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Software Development for Estimating the Cost of Injuries and Man-hour Downtime in Hydropower Plant, Nigeria a Case Study

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Abstract
This work understudied injuries/accidents in power generation plants in Nigeria. The work was based on the compilation of various hazards associated with individuals working in power plants, injuries/accidents exposed to and treatment given to the injured. The cost implication due to the accidents and man-hour lost were computed using the developed visual basic programming. Data regarding cases of injuries/accidents were collated for a given period in the power plants and used in the computation. It was discovered that a lot of financial losses were been incurred by the organizations due to injuries/accidents sustained by the workers in the process of carrying out their duties. The Visual Basic Programme developed was found to be versatile, easy to understand and suitable for the estimation of cost of injuries/accidents and man-hour losses in the power plants used as case studies. This programme can also be used to predict the cost of injuries/accidents in the sector even before they occur.
Keywords: hydropower, injuries, accidents, man-hour, risks, visual basic

1. Introduction

Hydropower plant is a large scale enterprise which uses water heights to turn the turbine blades without producing direct waste. Its operation has considerably lower output level of greenhouse gas emission as compared to fossil fuel powered energy generation plant. It is estimated that installed capacity of 1,010GW energy is been produced through hydropower generation (Mobolaji, 2004). Approximately, 16% of the world's electricity is renewable, with hydroelectricity accounting for 21% of renewable sources and 3.4% of total energy sources which may lead to injuries/accidents (Mobolaji, 2004).

In the generation of electricity through hydropower plants, there are varieties of hazards associated with the process of energy generation which include human and environmental hazards. This is because of the various heavy equipment and the processes involved in the operations. Workers are exposed to these hazards and have become daily occurrences in the operation and maintenance of the plant. These hazards include fall from heights, hit by moving objects, cut by sharp objects, chemical impact and collapse of structures. These undesirable occurrences result in human injuries, hospitalization and/or death, damage of properties, loss of production hours and distortion in the production and maintenance activities (Poltev, 1981; Hoo_Gon & Jungon, 2010; Mohan, Kumar, Patel, & Varghese, 2004).

In countries of the developing economy, cases of industrial injuries/accidents are usually rampant and not properly documented or reported. Workers in this part of the world are therefore prone to industrial related disability or death due mainly to poor attitudes towards safety issues.

There have been concerns shown at the high level of risks workers are exposed to in the working places whether in the underground mines (Duzgun & Einstein, 2004), petrochemicals (Burns, 2006), glass industries (Bazroy, 2003), in agriculture, Leigh at al (2001) and aviation (Gerard, 2001). Records have shown that the attitudes of workers and organizations to safety are not encouraging (Gerard, 2001; Rasmussen, 1997; Ives, 2002). It is for this reason that governments and pressure groups mounted crusades for observance of safety attitudes in commerce, entertainment centers and production and manufacturing industries. According to the International Labour Organization (ILO) report of 2002 (ILO, 2002), about two million men and women lose their lives every year through accidents and diseases linked to their work worldwide.

Workers suffer 270 million occupational accidents and 160 million occupational diseases each year worldwide (Aggrawal, 1990). HSE report released in the year 2010 showed that the total cost associated with workplace injuries and ill health (excluding occupational cancers) in Great Britain stood at 14 billion Pounds for 2009/2010 (Aggrawal, 1990). The Australian Safety and Compensation Council (ASCC) estimated that the total economic cost of industrial injuries for the 2005/2006 financial year was 57.5 billion Dollars, representing 5.9 per cent of the country's GDP. With the release of Work Related Injuries Survey data for the 2009/2010 financial year, the total economic cost was put at 60.6 billion Dollars, representing 4.8 per cent of GDP (Burns, 2006). National Safety Council (NSC) reported the cost of job-related injuries to be more than $27 million per year (Hauer, 2006; Harold & Moriarty, 1990).

