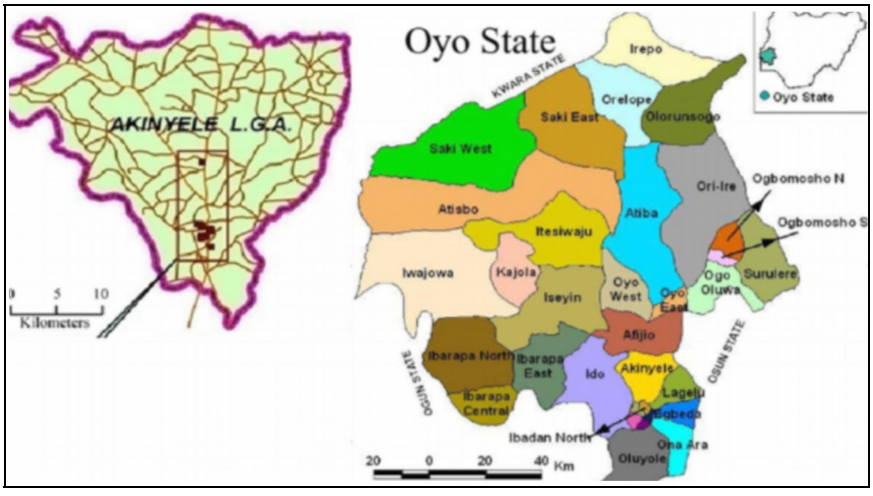
properties also depend on types of minerals a particular rock contains. The overburden present in these quarries is mainly laterite. Data were collected through oral interview conducted on site supplemented with the use of questionnaire. One hundred and forty-five (145) pre-tested well-structured questionnaires were distributed to the sample population, out of which 135 were returned. The collected data were subjected to percentage and statistical analyses. The results of the analyses are presented in Figures 4 to 10. Tables 2 to 6 which summarised the seasonal variation impact on quarry operation gathered from the respondents.

Figure 2 Map of Ogun state showing Odeda Local Government (see online version for colours)



Source: Adeleke et al. (2015)

Figure 3 Map of Oyo state showing Akinyele Local Government (see online version for colours)



Source: Kodaolu et al. (2020)

3 Results and discussion background information of the quarry workers

Figure 4 shows that the quarry workers were between the ages of 20–30 years which was 49%; ages 35–40 years was 34%, while ages 40–50 years was 11%. The respondents above the age of 50 years were less than 6%. With this scenario, it could be inferred that the percentage of younger workers are more than older workers. The research conducted gives an overview that most of the people working in quarries are male.

According to Figure 5, about 9.9% have gotten the primary education, 64% of the quarry workers had gotten to the secondary level of education, 19% had gone beyond post-secondary education and 5.6% do not have any form of education. We can deduce that the workers educational background was generally poor resulting from lack of finance and lack of interest in education. Figure 6 shows the operation carried out in the quarries. It can be deduced that loading and hauling have more percentage of workers (32%) and Account and sales have the least percentage of workers (1%).

Figure 4 Age of quarry workers (see online version for colours)

