



# Evaluation of Workplace Environmental Ergonomics and Method Development for Manufacturing Industries

Tomas C. Kassaneh<sup>(✉)</sup> and Ahmed A. Tadesse

Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, P.O. Box 26, Bahir Dar, Ethiopia  
tomaspoly@gmail.com, wubied@gmail.com

**Abstract.** Though workplace safety is relatively satisfactory in developed countries, it does not receive proper attention in developing countries yet. It is known that productivity improvement mainly in labor intensive factories like metal and textile, is not easy without considering the workforce safety. Studies on Ethiopian manufacturing industries show that there are different workplace safety problems, and as a result of less attention, there are also very few practices on prevention and control. Even the few studies done on the area do not yet see the workplace physical factors in terms of complying standards and being causes for injuries and low performance. Thus, this study focused to assess and ergonomically evaluate the workplace environment and develop a control method. It is conducted on purposely selected 10 metal and 4 textile factories. Workplace observation, focus group discussion and measurement are methods applied and digital light, sound level and heat stress meters are measurement equipment used. The factories' environmental measurements compared to the Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) standards shows non-compliance and even some textile and garment factory work sections has lighting reading level less than 250 lx where 2000 lx is the standard, and metal factory work sections have also up to 128 dB from 85 dB noise exposure standard. Hazardous sections are identified as an intervention and the major causes and impact of the factors is assessed. Finally, a factory level strategic approach model is developed for workplace hazard prevention and control.

**Keywords:** Workplace safety · Environmental factors · Hazard control method

## 1 Introduction

Physical Environmental Ergonomic hazards are workplace conditions that pose the risk of injury to an employee. It includes vibration, temperature extremes, illumination, and noise exposures. Fasunloro (2004) defined occupational hazard as the “potential risk to the health of a person emerging from an unhealthy environment” which is a significant public health issue. Generally, the hazards at workplace can be classified as health hazards and physical hazards (Fatonade and Allotey 2016). As it is stated also by

Stephen (1998), the physical hazards include noise, temperature, illumination, vibration, radiation. The quality of working environment in any organization is a critical factor and may simply determine the level of employee's motivation, subsequent performance and productivity (Jonny and Nwonu 2014). Among the above types of physical hazards, most of them are prevalent in the metal, iron and steel, textile and garment industries. The World Health Organization (WHO) (2010) considers the workplace a priority setting for health promotion in the 21st century. Safe work and workplace are necessary for increased production and higher productivity and hence promotion and protection of safe work and workplace is the complementary aspect of industrial development (Upadhyaya 2002; Devanand 2015). The interdependence between working conditions and productivity is increasingly recognized.

In manufacturing industries of Ethiopia, development and labor market demand is increasing from year to year. The manufacturing industries increment alone without workplace safety improvement approaches is considered to be unproductive especially in metal and textile manufacturing industries-labor intensive sectors. Workplace accidents and work errors occur in the process of production as a result of unsafe working condition, unsafe acts, personal failure and lack of awareness on the side of both the employers and workers. As per the Ethiopian Ministry of Labor and Social Affairs (MOLSA) (2016), though accident reports don't clearly show the nature and causes of work accidents, the highest percentage (56.05%) occurred in the manufacturing industries. To enhance the metal and textile sector development which has been given priority by Ethiopian government, workplace safety is found to be mandatory and so; a company-wide ergonomic assessment should be developed.

## 2 Problem Description

Though occupational health and safety of workers has recently improved and is relatively satisfactory in developed countries, it receives yet little attention and comes at low level in the list of national priorities (ILO 2010). This is also true for Ethiopia, where slight consideration is given for workplace safety and associated problems are savior (Yessuf et al. 2014; Zeleke 2015; BOLSA 2017; Seife 2017; Kassu 2017). Moreover, some researches in Ethiopia shows that occupational health data collection and harmonization is in beginning stages and even the available data often done by different organizations, different criteria, infrequently and no information management system. As per the literature, few researches were conducted on metal, textile and garment industries in relation to occupational safety and health control in Ethiopia; with special focus on accident identification and severity for the reactive purpose. However, the factory working conditions in terms of complying standards in lighting, temperature and noise, and the associated impacts are not yet studied in the way that shows the specific sections of a factory. The above mentioned physical environmental factors are also a kind of root causes for the occurrence of different injuries identified by previous studies. For example, due to high temperature environment, a worker may

be forced to unsafe act of working which leads to body injuries and as a result error on the product quality. Therefore, the ergonomics hazards related to the physical environmental factors are becoming one of the major workplace problems which affect the safety and performance of Ethiopian metal and textile factories and needs a scientific evaluation and corrective measure.

