Chapter 5
Thermal Conditions in Artisanal Mine Sites: A Case Study of Ife Area, Southwest Nigeria

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Abstract In the past few decades, mining has recently become important in the southwestern Nigeria. Existing studies on the implications of mining activities in the region have mostly overlooked the capacity of activities around the sites to impact significant changes in the microclimate of neighbouring communities. The present study is thus an attempt to evaluate daytime changes in thermal conditions (in terms of air temperature and relative humidity, heat index and dew point temperature) and perceptions of 15 key respondents at the mining communities in Atakunmosa West Local Government in Osun State, Nigeria. Data were obtained at daytime (between 0900 and 1800 Nigerian Local Standard Time). Heat index and dew point temperature were computed for selected locations and the data were analyzed using geo-statistical and qualitative techniques. Results showed higher values of temperature and increased tendency for thermal stress at the mine sites than at locations far away from the site. Majority of residents (>60%) explained that heat-related illness (including dry skin, heat rash) has increased since the mining activities began in the area. The study concluded that temperature increase, and thermal and associated stress would be compounded in communities around the mine sites. Mine sites restoration, increased awareness on coping strategies to heat stress and inclusion of propensity for heat concerns in Environmental Impact Assessment for mining activities are therefore recommended.

Keywords Thermal conditions · Mine sites · Air temperature · Heat stress

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J. C. Egbueri et al. (eds.), *Climate Change Impacts on Nigeria*, Springer Climate,
https://doi.org/10.1007/978-3-031-21007-5_5

Introduction

Mining as a primary activity has been in existence from ages. Many researches have been carried out to explain that almost, if not, all the countries in Africa are active in one or more possession and production of minerals (Aigbedon and Iyayi, 2007; Oladipo et al. 2014; Adesipo et al. 2020). Their economic importance on the well-being of the environment was also discussed (Ralph et al. 2018; Omotehinse and Ako 2019; Adesipo et al. 2020). However, over 95% of the mining activity is artisanal and another 95% of this portion is illegal (Mallo 2012). Studies (e.g. Eludoyin et al. 2017; Oyebamiji et al. 2018; Orimoogunje 2010) have been carried out on Southwestern Nigeria to assess the multifaceted impacts illegal and artisanal mining activities can have on a community. Their results reveal that illegal and small-scale mining activities often take place in areas that are rural and undeveloped. Though mining has its positive impacts on the economy (Soderholm and Svahn 2015; Ralph et al. 2018), most of its discussed effects in studies (e.g. Eludoyin et al. 2017; Oyebamiji et al. 2018; Adesipo et al. 2020) have been disastrous to the environment (Human health, Land, Water, Atmosphere and Vegetation).

Itagunmodi, a rural area and village (of the many others) in Atakunmosa West Local Government in Osun state, Nigeria, is notable for artisanal gold mining. Itagunmodi and some other close villages have undergone many researches in times past focused on the impact of the mining activity on soil, plants and water. However, most of these researches have overlooked the capacity of activities around the mining sites to impact significant changes in the microclimate of neighbouring communities. Martinez et al. (2021), amongst other authors, noted that the method of mining in the area is associated with various environmental challenges. For example, studies showed that mining activities in the area typically involves search and identification process that includes creation of slurry (process involving soil-water mix), and setting up of a sluice system with jute sack to collect the gold particles as described by Bibitayo (2018) and Tun et al. (2020). At the end, a rubber pan is typically used for the finishing process and with the gold particles poured into a bowl for further treatment with mercury. The method of gold exploitation has come with various challenges due to the inappropriate methods applied and its environmental consequences. Release of obnoxious gasses such as sulphur-dioxide from processing plants, runoffs from mine processes and leakages that are injurious to human and environmental health are attributes of many mine sites (Ralph et al. 2018; Martinez et al. 2021). Gold mining also typically produces silica-rich respirable dust particles that are capable of causing dangerous health issues and sometimes loss of lives (Andraos et al. 2018).