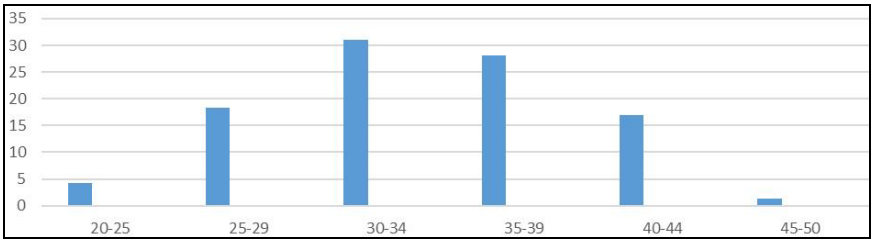
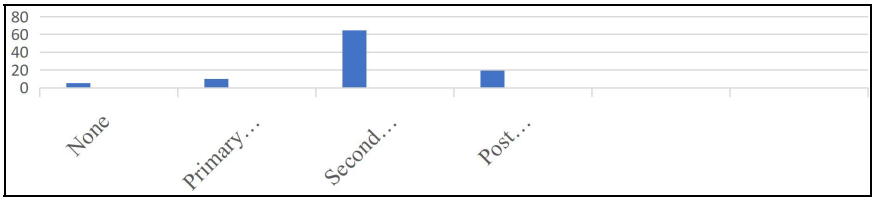
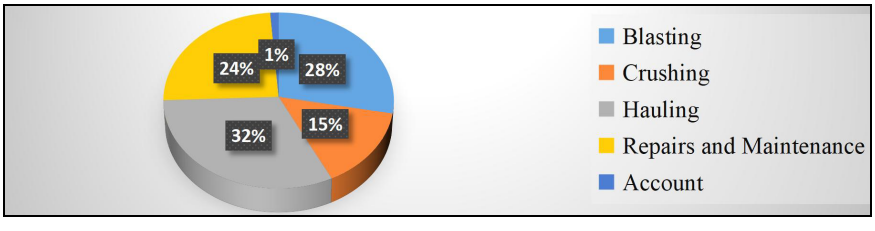


Figure 5 Level of Education of the quarry workers (see online version for colours)



Source: Ogundayo (2021)

Figure 6 Quarry operations undertaken at the quarries (see online version for colours)

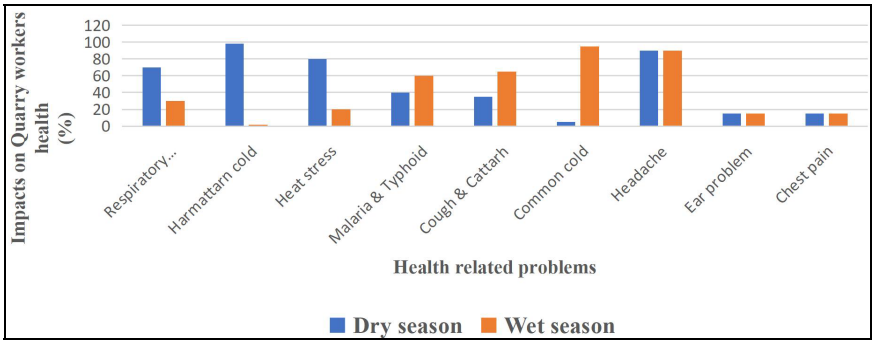


Source: Ogundayo (2021)

3.1 Impact of seasons on health of quarry workers

From the response gathered from the quarry workers, Figure 7 shows that seasonal changes have huge impact on the health of the quarry workers. Heat stress (80%), Harmattan cold (98%) and respiratory infections (65%) are high in the dry season. This was attributed to higher temperature and greater dust generation in the dry season. The wet season is characterised with a drop in temperature which causes common cold (90%), cough and catarrh (65%) and malaria and typhoid (60%). Headache (90%), ear problem (15%) and chest pain (15%) was felt both in the dry and wet season. These results are expected due to the nature of their job and the work environment.

Figure 7 Seasonal impact on health of quarry workers (see online version for colours)

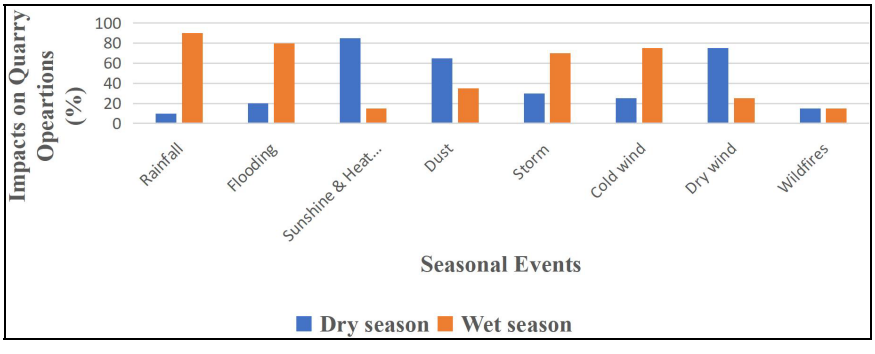


Source: Ogundayo (2021)

