

# Environmental Ergonomics and Postural Job Analysis on Handcrafting Process of a Small-Scale Jewelry Enterprise

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**Abstract.** The Philippine Jewelry Industry has a great potential on contributing to the economic development. Large deposit of gold, abundant reserve of precious stones and cheap skilled labor of Filipino artisans are some of the country's resources which are essential elements for jewelry making. Handmade jewelry items are more appealing and attractive to local and export market. In spite of its consistent growth, a dying breed of artistry for the craft poses a high threat to the number of expert Filipino jewelry makers. Hence, the task analysis intends to help the industry by identifying ergonomic risk factors present on the work environment of a typical small-scale jewelry enterprise. It focuses on the traditional ways of jewelry making mainly by handheld tools which is locally known as Manu-manoor and performed by artisans commonly called as Plateros. Various physical and environmental methods are consolidated to detect risk factors which may potentially lead to occupational disorders. Data analysis plan consists of comparative assessment of actual measurements and acceptable levels for environmental variables. Also, descriptive statistics is used to interpret the results of environmental ergonomics and postural job analysis. At the end of the study, different recommendations are established to introduce an ergonomically designed workplace.

**Keywords:** Environmental Ergonomics, Postural Job Analysis, Jewelry Making, Plateros, Manu-manoor

## 1. INTRODUCTION

The Philippines is known to its abundant gold deposits and precious stones such as opal, jasper, quartz, tektite, Zambales and Mindoro jade, garnet, epidote, jadeite, blue and green schist. These rich natural resources lead to the emergence of a profitable trade in the country, the jewelry industry. In the Philippine context, a jewelry enterprise is defined as businesses engaged in manufacturing and commercializing any types of jewelry. The industry is made up of fine jewelry sectors and costume jewelry sectors. Jewelry items typically undergo processes such as cutting, shaping, refining, forming, polishing and stone setting. The traditional means of jewelry making mainly by hand and tools is locally known as Manu-manoor while artisans are commonly called Plateros. Accompanied by rich natural resources, Filipino artisans are well-known for their expertise in producing fine and costume jewelry by merely using tools controlled by hand. The availability of cheap but skilled labor resource in the country gives competitive advantage to the manufacturing sectors most especially for products with high expert labor content (Florencio, 2014).

Enterprises engaged in processing of precious stones and raw materials are viewed to contribute to the national development of the country (Manto-Beltran, 2015). Manufacturers of jewelry in the Philippines are mostly small enterprises which until now performing traditional ways of jewelry making. As reported in "Profile and Taxation of the Philippine Jewelry Industry" of NTRC Tax Research Journal (2013), there are approximately 10,000 cottage-type firms with marginal investment on technological tools and equipment. Most of these firms are located in provinces like Bulacan, Benguet, Manila, Cebu, Davao and Caraga Region.

Small-scale jewelry enterprises are largely concentrated in Meycauayan, Bulacan. The Meycauayan Jewelry Industry Association (MJIA) reports that 12% jewelry manufacturers in the province are medium to large scale firms as reported in Province of Bulacan website in 2012. Jewelry makers are normally paid on a piece-rate basis. In addition, jewelry making industry can absorb less educated workers and pay them reasonable income. Depending on the expertise level, a jewelry maker can earn a Php700.00 to Php1, 500.00 per day (Florencio, 2014).

Despite the emergence of jewelry industry in the country, a dying breed of artistry for the craft poses a great threat to the resource of expert Filipino jewelry makers. Younger generation prefers high-status jobs thus discontinuing the craft passed by their fathers. Moreover, the nature of work practices and environmental conditions are probable contributing factors in ceasing the artistry. As reported on National Profile on Occupational Safety and Health for the Philippines (2006), less than 10% of 32.4million workers benefit from effective occupational safety and health programs. This proportion is generally occupied by medium to large scale businesses. Thus, it manifests that workplaces in jewelry industry which belongs to informal sectors have inadequate occupational safety and health conditions.

