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Evaluation of Occupational Therapy Practices for Artisanal Gold Mining in Bagega Community, Zamfara State, Nigeria

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ABSTRACT

Background: The enormous numbers of people involved in artisanal gold mining (AGM) together with primitive methods being used in processing gold have resulted in health and environmental challenges. Based on this, both the local and international stakeholders in mining and health sectors engaged in therapeutic practice to mitigate the challenges.
Methods: Physical observation and soil samples were assessed in order to identify the occupational health hazards associated with AGM while questionnaire was used to evaluate the effectiveness of adopted occupational therapy practices across the study area. Soil sample was randomly collected between the depths of 0-20 cm. Soil digestion was carried out in triplicate and lead concentration was determined using Atomic Absorption Spectrophotometer.
Results: The result of a cumulative carcinogenic risk lifetime for ingestion, dermal contact and inhalation exposure pathways were given as 1.86×10^{-1}, 8.83×10^{-4} and 5.45×10^{-6} respectively. The major occupational health hazards associated with AGM were body weakness, brain damage, gastrointestinal tract, neuropsychiatric, injuries and death of miners while the removed occupational therapy practices adopted were awareness campaign, remediation/chelating treatment, sensitization and use of modern equipment training.
Conclusion: The study established that most of the adopted occupational therapy practices were efficient and effective to ensure safe practices of AGM across the study area.

1. Introduction

Zamfara state is blessed with abundant mineral resources most especially gold deposits which were found in Maru, Anka and Bukkuyum Local Government Areas of the state [1]. The gold deposits have been in existence for many years and are being mined by Artisanal Gold Miners (AGMs).

Hinton attributed the enormous rise in the figure of Artisanal Gold Miners in Zamfara State in 2009 as a result of the increase in the price of gold across the world. United Nations Environment Programme (UNEP) revealed that over one hundred million people are participating in artisanal gold mining (AGM) worldwide while opafunso predicted that about ten thousand people are having their living from artisanal gold mining (AGM) in Zamfara State [2-4].

Consequently, the high numbers of people take part in AGM together with primitive methods being used in processing the gold; the miners have witnessed a lot of health and environmental challenges [5]. For instance, Katz reported numerous injuries and deaths of miners due to shaft collapse during gold ore extraction while MSF identified the non-immediate consequence of environmental health problems caused by AGM as increasing in mortality rate [6,7].

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Also, the recent outbreak of lead poisoning from AGM in Zamfara State was described as the worst outbreak in the modern history [8].

The lead poisoning was discovered by Medecins Sans Frontieres during the immunization programme in Bagega communities in Zamfara State, Nigeria [7]. The study carried out by teams of adept discovered high levels of lead in the blood of miners' children, which claimed more than 400 children's lives [9]. The studies of Hurwitz discovered that soil, air and water of the Bagega Community were polluted by the chemical used for the processing of gold which caused various health challenges to the miners[10].

As a result of serious environmental issues and high number of children poisoned from the activities of AGM across the study area, both the local and international stakeholders in mining and health sectors engaged in therapeutic practice. According to Gutman and Raphael, occupational therapy is the use of assessment and treatment to develop, recover, or maintain the daily living and work skills of people while WFOT defined occupational therapists as someone that can design and prescribe assistive devices that can improve the quality of the activities of daily living for people [11,12]. The principal aim of engaging in occupational therapy practice is to aid the miners to carry out their work in a way that abate the occupational health hazards. Therefore, this study highlighted various occupational health hazards associated with the AGM and evaluated the sustainability of adopted occupational therapy practices that will enhance miners good health and environment friendly.

2. Materials and Methods

2.1. Description of the Study Area

The study area is located in Anka Local Government Areas of Zamfara State with the coordinates: 5.999E and 6.049E; 11.873N and 11.861N as shown in Figure 1.

Farming is the major occupation of the people until 2009 when artisanal gold mining becomes important socioeconomic activities of the people due to rise in worldwide gold prices [13]. The major farming products produce in the study are: carrot, sweet potatoes, millet, guinea-corn, maize, rice, groundnuts, cotton, vegetables, tobacco and beans.

2.2. Physical Observation

The study made use of naturalistic observation which involves making systematic observations of human behaviour in the study area where artisanal gold mining is being carried out. The physical observation was used as instrument to describe the mine setting and the activities of the miners regarding the perspective of the participants so as to get knowledge of the context of occupational health hazards in the study area. The physical observation made in the study includes: source of the gold ore; methods of processing of gold ore; people involved in the processing of gold; chemical used for the processing of gold; sources of water used for the processing of gold and symptom(s) preceded the death of children. The data collected from physical observations were documented and digital photographs were taken to actualize the reality of the facts collected during the study.