3.2 Seasonal events affecting quarry operations

According to the response collated from the workers, Figure 8 shows that rainfall, flooding, heat, and dust generation among others are the main seasonal events that affect quarry operations. It is evident that quarry operations in the wet season were greatly affected by rainfall (90%), flooding (80%), cold wind (75%) and storm (70%). Sunshine and heat wave (85%), dry wind (75%), and dust (65%) were high in the dry season. Wildfire (15%) affects quarry operation both in the dry and wet season.

Figure 8 Seasonal events that affect quarry operations (see online version for colours)

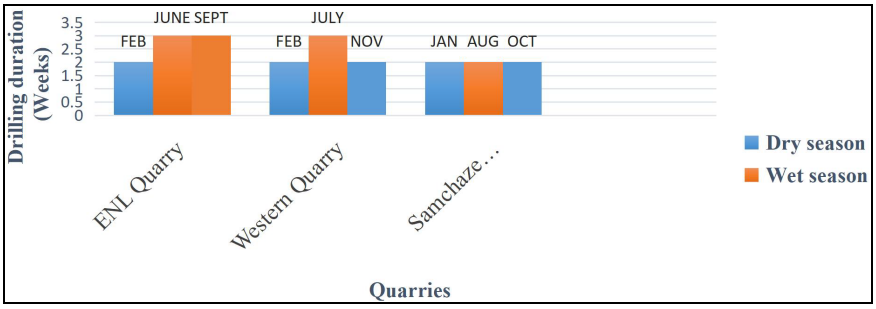


Source: Ogundayo (2021)

3.3 Effect of seasons on drilling operation

Figure 9 shows that in the wet season (June, September and July), the drilling duration lasted for three weeks while the dry season (February, November and December) drilling duration lasted for two weeks in all the quarries. The longer drilling duration in the wet season was because of increased downtime caused by frequent rainfall. Drilling duration in the month of August lasted for two weeks resulting from a break in rainfall which was attributed to the shorter drilling duration in that month. From the research conducted it is noted that dust in the dry season in greater than the wet season which results in higher cough, respiratory problems in the dry season. Table 2 gives the impact of season on drilling operation.

Figure 9 Drilling months and their duration (see online version for colours)



Source: Ogundayo (2021)

Table 2 Drilling data and seasonal variation impact on drilling operations in the quarries

Quarry	*Drilling duration*	*Season*	*No. of holes*	*Seasonal variation impact*
ENL quarry	February (2 weeks)	Dry	190	Heat wave, dust dispersion, bit breakage, greater rock strength, and reduced downtime
	June (3 weeks)	Wet	195	Increased moisture content, flooding, blowout, easy bit penetration, and reduced rock strength
	September (3 weeks)	Wet	205	Flooding, blowout, increased moisture content, easy bit penetration, and reduced rock strength
Western quarry	February (2 weeks)	Dry	200	Heat wave, dust dispersion, greater rock strength bit breakage, and reduced downtime
	July (3 weeks)	Wet	207	Flooding, easy bit penetration, reduced rock strength, increased moisture content, and blowout
	November (2 weeks)	Dry	205	Heat wave, dust dispersion, greater rock strength, and bit breakage reduced downtime
Samchaze quarry	January (2 weeks)	Dry	200	Heat wave, dust dispersion, bit breakage, greater rock strength, and reduced downtime
	August (2 weeks)	Wet	180	Blowout, easy bit penetration, increased moisture content, and reduced rock strength
	October (2 weeks)	Dry	200	Heat wave, dust dispersion, bit breakage, greater rock strength, and reduced downtime

Source: Ogundayo (2021)

3.4 Effect of seasons on blasting operation

Table 3 shows that blasting in the wet season was affected by increased dewatering operation, self-initiation of holes, flooding of pit, formation of mud, bad explosive transport route and increased downtime. It can also be deduced that blasting in the dry season is affected by high heat wave which can lead to explosion, increased wildfires which can be detrimental to safety of lives and properties. Table 3 shows that 14,000–15,500 tons of aggregate was blasted in ENL quarry, 19,000–21,000 tons was blasted in Western quarry and 39,000–43,800 tons was blasted in Samchaze quarry. This indicates that the tons of aggregate blasted during the wet and dry season in the quarries are within a closed range.