There are recorded numbers of workers exposed to hazardous risks at their respective workplaces. These risks eventually lead to occupational diseases and disorders which affect workers performance. Based on International Labour Organization (ILO) in 2013, an occupational disease is defined as illness acquired from exposure to risk factors present in workplace.

Ergonomics is a scientific discipline which primarily focuses on analysing the interactions among human and structure's elements in order to optimize well-being and overall systems performance (Salvendy, 2012). It aims to modify the work environment so as to minimize risk exposure and safeguard occupational safety and health.

In general, the case study concentrates on inclusive assessment of workplace of a typical small-scale jewelry enterprise in Meycauayan, Bulacan. It merely identifies the ergonomics factors and the risk level present on fine jewelry production. Consequently, the analysis may initially lead to the development of recommendations in order to optimize the human well-being and crafts workers performance. Also, this may serve as an exploratory study for future researches to deeply understand the identified ergonomics risk factors and their correlation to system performance.

### **1.1 Objective of the Study**

The study aims at identifying ergonomic risk factors present among workers in small-scale jewelry industry thus ensuring occupational safety and health. In addition, it intends to assess the fundamental characteristics of fine jewelry making process and its exposure to risk factors that eventually may give the workers the possibility of developing physiological disease or disorders. The outcome of the study leads to the establishment of recommendations which targets to minimize the physical constraints in a jewelry making environment.

Particularly, the task analysis intends to assess the

following factors which may pose risk to jewelry makers' safety and health:

- Illumination
- Thermal condition and ventilation
- Noise level
- Musculoskeletal and static load;
- Postures

### **1.2 Rationale of the Study**

The jewelry industry is seen to be an emerging profitable business sector in the country. As a result of economic growth, there is an increasing local demand for jewelry items parallel with the improvement on purchasing power of consumers. In addition to its capability of contributing to economic development, the jewelry industry provides social benefits through creating job opportunities. It provides source of livelihood for less educated locals in which their abilities are inherited from their fathers or acquired merely by experience.

The progression of the sector is significant given the fact that small to medium-scale manufacturers dominate the 50 percent of the jewelry industry whereas the top 10 largest jewelry manufacturers account for less than 25 percent share according to the Board of Investment.

Handmade designs completed by means of traditional ways make the fine jewelries more appealing and attractive to customers. In fact, Chairman Cecilia Ramos of Meycauayan Jewelry Industry Association once stated that buyers are now looking at Philippine-made fine jewelry due to its beautiful designs perfected by Filipino goldsmiths, silversmiths and stone setters.

Taking into consideration these opportunities, it reveals the need to support the Filipino jewelry makers particularly those who belong to small and medium scale industry. It is known that jewelry making process requires high degree of precision and attention to details. Identifying ergonomic risk factors in jewelry making process may prevent the development of work-related disorders. Ensuring occupational safety and health of these crafts workers can protect the dying breed of traditional artistry of jewelry making.

### **1.3 Problem Statement**

Jewelry fabrication is evidently a labor-intensive process given that each piece is manually shaped, hammered, polished and put into precise place using different handheld tools. Only few large businesses have acquired casting machines and wax injectors in order to achieve intricate jewelry designs. On the other hand, workers in small and medium scale enterprises (SMEs) are more likely to be vulnerable to risks exposure and

occupational diseases (ILO, 2013). Work-related illnesses have negative effect to both firm and workers welfare.

A study conducted by WHO identifies the topmost occupational risk factors as follows: 37% of back pain, 16% of hearing loss, 13% of chronic obstructive pulmonary disease (COPD), 11% of asthma, 8% of injuries, 9% of lung cancer and 2% of leukaemia. Some occupational disorders do not directly pose severe effect on workers' condition. For example, musculoskeletal disorders and hearing loss are caused by cumulative stress and exposure to poorly design work environment. In 2009, World Health Organization (WHO) estimated that at least 10% of the annual lost to disability was due to MSDs cases.