In Nigeria however, the situation may not be different as inferred in the report by the Nigerian Institute of Safety Professionals (NISP) in 2000. In the report, it was estimated that 11,000 people died from on-the-job related

accidents and a worker is injured every 18 seconds in chemical related industries within the same period. The report showed that there was high rate of incidence of fatal work-related injuries in developing countries than in developed economies most of which were not officially recorded or documented (Aggrawal, 1990).
This study presents a developed computer-based method of estimating the cost of injuries/accidents in hydroelectric power plants using Visual Basic programming. The programme provides the management of the organization with a tool for computing the cost implication of injuries/accidents of workers and the financial loss due to downtime. The programmee could also serve as a predictive tool for estimating the financial implication of injuries/accidents in the plant even before they occur so that the management will put all necessary measures in place to prevent or minimise occurrence of such accidents.

2. Methodology

Risk Management is a non-intuitive field of study, where the most simple of models consist of product of probability and impact (Hauer, 2006; Atambo, 1999). Understanding individual risks is difficult as multiple probabilities can contribute to risk total probability and impacts can be "units" of; cost, time, events and market states. This is further complicated as there are no straightforward approaches to considering how multiple risks will influence one another or increase the overall risk of the subject of analysis.
To develop this programme, two hydropower plants were visited in Nigeria. Data regarding injuries/accidents occurrence for a period of twelve months were collected at each of the plants' clinic and at the generation section. The data were analyzed and categorized as minor, major and catastrophic.
Two mathematical models were adopted in carrying out this research work. The first model was used to determine the cost of accidents recorded using the values of the workplace parameters derived from the data obtained from the plant. The second model computed the financial loss due to man-hour downtime resulting from injuries/accidents sustained by workers.
Al-Ghamdi, A., (2002) used the logistic regression to estimate the influence of accident factors on accident severity. Gerard (2001) developed a rate model to evaluate aircraft accidents in an aviation industry using maximum likelihood estimator expressed by the equation;

$$R_a = \frac{N_a}{N_f} x\, 10 \qquad 1$$

Where,

R_a -accident rates,
N_a -number of reported accidents,
N_f -number of flights.

Safety sampling model to determine the expected number of safe work activities in a given plant using probability theory as developed by Aggrawal (1990) was developed. Thus mathematically expressed as,

$$N = \frac{4\,(1-P)}{Y^2\, P} \qquad 2$$

Where,

N -Number of observations made to achieve a desired accuracy of safety
p -Probability of accident occurrence
Y -Safety accuracy (mostly taken as 10%).

This approach determined an expected number of safe work activities but failed to address how much gain/loss is being achieved to justify continued investment.
The approach used by Duzgun and Einstein (2004) to estimate the cost of road traffic accidents was adopted and applied for the power plant generation. The mathematical expression is given;

$$C_{ij} = \frac{1}{N}\left(\sum_{j=l}^{N} H_{ij} + I_{in}\right) + A_i \qquad 3$$

Where;

C_{ij} -Unit cost of accident class i
H_{in} -Direct cost of property damaged associated with accident class i.
A_i -Establishment's compensation on human disability involved in accident class i
I_{il} -Total indirect cost associated with injury/accident class i.
i -Number of accident occurrence
n -Number of number of cases of accident class i considered.
N -Number of cases of accident i considered

Financial loss due to man-hour downtime, δ_p as a result of injuries/accident sustained by workers as in Adegun et al (2011) was used in the computation thus;

$$\delta_p = \sum_k^i \rho \; N_{i,k} H_{i,k} R_j \qquad 4$$

Where;

$N_{i,k}$ -number of occurrence,
$H_{i,k}$ -hours lost due to a particular injury/accident,
R_j -hourly rating depending on the ranking,
i -accident type,
k -accident severity categories (minor, major, hazardous/Catastrophic)

The output probability of the programme is given as;

$$P = \frac{e^{-\lambda} \lambda^Z}{Z!} \qquad 5$$

With the variance,

$$S^2 = \frac{(X - \vec{X})^2}{(N - 1)} \qquad 6$$

Where,
Z number of occurrence
λ mean or average number of occurrence
e exponential function
x value
N data number

2.1 Computer Programme

A computer programme which was written in Visual Basic was developed to determine the financial implication resulting from injuries/accidents sustained and downtime loss in the power plant which was a two-loop visual basic programme. The first loop was the computation and estimation of unit cost of injuries/accident using equation (3). It computed the unit cost of injuries/accident ($C_{i,j}$) by summing the direct and indirect costs of property damaged associated with the injuries/accidents based on the establishment's compensation policy regarding the injured involved in the accident.