Consequently, as much as mining activity takes place, it continues to alter an area's environmental balance (Eludoyin et al. 2017). In developed countries, measures are being employed to mitigate the adverse effects of mining activities, though may be inadequate (Soderholm and Svahn 2015). However, in underdeveloped and developing countries as Nigeria, the effect of artisanal mining affects the environment strongly. Researchers have revealed the adverse effect of mining to the environment (Salami et al. 2003; Oyebamiji et al. 2018; Adesipo et al 2020), which includes its effect on soil, flora and fauna, water and chemical compositions (Orimoogunje 2010; Omotehinse and Ako 2019). This study aims to assess the impact of this primary and small-scale activity on the microclimate of the neighbouring communities.

Materials and Methods

Study Area

Itagunmodi is a region located within latitude 7°30′ N–7°36′ N and longitude 4°37′ E–4°42′ E, in Atakunmosa West Local Government, Osun state, Southwestern Nigeria (as seen in Fig. 5.1). Itagunmodi is close to towns such as Ile-ife, Ilesa in Osun state. The region covers an area of about 73.6 km^2 and labelled by tropical dry and wet climate pattern. It has mean annual temperature varying between 25.7 and 27.7 °C, while relative humidity over the area varies from 60 to 80%. The average rainfall of the study area is about 140 cm or approximately 1343 mm per year. The characteristics of the study area is a reflection of the parent materials and the climatic region within which it falls (Eludoyin et al. 2017). Itagunmodi's major land use is agriculture, in particular, the cultivation of cash crops such as plantain, oil palm, cocoa and kola. Also, it accommodates the plantation of food crops amongst which are yam, cassava and fruits. The soil is largely a mixture of sands and clays on the surface.

Data Collection and Methodology

Air temperature and relative humidity of different locations were obtained through north–south and west–east axes of selected region using portable weather station. The coordinates (x, y) of selected stations were also obtained with a handheld global positioning system (GPS, Magellan etrex model, ±10 m accuracy). Data were obtained at daytime (between 0900 and 1800 Nigerian Local Standard Time) at different locations within active and dormant mine sites' region and areas outside them within the study area. Heat index and dew point temperature were computed for selected locations and the data were analyzed using the National Weather Service Heat Index and Dew Point Temperature Calculator of the National Oceanic and Atmospheric Administration (NOAA). The heat index and dew point temperature are well known integrative thermal indices, while air temperature and relative humidity are considered as unitary indices. Both integrative and unitary indices have been found to be part of the many accepted indices for use in the regions (see Eludoyin and Oluwatunmise 2021).

Although studies have revealed that temperature variations are better noted at night, however, they could not be assessed for security reasons and lack of standard unmanned recording instruments for such measurements during the time of

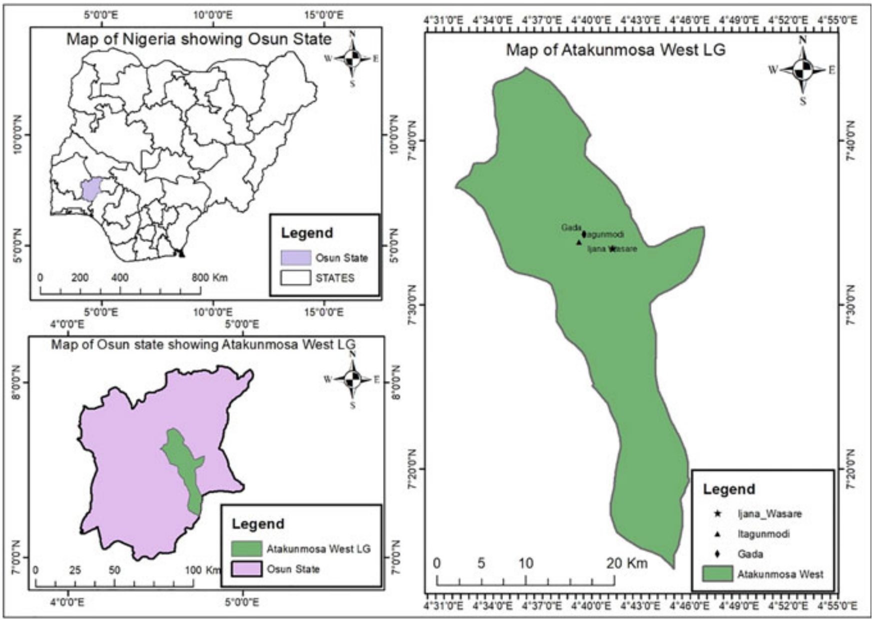


Fig. 5.1 Map of study area (*Source* Researcher)