Occupational diseases and disorders as a result of repetitive exposure to risk factors on workplace may impose huge cost to both business operation and workers well-being. This condition has the greatest consequence on labour-intensive operations like jewelry making. Moreover, ILO assessed that there is an average of 4% annual loss in global gross domestic product (GDP) due to occupational accidents and diseases.

The above discussed issues are highly connected with the present dilemmas encountered by SMEs like jewelry making industry. Consequently, a case study on a small-scale jewelry enterprise in Meycauayan, Bulacan intends to have an overall assessment of the existing work environment and practices in jewelry fabrication. The ergonomics evaluation plans to determine the environment and physical risk factors in which crafts workers are highly exposed.

## 1.4 Scope and Limitation

The case study on a small-scale jewelry making enterprise primarily focuses on identification of ergonomics risk factors present on the work environment. Since the task analysis concentrates on a small-scale enterprise, the case study is designed in which recommendations are not confined to financial constraints of the business. Following an ideal system approach permits boundless solutions to work environment and physical problems. Thus, a further study is essential in evaluating the economic aspect of proposed ergonomics interventions. The study is conducted in Brgy. Calvario, Meycauayan, Bulacan from January to May 2016.

## 2. METHODOLOGY

### 2.1 Subjects

The subjects under study cover artisans who are adept in the traditional way of jewelry making. It covers craft workers engaged in the process of handcrafting.

Handcrafting involves fabricating raw materials by means of tools controlled by hands. Precious metals and stones are manually shaped and forged to attain the desired jewelry designs.

All craft workers are male with age ranging from 36 to 54 years old. In addition, the subjects have at least 20-year experience on the craftsmanship of jewelry making. The average height of the respondents is 164.59cm with standard deviation of 2.13cm. In the same way, the average weight is 60.20kg with standard deviation of 12.85kg. The craft workers are compensated on a piece-rate basis but nevertheless they are working no less than 48 hours per week. Also, all of them are right-handed individuals.

### 2.2 Tool Set

The study develops an ergonomic tool set which consolidates various physical and environmental methods in order to evaluate the present working condition of jewelry makers and to detect risk factors which may potentially lead to occupational disorders. The task analysis considers ergonomic risk assessment tools which are relevant to processes requiring attention to details and with high precision demands. The tool set contains the following instruments:

1.) Environmental Factors Checklist (Freivalds, 2009). The checklist aims to assess the environmental constraints and characteristics where human-machine systems exist. Essential factors under consideration are noise, illumination and thermal conditions. Actual measurements of these parameters make use of Luxmeter for illumination level (lux), Decibel Meter for noise level (dBA) and Temperature (degree Celsius) and Humidity Meter (% humidity).

2.) Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993). It is designed to investigate workplaces and identify risk level for upper limb disorders. A RULA score indicates the risk level of musculoskeletal disorders (MSDs) and recommends whether there is a need to ergonomically redesign the workplace.

3.) Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000). It is a survey method used to conduct wrists, forearms, elbow, shoulders, neck, trunk, back, legs and knees postures analyses. REBA score is interpreted similarly with RULA score.

4.) General Posture and Task Evaluation Checklist (Freivalds, 2009). This checklist provides a postural job analysis aligned with the basic principles of good work design. It examines the general posture; task design; sitting and standing posture; anthropometric, biomechanical and

physical factors; and manual material handling factors.

5.) Tool Evaluation Checklist (Freivalds, 2009). The checklist evaluates the tool used by the workers based on fundamental principles, anatomical concerns, recommended handles and grips, and other considerations for power and precision use.

6.) Nordic Questionnaire (Kourinka, 1987). A Standardized Nordic questionnaire verifies the existence of ergonomic risk factors among jewelry makers. This diagnostic tool aids to screen the work environment and to assess the mismatch of the workers and tasks that may eventually develop to musculoskeletal diseases.