### **3 Objective of the Study**

The major aim of the study is to measure and evaluate the workplace physical environmental ergonomics factors in Ethiopian metal and textile manufacturing factories and develop strategic approach model with its implementation strategy. Specifically, it is to assess working practices of the case companies with respect to ergonomics and safety, to measure the level and intensity of factors, to identify the gap compared to the OSHA & NOISH standards, to identify hazardous work sections, to investigate the causes and show the impact of the incompliance.

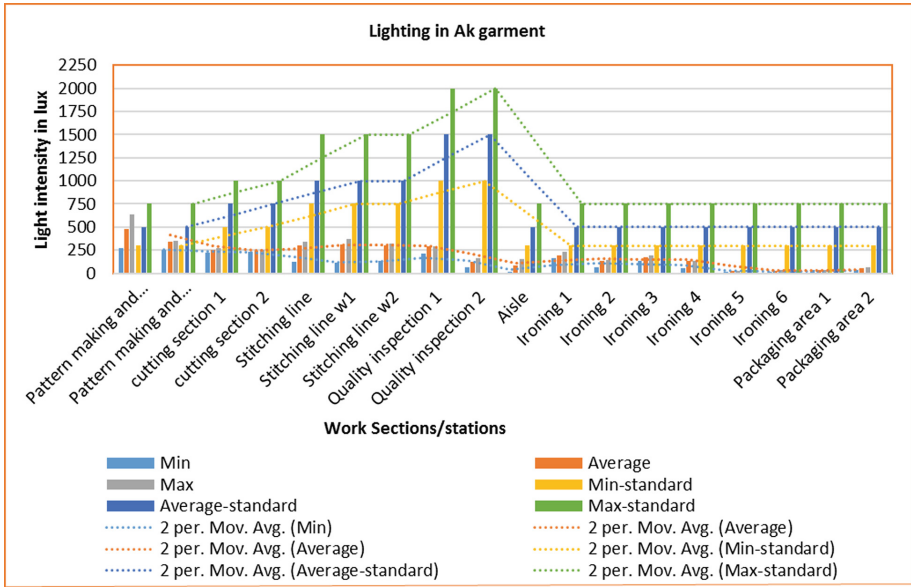
### **4 Methodology of the Research**

This research used workplace observation, interview and workplace environment measurement as primary data collection methods. Each workplace of the selected factories is scientifically observed in the view of ergonomics and safety. Then identification of abnormal sections or work sections having discomfort is made so as to be used for measurement. The measurement equipment used includes Sound level meter (Model HD600), Lux level meter (Model 407026) and Heat stress meter (Model HT30). Interview in the form of discussion is used to get information from workers and experts regarding to safeness and suitability of the working environment, the workplace hazards faced and prevention practices. Books, articles, government and company reports and previous studies are also used. The study is conducted in 10 metal and 4 textile and garment factories as samples which are selected using purposive sampling technique. The researchers selected Metal Industries and Textile and Garment Factories as a case because these factories are labor intensive, have exposed work nature for physical environmental factors and have also more manual works than other types of industries. Moreover, prior attention is given by government on these sectors. Comparison of the case factories' environmental measurements is done with the OSHA and NOISH standards. After the data analysis, discussion and identification of major hazardous work sections, the major causes and impact on the safety and productivity of the factories is assessed so as to use for the development of hazard prevention and control method.

## 5 Result and Discussion

### 5.1 Workplace Measurements, Analysis and Findings

The light, noise and temperature measured data from the sample factories are organized, analyzed and the summary of results are presented in Table 1. The analysis of each individual factory is undertaken in similar fashion as of the lighting analysis of Ak garment shown for instance with Fig. 1.