The second loop estimates the plants' losses due to man–hour downtime by workers of the organization involved in the injuries/accidents. This is done based on the organizations' rating of the workers, accident types, severity of accidents and period of downtime experienced.

2.2 Programme interface

The programme has user interface made up of 5 windows. The outputs of the programme are displayed as tables and bar charts on an excel sheet for costs of injuries/accidents and downtime.

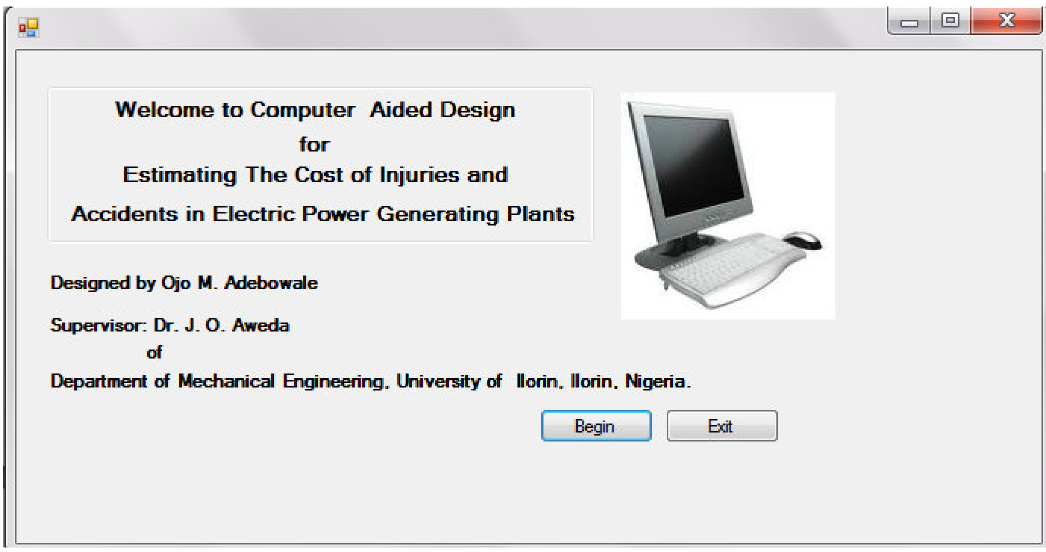

Figure 1: Welcome Page

The welcome page dialog box as shown in figure 1 is the beginning of the computation and shows the “Begin” and “Exit” boxes for action as appropriate. When the “Begin” box is activated, figure 2 appears.