Table 3 Blasting month, tonnage, and seasonal variation impact on blasting in the quarries

Quarry	*Blasting month*	*Season*	*Amount (tons)*	*Seasonal impact*
ENL quarry	February	Dry	14,364	Heat wave, explosion, and wildfires
	July	Wet	14,742	Dewatering, self-initiation, flooding, and mud formation
	October	Dry	15,498	Heat wave, explosion, and wildfires
Western quarry	January	Dry	19,440	Heat wave, explosion, and wildfires
	June	Wet	20,120	Dewatering, self-initiation, flooding, and mud formation
	November	Dry	19,926	Heat wave, explosion, and wildfires
Samchaze quarry	February	Dry	43,740	Heat wave, explosion, and wildfires
	August	Wet	39,366	Dewatering, self-initiation, flooding, and mud formation
	October	Dry	43,740	Heat wave, explosion, and wildfires

Source: Ogundayo (2021)

3.5 Impact of seasons on crushing operation

According to Table 4, it can be deduced that November to March has an average of 23 days without hindrance of rainfall in all three quarries this shows that the dry season is accompanied with minimal crushing operation downtime resulting from rainfall disturbance. Table 5 also shows that from April to October there was an average of 12 days without hindrance of rainfall in all the three quarries. This shows that there was an increase in crushing operation downtime resulting from increase in rainfall in the wet season.

3.6 Effect of seasons on productivity

From Table 5, ENL produces 22,800–28,000 tons, Western quarry produces 11,500–14,080 tons and Samchaze quarry produces 54,400–64,000 tons of aggregates from November to March. This implies that in the dry season, the production was at its peak in all the quarries. This could be attributed higher aggregate demand from the consumers in the dry season. The rate of engineering construction projects from construction companies during this period is higher which in turn leads to higher demand

for aggregates. Also, families will want to spend the festive period in their own apartment; hence, causing a rise in building construction leading to higher aggregates demand. It can also be deduced from Table 5 that ENL quarry produces 12,000–18,000 tons, Western quarry produces 7,040–10,240 tons and Samchaze quarry produces 32,000–48,000 tons from April to October. This shows that there was a fall in production in all the quarries resulting from the drop in engineering construction project due to rainfall and lack of funds. There was a sharp rise in the production rate in the month of August in all quarries which is because of the break in rainfall (August break) in that month.

Table 4 Number of crushing days per month in the three quarries without disturbance from rainfall

Quarry	*January*	*February*	*March*	*April*	*May*	*June*
ENL	20	19	17	15	13	12
Western	22	19	18	16	14	14
Samchaze	20	18	17	15	14	12
Quarry	*July*	*August*	*September*	*October*	*November*	*December*
ENL	12	18	10	19	21	23
Western	13	20	11	19	22	22
Samchaze	12	19	10	18	20	24

Source: Ogundayo (2021)

Table 5 Calculated monthly production rate with respect to rainfall in the three quarries