data collection. The data were analyzed using geo-statistical and qualitative techniques. Readings were collected from portable weather station held about 1.5 m above the ground surface with hands stretched out for at least two minutes to minimize interference with land surface heat at each data point.

A set of structured questionnaire backed with in-depth interviews were administered to 15 purposively selected residents (surrounding village dwellers and miners) who were considered key informants for the study. The responses were analyzed using descriptive statistics and content analysis. The air temperature, relative humidity and thermal indices data were described using both descriptive and graphical analyses, including isotherms with PAleontological STatistical (PAST; Version 3). Trends were also examined using simple linear regression.

Results and Discussion

Statistical Analysis

Data were generally subjected to statistical analysis using Microsoft Excel (version 2013) and PAleontological STatistics Version 3.12 (Hammer et al. 2001), while descriptions of spatial variations in temperature values are drawn as Isolines. The relative humidity and temperature data, alongside the dew point temperature and heat index values, were further analyzed in Microsoft Excel to assess their respective mean and standard deviations. The relationship as well as the linear regression equation between the temperature and the relative humidity, heat index temperature and dew point temperature were assessed using Past 3.

Results

Relationship between air temperature and relative humidity, dew point temperature and heat index temperature.

Table 5.1 shows the mean, coefficient of variation and standard deviation of data collected from 88 points within and outside 2 active mine sites as well as 2 passive mine sites, in the morning and afternoon in Atakunmosa West Local Government.

Observably, data collected and analysis made (Table 5.1) show that the higher the temperature, the lower the relative humidity as seen in Fig. 5.2 and agreed by Ayanlade (2017). The mean temperature within the mine sites is seen to be greater than outside the mining sites while its relative humidity reduces. This is also observed in the mean heat index and mean dew point temperature of the mine sites (Table 5.1). However, the mean data obtained from within and outside the active mine sites are higher than the mean data obtained from passive mine sites. This depicts that the passive mine sites are beginning to get restored back to normal; temperatures, heat indexes and dew point temperatures are reducing while relative humidity is increasing. This is a pointer that the mining activity in the active mine sites has significant effect on the temperature, relative humidity, heat index and dew point temperature values of the area. By extension, this relationship could be similar for other mine sites.

On the other hand, heat index combines the air temperature and relative humidity to be explained. Heat index expresses in numerical values the relationship between comfort and discomfort. It explains how temperature (hotness) is felt on the body compared to the initial air temperature and humidity present in the atmosphere of a given location. Heat index and air temperature values collected and analyzed exhibit a direct relationship and increase as temperature increases as shown in Fig. 5.3. This is due to the intervening impact of relative humidity values.

The mean heat index (body heat) values are also seen to be higher within the mining sites than outside the mining areas (Table 5.1). Observably, the body-felt temperature, that is, heat index temperature, is greater than the air temperature, implying that the humidity level in the atmosphere does not permit for perspiration evaporation, thus resulting in excess body-felt temperature.

The coefficient of variance in the mine sites is observed to vary quite significantly from within to outside the mining sites (Table 5.1). On the average, the coefficient of variance within the mine sites is still seen to be greater than that of the outer areas of the mining sites. There is also a higher body-felt temperature within the mine sites