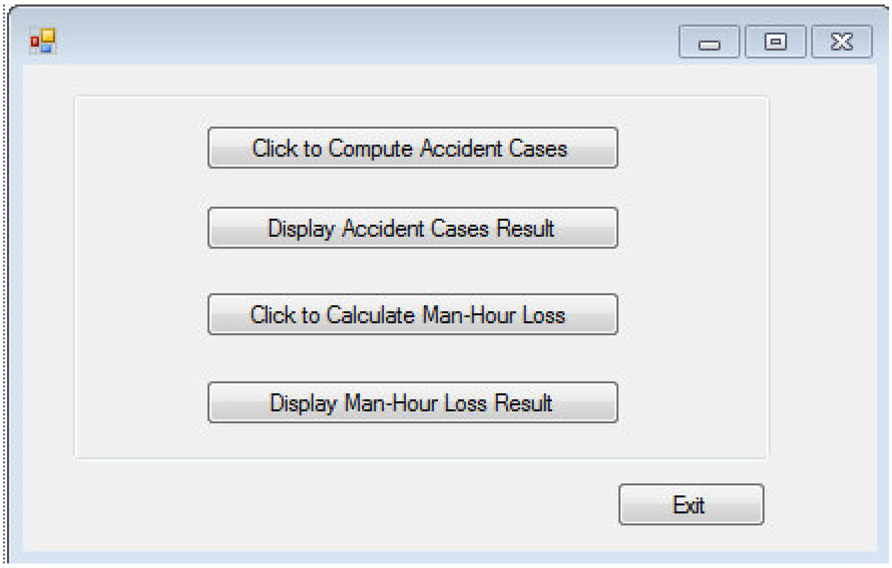

Figure 2: Home Page

The home page window of figure 2 has four features. A click on “compute accident cases” or “calculate Man-hour loss” depending on what is required for determination, navigates the user to figure 3. In either situation, results are displayed by clicking either “Display Accident Cases Result” or “Display Man-Hour Loss Result”.

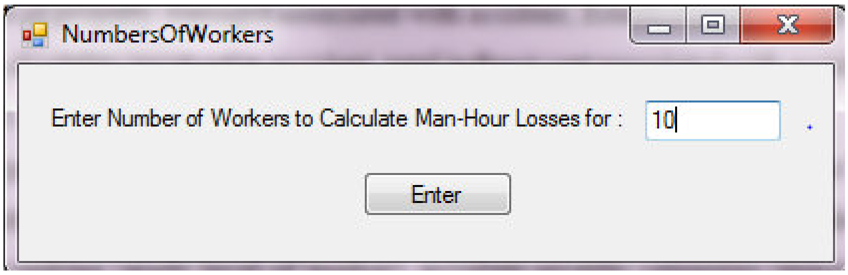

Figure 3: Window for entering the number of workers to calculate man-hour loss

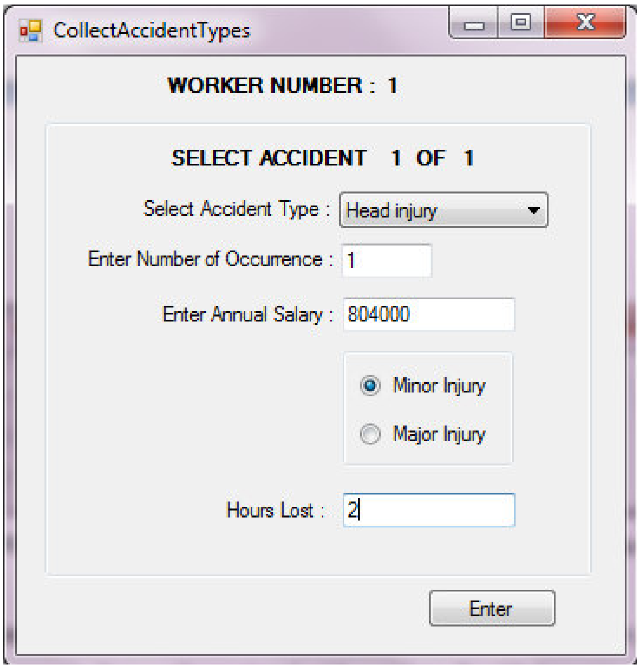

Figure 4: Window for entering accident details for each worker

A click on "man hour loss" of figure 3 navigates to figure 4. Figure 4 dialog box shows the procedure for entering the accident details for each worker. The type of accident recorded for the worker is first entered followed by the number of occurrence of the accident, annual salary of the worker involved, category of the accident and hours lost due to the injury/accident. On clicking "Enter" box, figure 5 appears after entering data in the appropriate boxes.

