Abstract: This study has modeled occupational injuries at Gold Fields Ghana Limited (GFGL), Tarkwa Mine using time series analysis. Data was collected from the Safety and Environment Department from January 2007 to December 2010. Testing for stationarity condition using line graph from Statistical Package for Social Sciences (SPSS) 17.0 edition failed, hence the use of Box-Jenkins method of differencing which tested positive after the first difference. ARIMA (1,1,1) model was then applied in modeling the stationary data and model diagnostic was done to ensure its appropriateness. The model was further used to forecast the occurrence of injuries at GFGL for two year period spanning from January 2011 to December 2012. The results show that occupational injuries for GFGL are going to have a slight upward and downward movement from January 2011 to May 2011, after which there will be stability (almost zero) from June 2011 to December 2012.

Key words: Differencing, forecasting, mining, safety, stationarity

INTRODUCTION

The main aim of any mining company is to mine an orebody in a given environment as safely, efficiently and economically as possible. Unfortunately, mining activities are generally associated with dangerous working conditions which result in accidents and injuries. The consequence is the loss of production time, the victim’s incapacity to work and the loss of special skills to the mining companies.

As a result of such losses, most mining companies worldwide are placing high premium on safety (accident control and prevention). However, as posited by Donoghue (2004), although substantial progress has been made in the control of occupational injuries there remains more room for further reduction of injury cases in the mining industries. Gold Fields Ghana Limited (GFGL), the highest gold producing company in Ghana, for example, places more emphasis on minimizing occupational injuries so as to increase production levels and also to protect the wellbeing of the workforce. It is also the aim of the mine to comply with international standards such as OHSAS 18001 in assessing safety at the workplace.

In this study, a time series model based on the stationarity condition is used to forecast occupational injuries at Gold Fields Ghana Limited, Tarkwa Mine, to serve as a tool for managerial decision in reducing injuries on the mine.

MATERIALS AND METHODS

Brief information about the study area: Gold Fields Ghana Limited, Tarkwa Mine, is located in Tarkwa which is on longitude 2º00’ and latitude 5º15’. Tarkwa is about 90 km by road from Takoradi, the Western Regional capital and about 300 km west of Accra, the national capital. The concession covers an area of 294 km² extending from the town of Tarkwa in the south, for a distance approximately 25 km to Huni Valley at its north-east limit and is averagely 152.41 m above sea level (Kesse, 1985). The topography of Tarkwa area is generally described as a remarkable series of ridges and valleys parallel to one another and is the true reflection of the pitching folding structures of the Banket series of the Tarkwaian system. The orebody consists of a series of sedimentary banket quartz reef units (conglomerates) of the Tarkwain System that are similar to those mined in the Witwatersrand Basin of South Africa. The company is currently mining multiple-reef from open pits and there is potential for underground mining in the future (Gold Fields Limited, 2011).

Method of data collection and analysis: The data was sampled from January 2007 to December 2010 incident statements and investigation reports at the Safety and Environment Department of Gold Fields Ghana Limited (GFGL), Tarkwa Mine. Interviews and discussions were also conducted to gain deeper insight on some of the
Table 1: Occurrence of injuries at Gold Fields Ghana Limited, Tarkwa Mine

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
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<td>4</td>
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<td>3</td>
<td>7</td>
<td>7</td>
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<tr>
<td>2008</td>
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<td>4</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>9</td>
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<td>2</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>9</td>
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<td>10</td>
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<tr>
<td>2010</td>
<td>4</td>
<td>4</td>
<td>15</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>5</td>
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Table 2: ARIMA (1, 1, 1) and ARIMA (2,1,1) model statistics

<table>
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<tr>
<th>Model Diff</th>
<th>No. of predictors</th>
<th>Stationary R²</th>
<th>R²</th>
<th>RMSE</th>
<th>MAPE</th>
<th>Normalized BIC</th>
<th>Ljung-Q(18) Statistics</th>
<th>df</th>
<th>Sig</th>
<th>No. of outliers</th>
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<tr>
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<td>0.712</td>
<td>0.161</td>
<td>4.101</td>
<td>1.097E2</td>
<td>3.072</td>
<td>22.322</td>
<td>16</td>
<td>0.133</td>
<td>0</td>
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<td>(Occupational Injuries, 1) - Model 1 ARIMA (1,1,1)</td>
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<tr>
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<td>(Occupational Injuries, 1) - Model 2 ARIMA (2,1,1)</td>
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Fig. 1: Non-stationarity graphs of occupational injuries versus months

Fig. 2: First difference stationarity graph of occupational injuries versus months

issues in the reports. Table 1 presents the rate of occurrence of injuries for the period under study. The data was analysed using time series analysis tools in Statistical Package for Social Sciences (SPSS) 17.0 edition software.