**Fig. 1.** Lighting data compared with standard for AK garment factory

**Table 1.** Summarized result of the measured and analyzed data of the case factories

Factory	Noise	Lighting	Temperature
KTSC textile	Out of 12 sections assessed almost all does not comply the standard level except one section	With the exception of grey inspection, all other sections have below standard lighting levels expected for the task	All sections are in good temperature except the Ring frame section which have much higher temperature of 34 °C
MA garment & textiles	Knitting and open-end machines have higher noise but ring frame is normal	Except Sewing line, cutting machine, cutting manual and Ring frame all other sections are to standard	Boiler section has 31.6 °C where the standard is 30 °C. Other sections are normal

(continued)

**Table 1.** (continued)

Factory	Noise	Lighting	Temperature
BTSC textile	Sections like open end, Picanol and Somet machines in weaving area, and other workshop sections do not comply with the standard	With the exception of packaging, sewing, cutting and inspection sections, all other sections have lighting level of below standard	Except fractional difference of 0.1–0.4 °C in spinning, wood workshop, Printing, bleaching and dyeing sections, others are normal
AK garment	Here noise has no impact in the factory	All measurements lag behind the minimum standard with the exception of pattern making and cutting 1 & 2	The temperature in the factory is normal
HMMBI metal	Most of the sections have noise levels above the standard. Hammering activities have the reading of above 108 dB which is very risky	All work sections are normal except the Leath machine area & grounding room which have low light level as compared from the standard	All sections comply with the standard except heat treatment area
KO steel	Except shearing m/c, corrugation m/c, Nail making m/c 1, Collusion m/c, all other sections are up to the standard	Lighting level is almost around the standard range and has no effect on the worker and the work	The factory has comparably good temperature
Ak metal industry	Most sections are very risky for workers to accomplish their task without any PPE even some sections have over 100 dB which is much higher from the standard, 85 dB	In milling section, the lighting is slightly lower, whereas, the minimum lighting in plating room is far behind the standard, while maximum lighting is comparable with the standard	The melting shop is risky and also causes the rise of air temperature in room. There is also the sparkling of molten particles and the working practice is very hazardous in the shop
MI metal	In dome welding and hammering the noise reading reach 128 dB which is very hazardous	The lighting condition in the factory is normal	Temp. is normal except dome manufacturing area which is hazardous due to smoke and poor ventilation

Both metal industries and Textile and garment factories have workplaces with under the standard requirement of lighting and above the standard limit of noise and heat exposure. Lighting factor problem is affecting the textile and garment factories whereas noise exposure problem is visible in metal factories. Temperature or heat stress problem is not significantly shown in both of the industry types except few sections like furnace areas in metal and ring frame section in some textile factories. However, the metal melting work and practice shown is very hazardous as there is sparkling of molten metal that can injure workers. In some of the textile factories, specifically garment section, there is a light bulb which can provide standard lighting level;

however, due to afraid of the warming resulted from such bulb, they are not using it and as a result they are working with poor lighting. Due to the different technologies used in textile factories, the level and intensity of the factors is different and it is found that in the factories having recent technology machines, there is less intensity of generating heat and noise.

## 5.2 Identification of Causal Factors and Impact Assessment for the Incompliance of Workplace Environment

After the study finds the presence of incompliance in the workplaces, it is tried to identify the major causes/factors and assess the impacts of it. This will help the researchers in developing the mitigation ways.

**Identification of Causal Factors.** From the observation of work places and discussion made with factory workers and experts, the major causes identified are briefly presented below.

*Lighting.* The major possible causes identified for the lighting factor includes poor lighting design, lack of proper maintenance on failed bulbs, deliberately making some bulbs off to avoid the heat generated, and farness of the light source from a work station. Moreover, lack of awareness about the advantage and disadvantages of proper lighting on health and productivity contributed for the problems listed above. For instance, rather than making off intentionally some bulbs to reduce the heat generated, they can fully on the bulbs and prevent the heat through proper ventilation. The incorrect lighting design and poor installation of lighting source can cause disability glare from a light fitting, color effects and distracting reflection.

*Noise exposure.* Regarding to the noise factor, poor work practices, lack of regular maintenance of machines, lack of sound protecting guards, poor workplace design (nearness or collecting of high sound generating tasks in one station/section), use of old technology, are the major factors identified.

*Temperature/heat stress.* The high temperature recorded in some sections of the case factories is due to high heat generating machines, lack of protecting guards, poor ventilation system, confined working area, maintenance and use of old technology.

Generally, the failure on the part of the management in realizing and applying prevention methods and not giving attention for safety could be considered as one of the major causes to the incompliance which in turn affects workers' safety.