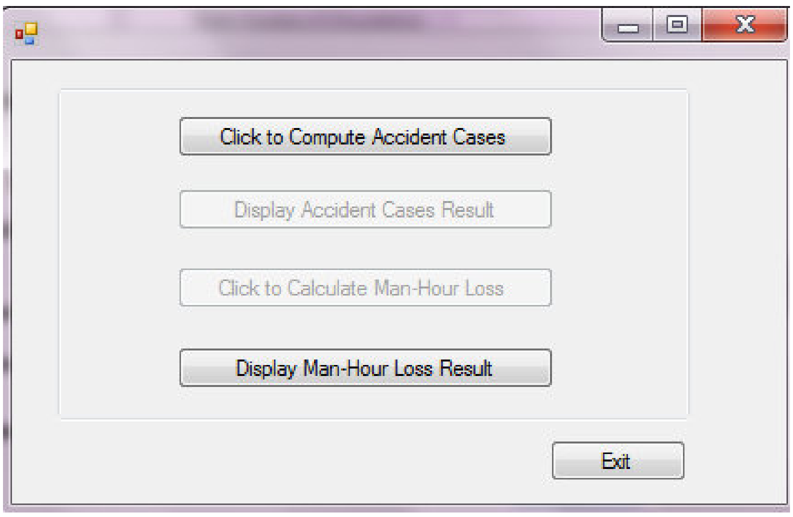

Figure 5: Window for displaying results of computation

Figure 5 brings the user to "Compute Accident" and "Man hour loss" boxes where the results of the computation for injuries/accidents cases and man-hour losses on Excel sheet are displayed in tabular form and as bar charts.

3. Results and Discussion

Table 1 shows the summary of injuries/accidents recorded within the study period in the plants as observed for a twelve-month period. An accident is regarded as minor if the treatment period given is less than three days, if hospital treatment is within 3 to 56 days it is major and catastrophic if it takes more than 56 days of treatment with or without disability as classified in the hydropower plant's clinic.

Table 1: Summary of number of injuries recorded within one year period

Injury/Accident	**Minor**	**Major**	**Catastrophic**	**Total**
Cuts/Laceration	80	1		81
Chemical impacts	5	-		5
Fracture	-	1	2	3
Head injury	5	-		5
Slip/Fall	7	2	2	11
Suffocation	1	1		2
Eye injury	2	-		2
Electrical shock	8	1		9
Burns	2	1	1	4
Fire/Explosion	-	1		1
Sprain	5	-		5
Total	**115**	**8**	**5**	**128**

On Table 1, there was one case of major injuries and 80 minor involving cuts/lacerations that were recorded during the study period. Most minor cuts occurred during maintenance activities carried out on the turbine blades which included machining operations in the machine shop.

It was observed that slip/fall occurred 11 times, two of which were catastrophic. Catastrophic and major cases of slip/fall as seen in the table occurred as a result of falling from heights on scaffolds and ladders. Minor slip/falls occurred due to slippery floors. In all, a total of 128 cases of injuries were recorded during the period of which 115 were minor, 8 major and 5 catastrophic situations. From these figures, there were significant numbers of accidents/injuries cases sustained by the workers.

Table 2: Man-hour losses due to injuries/accidents according to the severity

Injury/Accident type	Minor (Hour)	Major (Hour)	Catastrophic (Hour)	Total (Hour)
Cuts/Laceration	277	168	-	445
Chem. Impacts	72	-	-	72
Fracture	-	444	560	1004
Head injury	8	-	-	8
Slip/Fall	372	788	920	2080
Suffocation	5	168	-	173
Eye injury	6	-	-	6
Electric shock	42	240	-	282
Burns	27	120	220	367
Fire/Explosion	-	-	-	-
Sprain	720	-	-	720
Total	**1529**	**1928**	**1700**	**5157**

Table 2 is the man-hour losses due to each class of injury/accident recorded during the study period. Major cases of injuries/accidents recorded the highest number of lost hours. A total of 1928 hours were lost to major cases of injuries/accidents, 1700 hours to catastrophic and 1529 hours to minor cases during the study period. The highest man-hour loss were recorded for slip/fall that stood at 372 hours were lost to minor cases, 788 hours to major cases and 920 hours to catastrophic cases bringing the total to 2080 hours lost. This was due to the frequent problems associated with the repair works constantly being carried out within the operational areas of the turbines.