Table 5.1 Mine sites and their collected microclimatic parameter values

Mine sites	Areas	Temperature (°C)			Relative humidity			Heat index (°C)			Dew point temperature (°C)		
		Mean	C.O.V	S.D	Mean	C.O.V	S.D	Mean	C.O.V	S.D	Mean	C.O.V	S.D
Active	Within Mine Sites	38.87	8.18	3.18	46.38	12.14	5.63	48.86	11.73	5.73	25.36	7.37	1.87
	Outside Mine Sites	37.21	8.14	3.03	49.25	10.36	5.10	46.20	11.93	5.51	25.29	10.87	2.75
	Average	38.04	8.16	3.11	47.82	11.25	5.37	47.53	11.83	5.62	25.33	9.12	2.31
Passive	Within Mine Sites	32.03	17.64	5.65	55.07	24.50	13.49	35.63	21.67	7.72	21.25	10.07	2.14
	Outside Mine Sites	31.4	16.85	5.29	57.65	27.60	15.91	34.45	19.33	6.66	21.33	7.45	1.59
	Average	31.72	17.25	5.47	56.36	26.0	14.70	35.04	20.5	7.19	21.29	8.76	1.87

Source Field Survey Data Analysis, 2018

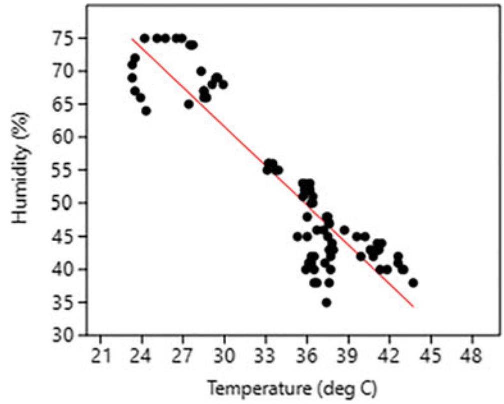


Fig. 5.2 Relationship between temperature and relative humidity values (morning and afternoon)

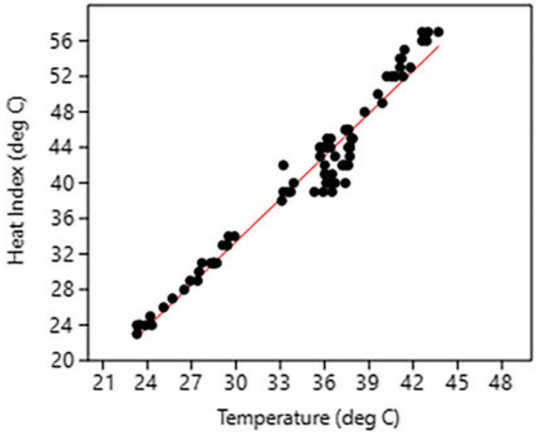


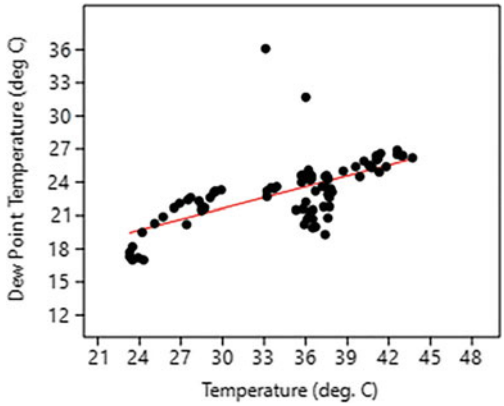
Fig. 5.3 Relationship between temperature and heat index temperature values (morning and afternoon)

than outside the mine sites. More to this, the average heat index values at the active mine sites are seen higher than those of the passive mine sites. This depicts that it is more likely for perspiration to evaporate faster at the passive mine sites than the active mine sites.

The aspect of finding the relationship between air temperature and dew point temperature may seem unimportant. However, to express how much the temperature of an environment must drop before dew can be seen also has an indirect relationship with temperature, as seen in Fig. 5.4. It states how much the environment is heated as well as the extent to which it must be cooled to experience any kind of precipitation.

With reference to Table 5.1, the mean dew point temperature of the active mine sites is seen to be slightly lesser within than outside the mine sites. This shows that the temperature outside the active mine sites must drop higher than within to experience dew. In the same wise, the mean dew point temperature outside the passive mine sites are seen slightly higher than the mean dew point temperature within the passive mine sites. More obviously on the contrary, the overall average mean dew point

Fig. 5.4 Relationship between the air temperature and dew point temperature (morning and afternoon)



temperature at the active mine sites is higher than those of the passive mine sites. This depicts that the temperature needs to drop more at the active mine sites than at the passive mine sites to experience dew.