Preliminary analysis (data exploration): The data has two components, the dependent variable and the independent variable. Occupational injury is dependent over time, hence occupational injury is the dependent variable and time is the independent variable. The time component is in months.

Fig. 1 shows a line graph of occupational injury against time as obtained from SPSS 17.0. The mean of the graph is not constant over time and hence non-stationary. Furthermore, the deterministic trend is not appropriate because the spikes are increasing and it is not returning to zero. The nature of the spikes suggests that the linearity is not intrinsic to the process and will not persist in the future.
The non-stationary pattern in a time series data needs to be removed in order that other correlation structure present in the series can be seen before proceeding with model building.

According to Box and Jenkins (1976), when a data is not stationary differencing can be used. Fig. 2 shows a first difference line graph of occupational injury against time. From Fig. 2, the difference observed data fluctuates around a constant mean independent of time and variance of the fluctuation, hence stationary.

RESULTS AND ANALYSIS

Model identification: To find provisional orders of Auto-Regressive (AR) and Moving Average (MA) models for the first difference stationary data, the following are examined in Fig. 3 and 4, respectively:

- The sample Auto-Correlation Function (ACF); and
- The sample Partial Auto-Correlation Function (PACF).

Both Fig. 3 and 4 indicate lags less than 1, meaning the first order autocorrelation coefficient is significant. Therefore, an AR (1) or MA (1) or ARIMA (1) can be started with. In this paper ARIMA for the first and second orders were investigated.

Model estimation: Table 2 presents model estimations for ARIMA (1,1,1) and ARIMA (2,1,1). It can be concluded that ARIMA (1,1,1) is a better model fit statistics since it has a lesser value of normalized Bayesian Information Criteria (BIC) and lower mean absolute percentage error as compared to ARIMA (2,1,1). Considering the ARIMA (1,1,1) model parameters in Table 3, it is shown that $|\phi_1| < 1$ and $|\theta_1| < 1$, which are the stationarity conditions for both AR (1) and MA (1) respectively. Furthermore, it is shown that AR (1) is significant at 0.007 levels which is less than 0.05. This shows that AR (1) is sufficient condition for the estimation of the parameter.

Model diagnostic: Model diagnostic is concerned with testing the goodness of fit of a model and if the model is poor suggest appropriate recommendations. The graphs of the autocorrelation and the partial autocorrelation in Fig. 5 and Fig. 6 respectively show that the points are scattered in a random manner hence it could be concluded that the model fit was appropriate.

Forecasted model: After the model diagnostic, the model was fitted for two years as presented in Fig. 7. From the model, it was found out that occupational injury is going to have small upward and downward movement from January 2011 to May 2011, after which occupational
injuries will decrease slightly from May 2011 to December, 2012. The slightly constant nature can be explained that if the current safety measures implemented are maintained or improved upon there will be a remarkable decrease in injuries for the forecasted period.

**Observations:** It was observed from field interactions that safety awareness has drastically increased among greater number of the workforce. However, some workers still have lackadaisical attitude to the safety measures put in place by management. It was further observed that the causes of accidents on the mines are mostly due to ground fall, machinery, electrocution, vehicular accident and slip fall. The body parts most susceptible to injuries are the hand, legs and head for the period considered.

**RECOMMENDATION**

Based on the study, the following recommendations are made:

- Management should pay more attention to areas such as the mining operations, workshops and repair bays where most of the risky activities take place.
- Safety talks must be held frequently and must be geared towards attitudinal change since a greater percentage of the causes of accidents are by unsafe or substandard acts.
- The use of personal protective equipment must be enforced to protect the vital parts of the body susceptible to injuries.
- Management should continue with its effort of enforcing safety regulations to drive injuries to decreasing numbers as depicted by the forecast.

**REFERENCES**