Table3: Cost incurred due to injuries/accident

Injury Type	Cost, ₦
Cut/Laceration	3,333.33
Chem. Impact	77,400.00
Fracture	200,000.00
Head Injury	1,777.78
Slip Fall	107,750.00
Suffocation	59,166.67
Eye Injury	13,750.00
Electric Shock	6,500.00
Burns	64,250.00
Fire Explosion	80,500.00
Sprain	92,750.00
Total	**707,177.80**

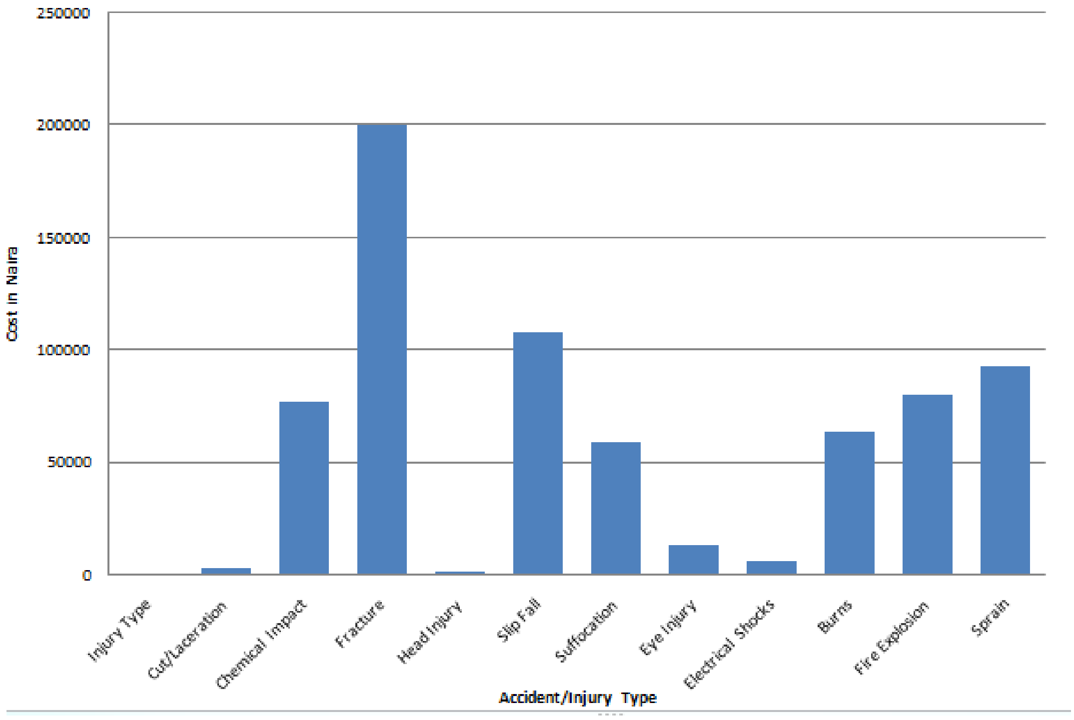

Figure 6: Typical Cost of Injuries/accidents in Naira

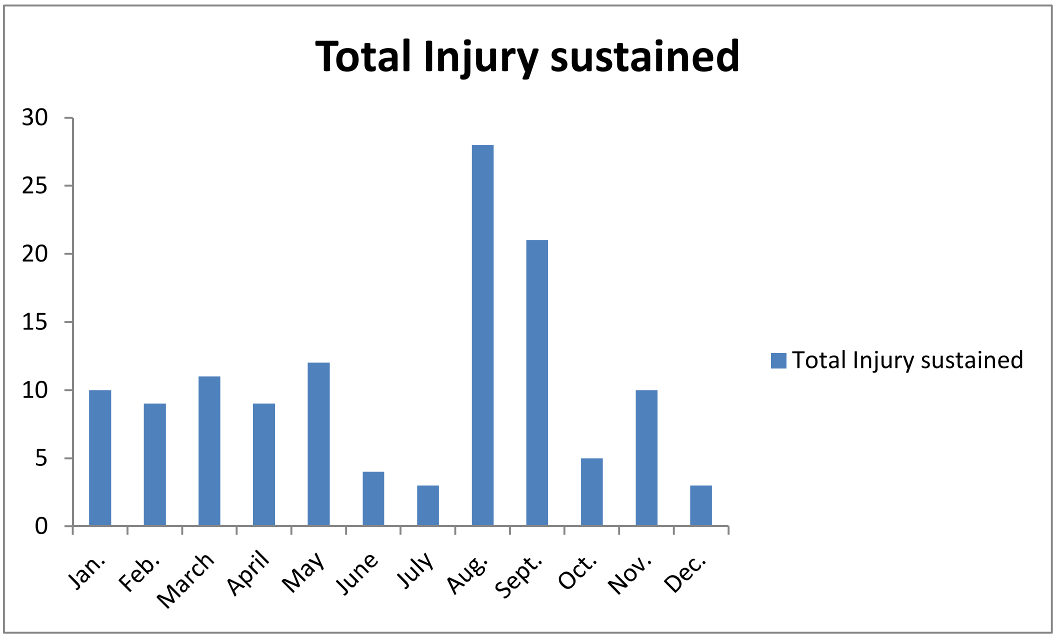

Figure 7: Monthly recorded injuries/accidents sustained during the study period

Figure 6 shows the bar chat of cost incurred on various types of injuries/accidents as obtained from the programme for a 12-month period. From this figure, the sum of 200,000.00 Naira was incurred on those that sustained fracture on the job which occurred 3 times. Other injuries/accidents in which substantial funds were incurred included slip fall 107,750.00 Naira, fire explosion 80,500.00 Naira and sprain 92,750.00 Naira. Several of these happened during the maintenance period of turbines when the water level steadily increased. It was observed that cases of cuts and lacerations occurred 81 times during this period with most occurrences happening in August and September as observed in figure 7. From figure 7, the months of August and September recorded the highest number of injuries and downtime losses. This was as a result of general maintenance activities carried out on the turbines and other facilities as the water level rises to the peak due to heavy downpour.

Occurrence of high accident rates during maintenance periods were attributed to the non-availability of turbine parts, where alternative materials used often led to frequent breakdowns and thus high level of injuries/accidents recorded. Other reason that could be attributable to the high number of injuries/accidents was the lack of aappropriate safety gadgets. It was discovered that maintenance officers did not even use correctly, the safety gadgets provided for them while working on the turbines which led to the increase in the injuries/accidents rate recorded in the power plants.

4. Conclusion

This work introduced the concept of risk analysis model in the operation of hydropower generation for effective cost saving in the amount spent on injuries and downtime operations. Safety measures implementation is by various stakeholders involving minimizing the probability of occurrence and protection of workforce from exposure to risk factors. The visual basic programme adopted is adequate and can be applied for the situation analyzed in this work. The programme developed was used to generate the amount incurred due to injuries/accidents in hydropower plants. From the study, much useful funds are lost to injuries/accidents totaling ₦ 707,177.80 for the period understudy. These huge losses can be minimized by frequently providing quality safety education to all the workers and enacting a strict adherence to work ethics and safe workplace.

The developed programme would be useful in continually presenting the safety personnel and management of such plants the likely financial loss and human injuries due to accidents should they occur and particularly be of great relevance in the effort at reducing its occurrence. The Visual basic programme can equally serve as a predictive tool for the top management of the organization which will afford them of possessing pre-knowledge of the cost implication of injuries/accidents even before they occur. These huge losses can be minimized by frequently providing quality safety education to all the workers.

The developed Visual Basic programme to estimate the cost implication of injuries/accidents sustained in hydroelectric power sectors was found very adequate for use in determining cost of injuries/accidents and downtime losses.

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