According to the urban heat island theory (Ayanlade 2017), places with higher temperature are notable for reduced population of vegetation that tend to make much more breeze and oxygen available to their surroundings. In the absence of or very low rate of vegetation in an area, coupled with an increasing temperature, there tends to be an increase in the body-felt temperature. Also, as air temperature increases within these areas, the temperature at which dew would be formed increases as the atmosphere loses more vapour to evapotranspiration.

Diurnal Variation in Temperature

Figure 5.5a and b show the diurnal variations in the mean temperature values in different land use in Atakunmosa West Local Government Local Government Area in the late parts of 2018. Figure 5a is an isotherm generated in the morning (09:00–10:00 LST) and Fig. 5.5b in the afternoon (12:00–13:00 LST). Figure 5a shows isotherm distribution lining in a north–south direction, except for hot spots with heat islands at Itagunmodi, Isaobi and an inverse heat island at Igun-Ibodi. On the other hand, isotherm lines southwest to East direction with no heat islands but higher temperature values at the rural parts of the map extract (Itagunmodi, Eriperi, Ijana Wasare, etc.). In Fig. 5.5a, highest temperature values were obtained in areas around mining sites 3 and 4, and towards areas southwards, as well as areas confluencing around Isaobi settlement (village). However, lower temperature values were seen at areas around Igun, Ibodi and along the main road on the map extract.

In Fig. 5.5b, highest temperature (44 °C) was obtained around the rural areas, most notably higher at areas southwest of mining sites 3 and 4 while the areas towards the Ilesha Township, north-eastward of mining sites 1 and 2, recorded the

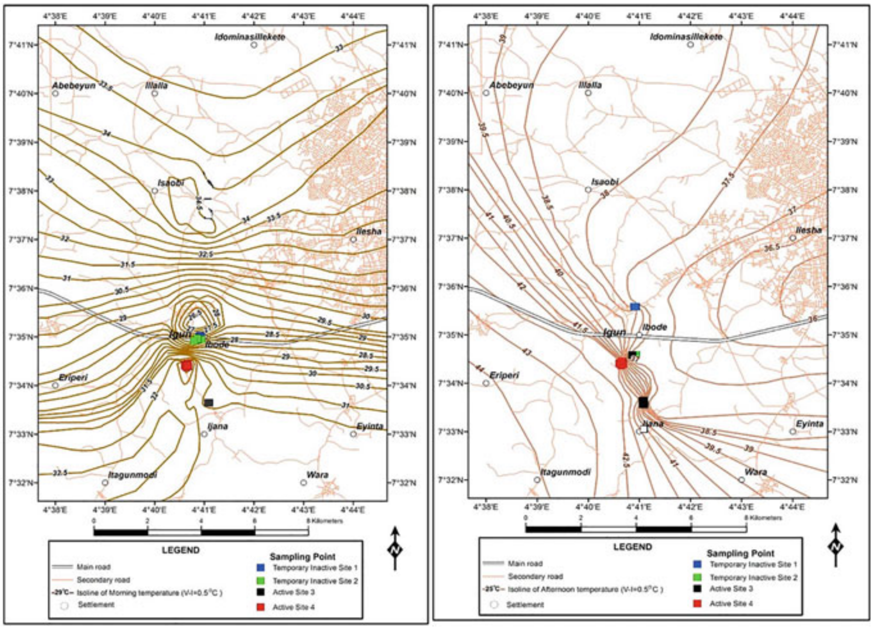


Fig. 5.5 **a** and **b**: Isoline maps showing morning and afternoon temperature variation around mine sites

low temperature values especially as seen on the nearest isotherm to Ilesha across the main road (36 °C). The outskirts of Ilesha town as shown in Fig. 5.5a and b appeared to contain lesser concretized, urbanized or cemented surfaces, and much more vegetation surfaces than the township of Ilesha. Similarly, the distribution pattern of Isotherms around the main road on Fig. 5.5a and b shows a closely lined pattern of Isotherm around the mining sites 1–4 (26.5–32.5 °C in the morning and 37–42 °C in the afternoon), depicting a close variation of temperature within the four mining sites, with mining sites 1 and 2 having lower temperature values and mining sites 3 and 4 having higher temperature values.