Figure 1: Map of Zamfara state showing the study area

2.3. Soil Sampling, Preparation and Analysis

Soil samples were collected at different locations where gold are being processed. The samples were group into A, B, C, D and E where thirteen (13) samples were collected at A, four (4) samples at B, ten (10) samples at C, nine (9) samples at D and five (5) samples at E. Completely randomized experimental design was used to collect soil samples between the depths of 0 – 20 cm with an auger in accordance with ASTM standard methods. The digestion was carried out in triplicate in accordance with ASTM standard procedures while the concentration of lead metal was determined using Atomic Absorption Spectrophotometer in accordance with ASTM standard method [14-16]. The carcinogenic risk values for lead metal through soil ingestion, inhalation and dermal exposure pathways were estimated in accordance with US EPA by using Equation (1) [17].

$$CR = CDI * SF \quad (1)$$

Where: CR-carcinogenic risk that represents the probability of an individual lifetime health risks from carcinogens ;
CDI - chronic daily intake of carcinogens ($mgkg^{-1}day^{-1}$):
SF - slope factor of hazardous substances ($mg\ kg^{-1}d^{-1}$).

The cumulative carcinogenic risk is the sum of individual risks and is calculated from Eq. 2:

$$R_{ing,inh,der} = \left(ED_{ing,inh,der}\right) * SF_{ing,inh,der} \quad (2)$$

Where: $R_{ing,inh,der}$ – risk cumulative carcinogenic rısk for soil ingestion, inhalation and dermal pathways;
$ED_{ing,inh,der}$ – soil exposure dose via ingestion, inhalation and dermal contact [mg/kg/day];
$SF_{ing,inh,der}$ – soil carcinogenic slope factor from ingestion, inhalation and dermal pathways [mg/kg-day]$^{-1}$.

The acceptable or tolerable risk for regulatory purposes is within the range of 10^{-6} [18].

2.4. Occupational Therapy Practices

For the purpose of this study, questionnaire was used to obtain useful information about the result of occupational therapy practices adopted for the miners in order to minimize occupational health hazards associated with artisanal gold mining in the study area. One hundred thirty-five questionnaires were randomly distributed to the miners of which one hundred twenty were returned. The occupational therapy practices carried out includes awareness campaign on the occupational health hazards associated with artisanal gold mining, sensitization of miners on the dangers of processing gold within the living/playing environment, remediation of lead polluted sites and chelating treatment for lead poisoned children, enforcing miners to relocation processing site outside the living environment, monitoring and regulating the activities of AGM by concerned Agencies and ministries, penalty for environmental offenders, formalization of miners into cooperative society and training of miners on the use of wet milling machine for gold processing.

3. Results and Discussion

3.1. Physical Observation

Digital photographs were used to portray the findings of physical observation as shown in Figure 2. P1 shows Horo gold mine site which is located between Bagega and Sunke Community. Gold ore was mined to the depth of 45-60 m using chisel, hammer and sometimes explosive and brought to the surface using ropes as shown in P2. The mined gold ore was then bagged into 50 kg and brought to the processing sites using motorcycles as shown in P3. The occupational health hazards associated with these primitive practices are: injuries caused by the use of mechanical tools (chisel, hammers); protracted injury and fatigue caused by the use of rope; burns, fractures and death of miners caused by the use of explosive, motorcycle and rock falls due to rickety supports. The severity of these primitive methods was also established in the study of Katz who reported numerous injuries and deaths of miners due to shaft collapse during gold ore extraction in many African countries [6]. At the processing sites, the miners engaged their families (wife/wives and children) in breaking the lead-rich gold ore into small sizes using metal bars or with mortar and pestle (which was also used for their food) and sun dried it as shown in P4 and P5 respectively. The major occupational health hazards associated with these primitive methods are: injuries caused by the use of metal bars; eye irritation caused by the dust; dizziness, faintness and excessive thirst caused by heat stress; ingestion of polluted soil, water and food caused by the use of domestic cutlery.

The dried gold ore was pulverized, using flour milling machine; then the gold was sluiced using wooden sluice box as shown in P6 and P7 respectively. The major source of water used for sluicing process is pond water filled with waste disposal as presented in P8. The major occupational health hazards associated with these methods include hearing impairment, eye irritation, dust inhalation and heat stress caused by the use of milling machine; convulsion, vomiting, body weakness, brain damage and death caused by the ingestion of lead contaminated soil and water. Similarly, MSF identified the non-immediate consequence of environmental health problems caused by AGM as increasing in mortality rate [7]. P9 and P10 presented lead poisoned patients admitted in Anka Hospital, Zamfara State, Nigeria and remediation of lead contaminated soil with trained youths.