### 2.3 Data Collection and Analysis

Data validation is essential to confirm the degree to which repeated measurements nearly give the same results. Taking this into account, one week observation of the process and random collection of pertinent data ensure the validity and precision of different physical and environmental measures. After the data gathering, the analysis plan includes means of interpreting and identifying values which depart from the available standard working settings. The analysis plan for factors such as illumination, noise level, temperature and humidity consists of comparative assessment of actual readings to the recommended levels. The study adapts the guidelines for standard illumination from Illuminating Engineering Society of North America (IESNA), permissible noise level exposure from Occupational Safety and Health Administration (OSHA), acceptable temperature and humidity level from American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). Next to collecting and assigning score for different body regions using REBA and RULA worksheet, the computed indices determines the level of musculoskeletal disorder risk. Descriptive statistics is used to summarize and interpret the ergonomics assessments. The scope of the methodology permits the general assessment of working environments where jewelry makers in small scale industry are normally exposed.

## 3. RESULT AND DISCUSSION

Different physical and environmental methods are employed to quantitatively and qualitatively analyze the working condition. The task analysis is categorized into two sections consisting of environmental ergonomics and postural job analysis. Environmental ergonomics refers to assessment of exposure level to environmental variables such as noise, illumination and thermal conditions. On the

other hand, postural job analysis illustrates different checklist results which exhibit percent conformance to acceptable working postures.

### 3.1 Environmental Ergonomics

There are high deflections from tolerable values for illumination level, thermal condition and ventilation. Figure 1: Work Environment Checklist Result displays the percent conformance and non-conformance to known environmental factors.

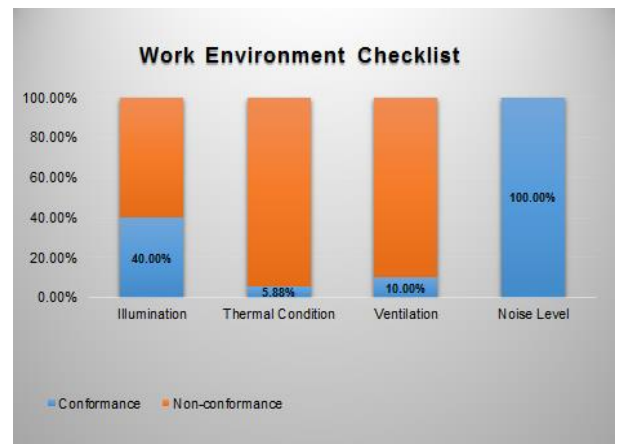


Figure 1: Work Environment Checklist Result

Illumination level on hand crafting workplace ranges from 891 to 1191 lux. Glare is present in one of handcrafting workstation due to metallic finished of its working surface. Fluorescent lamps provide artificial and localized light sources. There are down lighting ceiling-mounted luminaires which provide direct lighting to the working area.

Present thermal condition and ventilation of the workplace do not conform to acceptable settings. Random measurements of room temperatures show that the current working environment is outside the thermal comfort zone of 18.9 to 26.1°C. However, the actual room humidity measures exhibits conformance to acceptable relative humidity ranging from 20 to 80 percent.

### 3.2 Postural Job Analysis

A Standardized Nordic Questionnaire (Kourinka, 1987) is used as an initial survey method to investigate which body regions extremely experience cumulative pain and discomfort. Craft workers experience pain and discomfort in locomotive organs which is consist of elbow, wrists, hands, upper back, hips, thighs, knees, ankle and feet. The result also manifests trouble in neck, low back and shoulder due to its very contorted posture.