Summarily, Fig. 5.5a and b have temperature values closely packed around the mining sites 1–4 both in the morning and the afternoon. However, the mining sites 3 and 4 have higher temperature values than mining sites 1 and 2. Also, the rural areas and surrounding settlements (villages) exhibit higher temperature values than the CBD Ilesha Township. Incidentally, this forms the hotspots on the map, negating the theory of Urban Heat Island, even as much more vegetation is seen in both Fig. 5.5a and b, leaving the built-up areas of Ilesha north-eastward with much of tarred roads, higher population, denser housing structures and lesser vegetation than the other parts of the map.

These properties have been observed to be capable of absorbing and emitting heat (Samuels 2005; Ayanlade 2017; etc.), still, rural areas with more vegetation, scattered housing structures, lower human population and scattered untarred roads tend to absorb and emit more heat due to the mining activities rampant in the areas outskirt of the Ilesha Township (Fig. 5.5a and b). These pattern is contrary to the pattern obtained in Akure, Nigeria (Akinbode et al. 2008). Other studies carried out by scientists (Oke 1982; Svensson and Tarvainen 2004; McKenzie 2015 etc.) agree that urban areas tend to be warmer than the surrounding rural areas. From Fig. 5.5a and b, mining of gold plays a significant role in the 'abnormal' distribution of temperature. The areas exterior of Ilesha Township were generally warmer than the interior.

Perception on Effect of Thermal Discomfort in the Study Area

Of all the 15 people interviewed, 11 people (73.3%) prefer sleeping in their courtyards/backyards during the dry season. The other 4 people (26.7%) suggested the use of locally made hand fans. They explained that sleeping outside is not safe for them. They advised alternative means of generating breeze as they hope for a stable hydro-electronically generated power supply. Observably, all these 4 (26.7%) who dislike sleeping out are female while 9 of the 11 who prefer sleeping out are male. These 4 gave reasons for why they could not sleep outsides: to avoid being raped and to avoid excess mosquito bites.

As a result of excess heat, some of these population gave instances of the kind of sickness/diseases they have had in times past. This research reveals that 80% of the population experiences dry skin while 60% experiences heat rash. Some other suggested diseases/illnesses experienced more excessively since the activity had begun, malaria, dizziness, fainting and lots more, following the findings of Brousse et al. (2019) and Eludoyin and Oluwatunmise (2021).

This gave rise to the question of whether the season is as it used to be or changes abnormally. Of the total population, approximately 33% see the weather condition and seasonal change as normal while 67% see the changes as caused by some effects, thus being abnormal. The effect that was seen to be as a result of mining activity to have caused the abnormal weather condition was supported by 60% of the population who agreed that the weather is abnormal. The remaining 40% discussed that other factors gave rise to the weather change safe mining activity. The 40% of the population who discussed that the change in weather condition exist, but not due to mining activity, suggested other factors that could have given rise to weather change. These include deforestation, land degradation, atmospheric disturbances from anthropogenic activities, increasing population and nature (Spickett et al. 2011; Harden 2012; Parkes et al. 2019 etc.).

According to the statistics, of the population who discussed that the change in weather is not as a result of mining, 60% suggested that deforestation, cutting down vegetation and leaving land surface open are factors while all of them consented that land degradation causes excess heat as soil is being disturbed in the process of mining. About 40% of them agreed that the abnormal weather change is caused by anthropogenic activities such as constructions within the settlements. Around 40%

also discussed that the increasing population rate increases the temperature or heat in the environment. Lastly, 40% suggested that the change is a natural phenomenon.