Liquid mercury was added with sluiced gold ore to form an amalgam that picked up most of the gold from the silt. The amalgam was heated with blow torches to evaporate the mercury, leaving gold pieces behind as shown in P11 and P12. The major occupational health hazards associated with the methods include nausea, vomiting, headache, fever, chills, abdominal cramps, diarrhoea, direct irritation of the gastrointestinal tract, neuropsychiatric caused by the use of mercury to recover gold. Similar findings of the effects of lead and mercury from artisanal gold mining are also reported where gold are being mined across the world [19-24].

3.2. Cumulative carcinogenic risk (CCR) for soil exposure

The result of a cumulative carcinogenic risk lifetime for each exposure pathways is presented in Table 1. The table revealed that soil ingestion is the major contributor of carcinogenic lifetime risk when compared with 1×10^{-6} WHO standard of carcinogenic lifetime risk. Also, by comparing the cumulative carcinogenic lifetime risk posed by each site in relation with the combined exposure pathway as shown in Figure 3, it was established that site A has the highest percentage of 48% contribution to the carcinogenic lifetime risk descending order of A > D > E > C > B.

3.3. Occupational Therapy Practices

The results of occupational therapy practices (OTP) to curtail occupational health hazards (OHH) of artisanal gold mining (AGM) show that 67.0 %, 8.0% and 25.0% of the miners were sensitized to guard against occupational hazards through awareness campaign in village meetings, newspapers and radio as shown in Table 2. According to the miners, regulatory agencies made available guidelines for artisanal gold mining operations during the awareness campaign and penalty for offenders were clearly stated. Most of the miners commended the sensitization therapeutic practice of government/NGOs as accorded them the danger

of processing gold within living environment, danger of involving children in gold processing and what to do after processing before returning to their respective homes. As a result of this, the occupational health hazard of spreading of lead dust during gold processing was curtailed.

Figure 2: Digital photographs present the findings of physical observation

Table 1: Cumulative carcinogenic risk for soil exposure pathways

Site ID	Soil ingestion	Dermal contact	Inhalation
A	8.9×10^{-2}	2.6×10^{-4}	4.82×10^{-7}
B	7.60×10^{-3}	5.02×10^{-5}	4.14×10^{-7}
C	1.78×10^{-2}	1.16×10^{-4}	9.72×10^{-7}
D	4.65×10^{-2}	2.74×10^{-4}	2.26×10^{-6}
E	2.44×10^{-2}	1.87×10^{-4}	1.32×10^{-6}
Total	1.86×10^{-1}	8.83×10^{-4}	5.45×10^{-6}

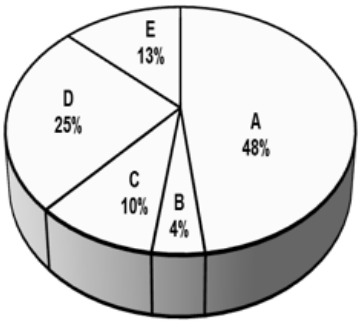

Figure 3: Percentage contribution of soil exposure

Relocation of processing sites outside the living/playing environment has also helped in preventing occupational health hazard of AGM and other chemicals used for gold processing. Table 3 revealed that 85.0% of the miners have relocated to the government approved processing sites as a result of sensitization against the occupational hazards in processing gold within the living environment. Also proper monitoring of miners by regulating agencies and the fear of penalty meted for the environmental offenders has ensured strict compliance to the relocation to government approved processing sites which minimizes the occupational hazards in AGM.

Table 2: Awareness campaign against OHH

Activities	Frequency	Percentage
Community Meeting	80	67
Media (Newspapers)	10	8
Radio and T.V stations	30	25
Total	120	100

Source: Computed from survey data, 2017

Table 3: Relocation to government approved sites

Activities	Frequency	Percentage
Yes	102	85
No	18	15
Total	120	100

Source: Computed from Survey Data, 2017

Meanwhile, Figure 4 illustrates the training organized by miners to ensure occupational therapy practices during the course of carrying out their work which includes sensitization training, remediation/chelating treatment training and use of modern equipment training. Figure 4 revealed that 53.0% of the miners have undertaken remediation and chelating treatment training, 34.0% have undertaken sensitization training and 13.0% have undertaken the use of modern equipment training. The training accorded the miners to avert the spread of lead dust and other occupational health hazards that have negative effects on their health.