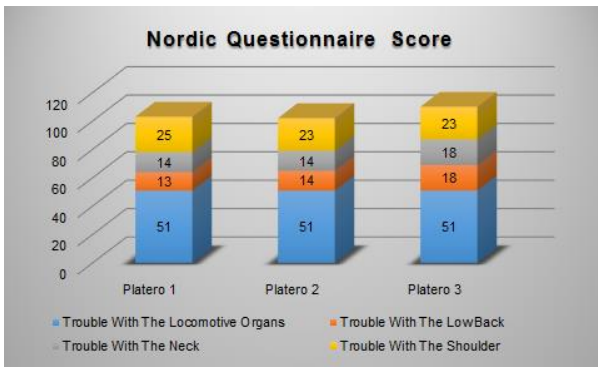


Figure 2: Responses to Standardized Nordic Questionnaire

Rapid Entire Body Assessment (REBA) scores indicate the levels of musculoskeletal disorders risks due to working posture. The result confirms that craft workers are at very high risk (REBA score 11+) and consequently there is a need to implement change on the workplace design. Right Upper Limb Assessment (RULA) results likewise states that there is high level of MSDs risk on all stages of jewelry making process.

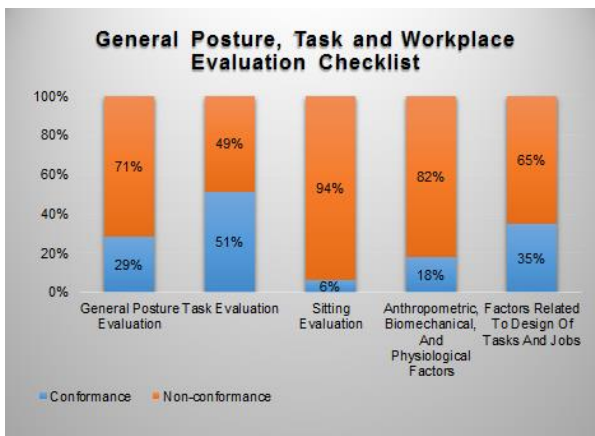


Figure 3: General Posture, Task and Workplace Checklist Result

A General Posture, Task and Workplace Evaluation Checklist is a supplementary survey method to confirm the results gained from RULA and REBA scores. Generally, the checklist marks a 78% non-conformance to identified ergonomics principles.

Sitting posture clearly takes 94% non-conformance to conventional working position since craft workers used to perform their tasks with contorted body postures. There is a great nonconformity on anthropometric, biomechanical and physiological factors for the reason that individual factors are not considered on the current workplace design.

Tool evaluation is also essential as it largely affect the posture of the worker while performing the job. The survey method for tool evaluation includes fundamental ergonomics principles, anatomical concerns, handles and grips, and miscellaneous considerations. Common hand tools used in jewelry making are torch, saw for cutting and shaping metals and other handheld devices for precision use. Inclusively, there is 65% nonconformance to criterions for handheld tools.