Of the 67% of the total population who agreed that the season/weather is abnormal, all gave suggestions to means of solving the problems. Amongst these solutions are to send the gold miners packing, stop deforestation, charge land owners to court, etc. About 60% of these 67% argued that the mining activity be stopped and the miners be sent packing and mining activities be stopped or reduced largely. Around 10% of the 67% argued that the land owners who gave land out to the miners be charged to court.

Observably, many who suggested that the miners be sent packing away from the environment and mining be stopped or reduced, are indigenes and inhabitants of the settlements. On the other hand, the only person who suggested that land owners be charged to court is a chief in Ijana Wasare who claimed that he opposed giving out land to miners few years ago but was opposed by the council of chiefs. He further discussed that greed made them lease out land but they regret their actions as at present moment because their farmlands are being snatched totally away from them.

Generally, 5 people of the total respondents (15 people) discussed that the effect of mining on the environment has been positive while the remaining population (10 people) expressed their view as to the negative impact of mining on the environment. Observably, the 5 people who viewed the effects of mining to be positive are either Chiefs or Hausas (miners and miners' wives). The opinion to stop mining was supported by 11 people of 15 while 4 people explained why it should not be stopped. Some of the reasons given by these 11 people include the need to stop deforestation, reduce crop/food loss, stop soil degradation, ensure safe movements, stop selfish interest of land owners, end abnormal heat/storms, prevent sexual harassments and prevent inter-tribal fights/accidents. On the other hand, the 4 people who suggested that mining should not be stopped gave reasons such as making a living and encouraging population growth.

Discussion, Conclusion and Recommendation

The investigation aimed at assessing the impact of small-scale artisanal mining on the thermal weather of Itagunmodi and its environs, Atakunmosa West Local Government, Osun state, Nigeria. Mining activity within the mining area settlements has increased the population of the area as suggested by the inhabitants of the study area, and as well increasing the net income of the land owners in the areas. Yet, mining activity has been seen to have adverse effect on the weather as well as the biodiversity of the environment (Aigbedon and Iyayi 2007; Singh et al. 2021). Small-scale illegal mining has been seen to directly affect the environment, weather, man, animals, water and plants and threatens life existence in an area (Mallo 2012; Darko et al. 2021; Suglo et al. 2021 etc.). The air temperature has been seen to be higher within mine sites than surroundings and also exhibit an inverse relationship with relative humidity.

The body-felt temperature is also seen to be higher within mining environments and was also experienced largely by inhabitants of the surrounding settlements. The isotherms constructed display the variation in temperature from the closest urban settlement (Ilesha) to the mining areas, showing that the temperature is higher in mine sites than in urban areas, both in the morning and noon. There is also diurnal variation in the temperature as seen in the isotherms. This is due to the anthropogenic activities of mining that takes place around the sites. This is to say that it is possible for the air temperature within a rural area to be greater than that of an urban area, provided the small-scale artisanal mining comes in place (Owolabi et al. 2021).

Researches carried out have shown that temperature is evident in artisanal mine sites in developed countries, though measures to reduce them are being taken (Soderholm and Svahn 2015; Ralph et al. 2018). However, their effect on man's health and well-being as well as the weather has been seen irrelevant as many studies are only been restricted to areas such as its effect on water bodies, biodiversity, geomorphology and economy. This study has thus revealed that small-scale artisanal mining activity affects the weather of an environment greatly, and also has adverse effect on the well-being of man and the surrounding biodiversity.

In conclusion, temperature increase and associated stress would be compounded in communities around the mine sites. Increased awareness on coping strategies to heat stress and inclusion of propensity for heat concerns in Environmental Impact Assessment for mining activities are therefore recommended.

Acknowledgements Special gratitude to my co-author, Prof. O.O.I. Orimoogunje, for his advice and assistances to the completion of this beautiful research. I definitely will not forget the immense contribution of Dr. A.O. Eludoyin for his wonderful assistances too. I acknowledge the colleagues who assisted in data collection processes. I also recognize the incomparable cooperation of miners and in-dwellers of villages where data were collected—it was an awesome moment with you all. In the same vein, I acknowledge the comments of the reviewers in making this manuscript better. Thank you.

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