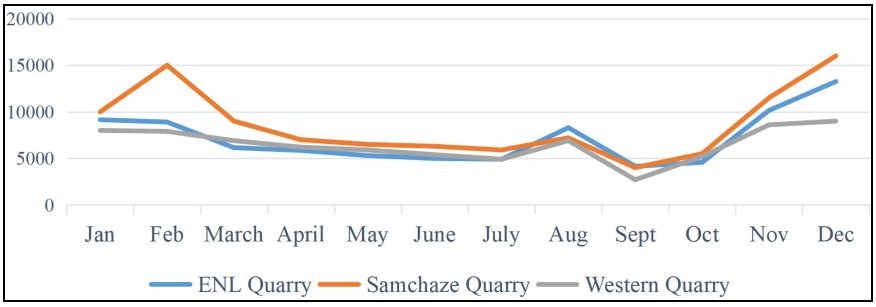
Quarry	*January (tons)*	*February (tons)*	*March (tons)*	*April (tons)*	*May (tons)*	*June (tons)*
ENL	24,000	22,800	20,400	18,000	15,600	14,400
Western	14,080	12,160	11,520	10,240	8,960	8,960
Samchaze	64,000	57,600	54,400	48,000	44,800	38,400
Quarry	*July (tons)*	*August (tons)*	*September (tons)*	*October (tons)*	*November (tons)*	*December (tons)*
ENL	14,400	21,600	12,000	22,800	22,800	27,600
Western	8,320	12,800	7,040	12,160	14,080	14,080
Samchaze	38,400	60,800	32,000	57,600	60,800	76,800

Source: Ogundayo (2021)

3.7 Effect of seasons on sales

From Figure 10, it can be deduced that there was rise in aggregate sales from November to March in all the three quarries. Aggregate sales in ENL quarry were 9,000–13,500 tons, Western quarry was 8,000–9,000 tons and Samchaze quarry was 11,000–15,000 tons, which indicates that aggregate sales increased to its peak during the dry season. It can also be seen that from April to October, aggregate sales reduced significantly in all the three quarries. Aggregate sales in ENL were 4,000–5,000 tons, Western quarry was 2,700–6,000 tons and Samchaze quarry was 5,500–6,500 tons, which indicates that aggregate sales dropped significantly during the wet season

Figure 10 Sales data of the three quarries over the course of a year (see online version for colours)



Source: Ogundayo (2021)

Figure 10 shows an increase in sales from January to February. There was a sharp decrease in sales in the month of March. It then starts decreasing progressively from March to September (which has the lowest sales in the months of the year) with a sharp rise in sales in the month of August. From November to December sales starts increasing progressively. The decrease in sales is attributed to rise in rainfall which reduced aggregates demand for engineering projects construction.

From the three quarries, Samchaze quarry made the highest sales both in the dry and wet season when compared with the dry season because the quarry is located closer to areas under development where more aggregates are used which contributes to the quarry having two production lines. Also, quarries in Ondo State are few when compared to other Southwest States. Since competitors are few, demand will be higher, and more sales will be made.

ENL and Western quarry are in already developed areas; therefore, aggregate sales will be lesser in this region due to minimal engineering construction projects leading to reduced sales. There are numerous quarries in this region leading to competition for demand. This also has greater impact on the sales of these two quarries.

3.8 Impact of season on aggregate demand and transportation

From Figure 10, it is evident that seasonal variation affects the demand of aggregates. It can be noted that from November to March, there was higher aggregates demand in all the quarries resulting from more engineering construction projects done during this period. This gives the indication that the dry season is attributed with higher demand for aggregates. From April to October, the demand for aggregates dropped significantly in all the quarries. This indicates that in the wet season, as the rain increases the demand for aggregates reduces.

3.9 Amount spent on road repairs

From Table 6, ENL quarry spent ₦212,500, Western quarry spent ₦218,550 and Samchaze quarry spent ₦182,500 to make hauling and transportation route assessable in all seasons. To reduce the impact of seasonal changes on hauling and transportation which is felt mostly in the wet season, the three quarries spent on compaction and sand filling of the hauling and transport routes with laterite and granite.