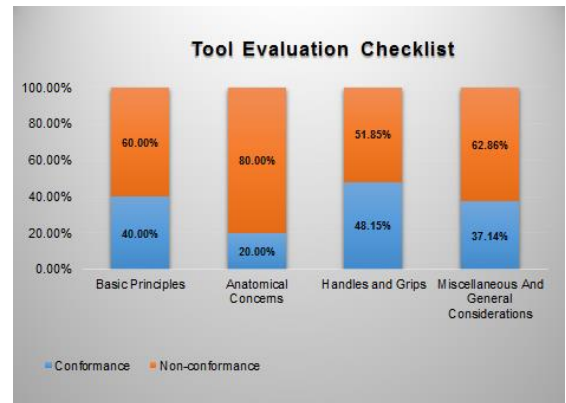


Figure 5: Tool Evaluation Checklist Result

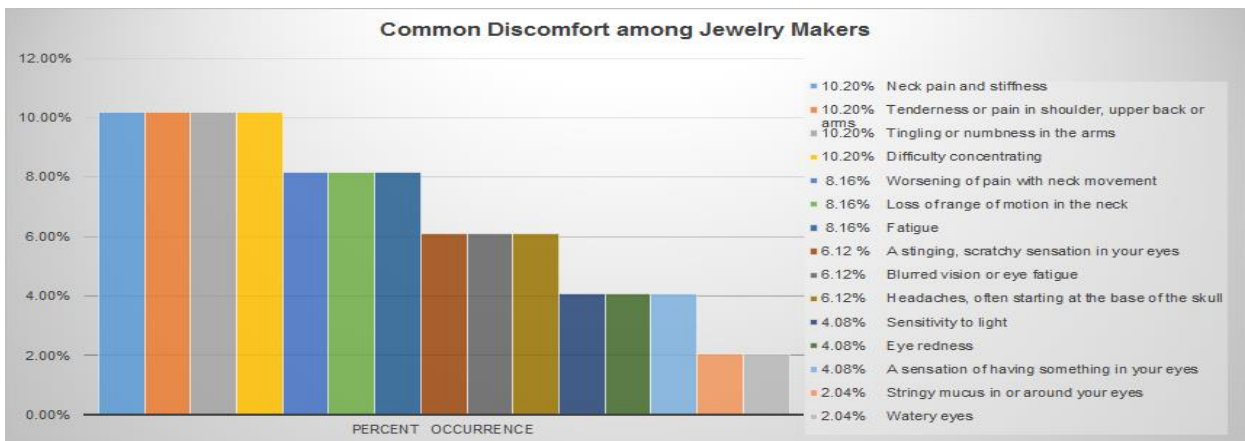


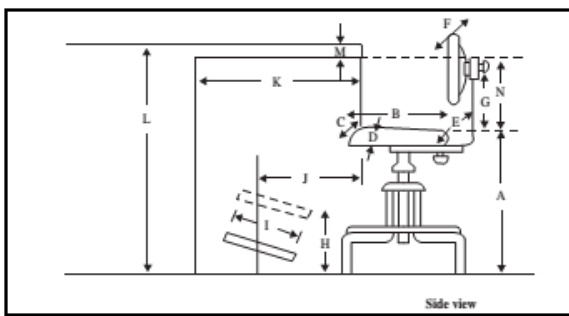
Figure 4: Common Physical Discomfort among Jewelry Workers

The collective effect of aforementioned environmental ergonomics and postural job analysis are recorded pain and discomfort among craft workers. Common physical discomfort among jewelry workers exhibits that the topmost discomfort which are neck pain and stiffness; tenderness in shoulder, upper back and arms; tingling or numbness in the arms, wrists and hands; and difficulty in concentrating. It is presumable that disorders are mostly relevant to workers posture problems.

#### 4. RECOMMENDATION

Physical method gives emphasis to risk factors attributable to contorted working posture of craft workers. At present, workstations use chair with 17cm in height. Recommendations for seat specifics and their design values are established based on the following ergonomics principles:

- Work surface height should be at elbow height wherein elbows are bent at 90° and forearms are parallel to the ground.
- An essential feature is the presence of support on back, legs and spine.
- Incorporate adjustability on seat parameters. Ensure that workers can sit with feet flat on the floor and thighs are parallel to the floor. There must be at least 90 degree angle between torso and thighs.
- Introduce active sitting by means of air-cushion chair to encourage postural flexibility. Unstable seating surface can encourage changes on posture easily. Active sitting helps the workers to have more trunk movement so as to maintain an upright sitting posture.



A-G Adapted from ANSI (1988); H-M from Eastman Kodak (1983)

Figure 6: Seat Parameters

Table 1: Recommended Seat Specifics Based on ANSI Standards and Filipino Anthropometric Measurements

Seat Parameter	Recommended Design Values (cm)
A- Seat height	40-49
B- Seat depth	41
C- Seat width	46.2
D- Seat pan angle	+10°
E- Seat back to pan angle	105°
F- Seat back width	32
G- Lumbar support	18
H- Footrest height	2.5-23
I- Footrest depth	28
J- Footrest distance	42
K- Leg clearance	66
L- Work surface height	74
M- Work surface thickness	5
N- Thigh clearance	20

The type of task being performed is the primary reference of work surface height. The craftsmanship of jewelry making requires excessive attention to minute visual details. Craft workers are imposed to be in intermittent to static working position for the entire shift. As a result, this condition also contributed to repetitive discomfort and pain on different body regions of craft workers. Slanting the work surface by approximately 15° or lifting it by 20cm may help to bring the workpiece nearer and more visible to the optimum light of sight of the workers. Likewise, tools and highly used materials should be arranged functionally and sequentially on the workstation. The proposed alteration on workplace design also considers the use of anthropometry which helps in minimizing hazards to individuals in a work environment and improving the systems performance (Anema et al., 2004). The design values are based on anthropometric measurements of 1805 Filipino workers in 31 manufacturing firms (Del Prado-Lu, 2007).