**Impact of the Incompliance.** It is difficult to quantify the impact of the environmental workplace problems because of lack of recorded data. The assessments made from different reports and expert discussions are summarized shortly below so as to show the criticality of the issue and thus get attention by the factory management or owners. Medical, lost wages, sick leave with pay, absenteeism expenses for replacement are included impacts from the cost perspective. For instance, a study revealed that the medical expenses due to accidents or diseases impoverished by metal, steel and iron industries incurred costs in sum of ETB 2,320,707.27 only from 19 industries in 2007 E.C. and sum of ETB 776,699.93 from 24 industries in 2008 E.C. (BOLSA 2017). While from health side, different body injuries, MSDs, hearing loss, sight problems are impacts shown. On the other hand, individual or team productivity will decrease, error

increases, delivery time will increase and generally affects the performance (productivity and quality). Researches in the quality field suggests that around 30–50% of quality defects are related to poor ergonomics (Axelsson 2000; Drury 2000; Lin et al. 2001, as cited in Neumann et al. (2002).

## 6 Strategic Approach for Hazard Prevention and Control

### 6.1 The Need for a Strategic Approach

In many of the studies made in Ethiopian industries, numerous accidents found to emanate from the less concern of safety and health at workplace by the organization's management, absence of guidelines and easily implementable methods, and enforcement possibilities. Moreover, as discussed earlier, the incompliance of the physical workplace environments are also causes for the accidents. Such safety problems are not one time and so difficult to solve by proposing specific methods to be implemented, rather it needs sustainable and strategic ways to follow. As it is supported by our assessment and other studies (Habtu et al. (2014); Zeleke (2015); BOLSA (2017)), though majority of factories provide some PPEs for their workers, it is not utilized properly by workers all the time while they are on duty. Accordingly, recommending PPE alone or some other specific method is not significant and effective measure. Regarding on improving company productivity, safety and work environment through strategic way, recommendations were given by Seife (2017) for Ethiopian textile industries and Kasu (2017) for manufacturing industries. In addition, Kasu (2017) develops an integrated model for OSH practice of Ethiopian manufacturing industries. Though we found that the model is good at national level as a framework, it will be a little bit complex and difficult for a company level at this OSH stage of our industries. These all calls up to develop a strategic approach than trying to implement single, specific and short-term mitigation methods.

### 6.2 The Proposed Strategic Approach Model

An integrated model (Fig. 2) is developed from a hierarchical hazard prevention and control method and hazard prevention and control program implementation model. The model is developed considering different practices, literature, case companies existing condition, and demand and results of the study so as to customize the general ergonomics and safety principles.

**Model-1: Hierarchical Hazard Prevention and Control Framework.** The model will serve as a framework for OSH experts on determination of the most effective and feasible corrective actions to be undertaken. The approach groups actions by their likely effectiveness in reducing or removing a hazard. Accordingly, safety department experts of factories can use this method to select and implement feasible and effective controls. Following this hierarchy normally leads to the implementation of essentially safer systems, where the risk of illness or injury has been considerably reduced. The Hierarchy breaks down as follows, with the most effective measures at the top of the inverted pyramid and the least effective at the bottom.

1. *Elimination (Physically Remove the hazard)*. This is the preferred method and most effective solution at reducing hazards; however, it is also tend to be the most difficult to implement in an existing process.
2. *Substitution (Replace the hazard)*. It is substituting or replacing the known hazard with a material, process, or equipment that is less hazardous.
3. *Engineering controls (a physical change to the workplace)*. It focuses on changing the structure of the work area by installing physical barriers/ using safety devices.
4. *Administrative and work practice controls (change the way people work)*.
5. *Personal protective equipment (PPE) (protect the worker with PPE)*. When all options mentioned above are exhausted, introduction of PPE is recommended.