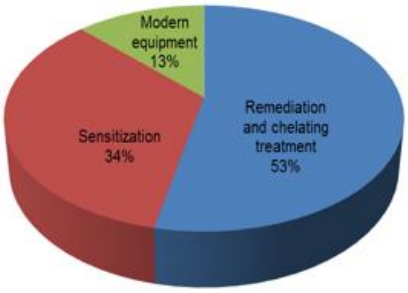

Figure 4: Types of training organized for miners

Remediation and chelating treatment carried out in the study area reduced the rate of miners' exposure to lead contaminant and minimized the number of child deaths in the study area. Figure 5 shows that 88.0% of the miners confirmed that remediation had successfully carried out in order to mitigate the lead poisoning. The miners enumerated the methods of remediation as the removal of lead contaminated soil surface and replaced it with clean soil, which was carried out by trained youth and supervised by TerraGraphics Environmental Engineering as shown in P12.

Also, 70.0% of the miners stated that chelating treatment had been successfully carried out for more than 5,000 children across the study area. The chelating treatment was done after the remediation in order ensure sustainable occupational therapy practices across the study area.

Figure 6 revealed that an average of 51.0% of the miners agreed that poverty is one of the major barriers stalled them to adopt OTP when carrying out their work while 18.0% responded that inaccessibility to modern equipment denied them to adopt OTP and 31.0% attributed the reason to the lack of technical know-how. The study therefore suggested that in order for miners to ensure OTP government and stakeholders in AGM sector should make available modern equipment and provide required technical know – how to AGM operators.

Strengthening of OTP among the miners can be sustained as 29.0% of miners suggested that the reinforcement of regulatory bodies would sustain OTP; 36.0% believed in awareness campaign; 44.0% agreed with the formalization of AGM sectors into cooperative societies and 11.0% expected that provision of modern mining equipment and training would guarantee OTP across the study area as shown in Table 4.

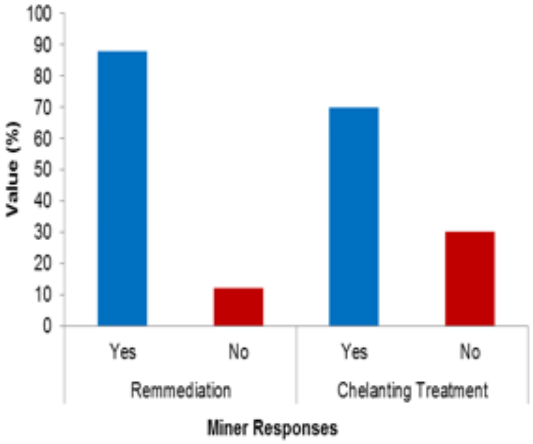

Figure 5: Remediated/chelating treatment

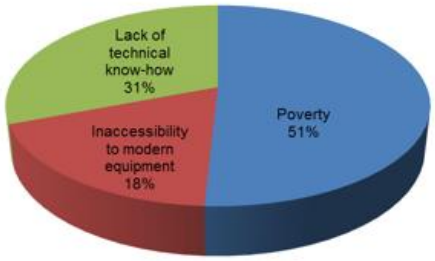

Figure 6: Barriers for adopting occupational therapy practices

Table 4: Sustainability of occupational therapy practice

Activities	Frequency	Percentage
Strengthened of regulatory bodies	29	**24**
Adoption of safe mining practice through awareness campaign	36	**30**
Formalization of ASGM sector into cooperatives	44	**37**
Provision of modern mining tools and equipment	11	**9**
Total	120	**100**

Source: Computed from survey data, 2017

4. Conclusion

The study has highlighted various occupational health hazards associated with the AGM and evaluated the sustainability of adopted occupational therapy practices that will enhance miners' good health and environment friendly. The physical observation has illustrated that the major occupational health hazard associated with artisanal gold mining are brain damage, body weakness, injuries and death of miners.

Meanwhile, soil samples revealed that soil ingestion is the major contributor to carcinogenic lifetime risk when compared with 1×10^{-6} WHO standard of carcinogenic lifetime risk.

Also, occupational therapy practices (OTP) show that 67.0 % of the miners were benefited from the awareness campaign in village meetings while 85.0 % of the miners have relocated to the government approved processing sites and 53.0 % of the miners have undertaken various OTP training while, 51.0 % of the miners have identified poverty as the major barriers stalled them to adopt OTP; 18.0 % identified inaccessibility to modern equipment and 31.0 % identified technical know-how as problems of adopting OTP. In order to ensure sustainability of OTP, 29.0 % of miners suggested strengthening of regulatory bodies; 36.0 % believed in awareness campaign; 44.0 % agreed with the formalization of AGM sectors into cooperative societies and 11.0 % expected that provision of modern mining equipment and training would guarantee OTP across the study area. The study therefore concluded that OTP is effective and have curtailed the spreading of lead poison across the study area.

Authors' Contributions

A.O.C., designed the study, wrote the protocol, managed the literature researches and wrote the manuscript.

Conflict of Interest

The author declare no conflict of interest.

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