Tool evaluation gives emphasis to uncomfortable hand position of craft workers in handcrafting process due to current coping saw design. The current design of coping saw is intended for working at standing position and using the tool while in sitting position forces the wrist to bend. Thus, a redesigned coping saw with hook grip which is more fitting to use in tilted work surface may support manual shaping of workpiece with straight wrists.

In order to avoid static working posture, craft workers should have an alternate sitting and standing postures. Based on study, 2 hours per day is the maximum time for voluntary sitting and the workers have to stand up and move after 30 minutes of constant sitting position (Owen N.

et al, 2011). Another means of promoting alternate sitting and standing is through dynamic or active sitting. Based on study, this method increases the trunk motion thus giving favourable effect on low-back. Active sitting refers to the use of unstable seating surface such as stability ball or air-cushioned surface which naturally obliged the worker to increase control and awareness of body posture in order to maintain an upright sitting position (Wang H. et al., 2014).

Environmental factors evaluation indicates nonconformity on recommended illumination level of IESNA. Because of insufficient light on the task, it is suggested to sustain the local lighting and increase the percent reflectance of working surface from the equivalent reflectance of wood finished which is less than 30%. It is also important to keep the luminaires clean and periodically replaced since illumination levels decrease with age.

In order to improve the current thermal condition in jewelry fabrication, adjustment on ventilation system is essential. Since there are less than ten workers in the fabrication area, local ventilation is more economical than ventilating the whole facility. According to Konz (1995), a rough rule of thumb is that at a distance of 30 fan diameter, there is a 10% drop of fan air velocity. Given this, it is suggested to have at least two wall-mounted fans enough to ventilate the entire jewelry fabrication area.

Generally, the above discussed recommendations can alleviate the degree of exposure to identified environmental and physical risk factors. In the long run, these alternatives may prevent the occurrence of occupational disorders and diseases.

## 5. CONCLUSION

The task analysis targets to identify various ergonomics risk factors present on a typical work environment of a small-scale jewelry enterprise in Meycauayan, Bulacan. The workplace assessment consists of two parts which are environmental ergonomics and postural job analysis. An ergonomics tool set is used which includes different checklists, standard posture worksheets and actual measurements of environmental variables. In general, ergonomics risk factors under investigation are illumination level, noise level, thermal condition, ventilation, posture, and musculoskeletal and static load. Data analysis shows that crafts workers are exposed to environmental factors such as illumination level, ventilation and thermal conditions which deviate from known recommended values by IESNA and ASHRAE. Moreover, postural job analysis manifests that there are high risks in sitting posture, anthropometric, biomechanical and physical aspects of workplace. Tool design evaluation recognizes safety concern on working with bent wrist due to current coping saw design on hand crafting. Furthermore,

65% of physiological discomfort presently experienced by jewelry makers involves tenderness and pain on neck, shoulder, upper and lower back, arms and fatigue. The remaining 35% consists of stinging, burning or scratchy sensation on eyes, blurred vision, sensitivity to light, eye redness, and other eye discomfort.

As a result, an ideal approach system is used to develop recommendations to ensure occupational safety and health of jewelry makers. Area for future study may probe the economic viability of proposed alternatives given that the study focuses on a small-scale jewelry enterprise. Also, the task analysis may serve as a pilot study for a more in-depth research in order to validate that the outcome is a representative of the entire jewelry makers population and to deeply analyze the relationship between identified risk factors and systems performance.

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To God be the glory!

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