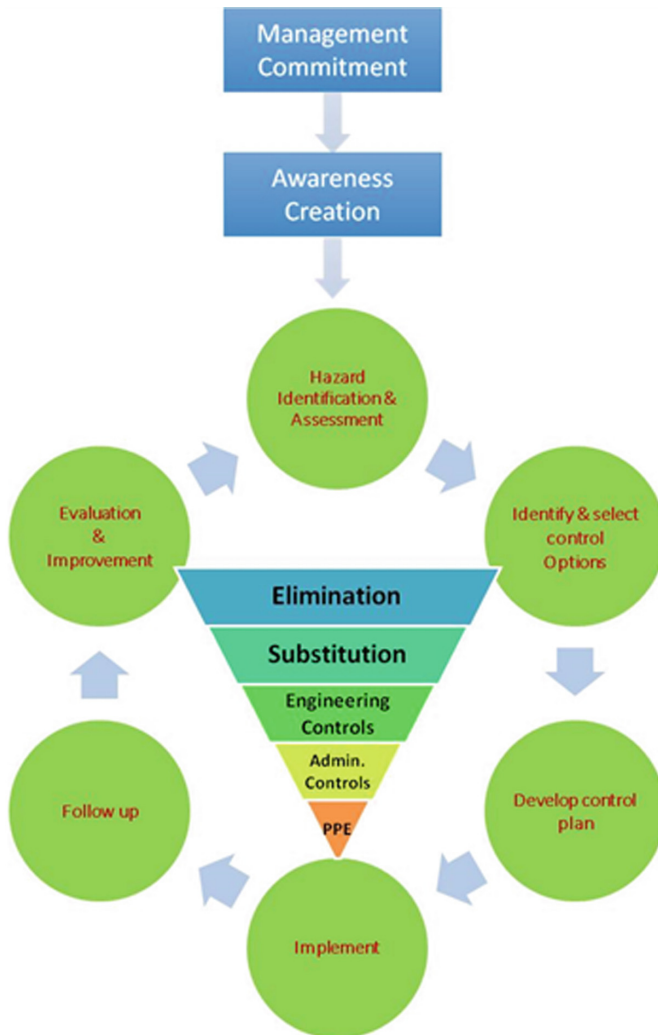


Fig. 2. Integrated model for hazard prevention and control



Here it should be noted that instead of relying on the lowest methods, safety department of a factory should look up the pyramid to the higher order solutions and risk elimination strategies. Moreover, the full control of some hazards may require the combined use of two or more control methods.

**Model-2: Hazard Prevention and Control Program Implementation Model.** Based on OSHA's recommended practices for safety and health program an eight step modified strategic hazard prevention and control program implementation model is developed. The model is modified to integrate with the NOISH hazard prevention and control framework (inverted pyramid) and to make it easily applicable for manufacturing industries and government agencies. Management commitment and awareness creation are introductory steps of the safety program to a factory. Whereas, the next six steps are major tasks which should be continuously done in order to implement safety prevention and control method. The detail steps are presented below.

1. *Management commitment.* The management should provide the leadership, vision, and resources required to implement an effective safety and health program.
2. *Company-wide awareness creation through training.* Awareness creation training has to be given to the whole workers of the company on safety program.
3. *Hazard identification and assessment.* At this step, safety department experts/supportive team should start implementing safety programs by hazard identification and assessment and go through the next five steps.
4. *Identify and select control options.* Based on the hazards identified in step 3, the team with the involvement of shop floor workers should choose feasible and effective control methods from the hierarchy.
5. *Develop hazard control plan for implementation.* A prioritized implementation plan should be developed with an overall goal to ensure effective long-term control of hazards.
6. *Implementation of the selected hazard prevention and control method.* Based on the previously developed control plan, implement the hazard control methods according to the priorities established in the control plan.
7. *Follow up.* Confirm the effectiveness of the implemented control options by tracking the progress in implementing, inspect and evaluate once they are installed, and follow routine preventive maintenance practices.
8. *Evaluation and Improvement.* Lastly, to improve safety practice continuously through the cycle, evaluation of the implemented specific hazard prevention and control method and evaluation of the whole safety program should be done.

## 7 Conclusion

Though it is a fact that meeting the workplace safety standard is very essential for organizations' performance, the studies indicate that it is given less attention in Ethiopian manufacturing industries. Most of the critical workplaces observed in the metal and textile industries were characterized by incompliance with the standard in noise and lighting, whereas temperature was found to be normal with the exception of

few sections. Some sections in textile industries, such as weaving sections has noise up to 102 dB and in metal industries, it rises up to 128 dB in hammering activity from 85 dB of standard. While, lighting level in textile and garment quality inspection areas measured less than 250 lx from 2000 lx of standard which is very far from the standard. Lack of attention and commitment from factory owners or management in realizing and applying properly guarded machine for reducing heat and noise, proper illumination and ventilation, workplace design are the major causes for the in-compliance. From the interview and discussion made, it is concluded that the in-compliance is affecting workers on their health and efficiency. The study also concludes that the use of specific, single and short term temporary measures will not be effective and brings continuous improvement on the safety and health issues of manufacturing industries. Hence, a strategic approach model is developed that helps industries to introduce easily, implement hazard prevention and control at a company level and bring continuous safety and health improvement sustainable. Workplace assessment other than light, temperature, noise; for instance, dust in textile and cement factories, vibration in metal industries and chemicals in processing industries are highly recommended as a future study.

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