Table 6 Amount spent on road repair at the three quarries

Quarry	*Hauling routes*		*Transport routes*		*Total amount used (₦)*
	Granite	*Laterite*	*Granite*	*Laterite*	
ENL quarry	20 tons	30 tons	40 tons	50 tons	212,500
Western quarry	30 tons	40 tons	30 tons	45 tons	248,500
Samchaze quarry	20 tons	30 tons	35 tons	40 tons	195,500

Source: Ogundayo (2021)

4 Conclusions and recommendation

In this paper, the impact of seasonal variations on quarry operations in South-Western Nigeria had been investigated. From the results obtained, both from the respondents, through oral interview and supplemented with questionnaires, it could be established that seasonal variations have massive impact on quarrying activities. The impacts of changing seasons on quarry operations like drilling, blasting, crushing, productivity, aggregates sales, aggregate demand and transportation has been highlighted extensively in this research.

Seasonal events affecting quarry operations are rainfall, flooding, cold wind and storm which have greater impact in the wet season. The impact of heat, dust and dry wind are high during the dry season. Wildfire has same impact on quarry operations both in the dry and wet season. From the research conducted, it can be concluded that seasonal variation impacted the workers' health. Health challenges like respiratory infections, heat stress and dry cold was greater in the dry season while common cold, malaria and typhoid, cough and catarrh were greater during the wet season. Other health challenges like headache, eye infections, chest pain and hearing problems were felt in all seasons. Seasonal variations impact like increased downtime, easy bit penetration; reduced rock strength among others affects drilling operation. From the research conducted, drilling duration in the wet season was longer (three weeks) than that of the dry season (two weeks). Blasting operation was affected by seasonal variation impacts: like self-initiation of holes, dewatering operation, and mud formation. According to the research conducted, Samchaze quarry had the highest tones of blasted materials of 39,000–43,800 tons. Crushing in the dry season has greater number of days without disturbance of rainfall (23 days) compared to the wet season (12 days) across all three quarries. This shows that seasonal changes have greater impact on crushing operation. With regards to productivity, aggregate production was higher in the dry season across the three quarries with Samchaze having the highest production of 54,400–64,000 tones. Aggregate production decreased across the three quarries with Samchaze quarry having the highest production of 32,000–48,000 tons in the wet season. The impact of seasonal variation on aggregates sales has been established. From the research conducted, aggregate sales were higher in the dry season across the three quarries with Samchaze quarry having the highest sale of 11,000–15,000 tons. Aggregate sales dropped significantly in the wet season with Samchaze quarry also having the highest sale of 5,500–6,500 tones. This sales information gave the indication that aggregates demand was higher in the dry season when compared with the wet season. The three quarries spent on making hauling and transportation routes accessible to reduce the impact of seasonal variations in all

seasons. ENL quarry spent ₦212,500, Western quarry spent ₦218,550 and Samchaze quarry spent ₦182,500 on hauling and transportation routes.

Since our season is not stagnant, the main issue that should be considered by all quarries is to mitigate the impact caused by seasonal variations on quarry operation. Seasonal changes are a major factor that must be put into consideration for the easy running of a quarry. Since seasonal events cannot be prevented, quarries must find a way to adapt to them so that operations will not be disturbed. The following recommendation should be implemented by quarries to mitigate the effects of seasons on quarry operations:

1 All equipment and machines should be in good working conditions.

2 Enough personnel should be on site to attend to every operation.

3 Work tents should be constructed over the crushing unit so that minimal rainfall will not result to the suspension of the crushing operation.

4 Weather forecast should be checked before engaging in blasting operation to minimise unfriendly weather condition.

5 Enough blasting should be done during the dry season to cater for the wet season.

6 Muck piling of runoff mine should be done closer to the crushing unit during the dry season to prevent difficulties in hauling during the wet season. The runoff mine should also be mucked under work tents.

7 Watering of the crushing unit should be done at interval to reduce dust generation and inhalation.

8 Hauling and transportation routes should be constructed to withstand every seasonal condition and review should be done at intervals.

9 Protective gears should be provided for all workers and must be always worn on the quarry site. Healthcare facilities should be provided for the quarry workers. Check-up should be done monthly for the quarry workers.

Acknowledgements

The authors wish to appreciate the three quarries (Samchaze quarry, Western quarry and ENL quarry) staff for their support during data collection and also TETFUND NRF with code (TETF/DR&D-CE/NRF 2020) for supporting this research work.

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