Impact of Low Illumination and High Noise Level on Occupational Health of Indian Handloom Weavers: Special Reference to Bargarh District of Odisha

A Thesis

Submitted in partial Fulfillment of the Requirement for the Degree

of

Doctor of Philosophy

by

Surendra Kumar

(Roll No.-126105004)

Under the Supervision of

Dr. Sougata Karmakar

Department of Design
Indian Institute of Technology Guwahati
Guwahati - 781039, Assam, India

Declaration Certificate

6th June 2018

I hereby declare that the thesis entitled **"Impact of Low Illumination and High Noise Level on Occupational Health of Indian Handloom Weavers: Special Reference to Bargarh District of Odisha"** being submitted in the partial fulfillment for the award of PhD degree, is an authentic work of my research work carried out during the period from July 2012 to May 2018 in the Department of Design, Indian Institute of Technology Guwahati under the guidance and supervision of Dr. Sougata Karmakar. The thesis has not been submitted by me earlier for any other degree or diploma.

Surendra Kumar
Roll No.-126105004
Department of Design,
Indian Institute of Technology Guwahati,
Guwahati - 781039, Assam, India.

Dr. Sougata Karmakar
Associate Professor
Department of Design

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
Indian Institute of Technology Guwahati
Guwahati-781 039, Assam, India

Phone : +91 361 2582464
Fax : +91 361 2690762
Mob : +91 8011403513
E-mail : karmakar.sougata@iitg.ernet.in
karmakar.sougata@gmail.com

DEPARTMENT OF DESIGN

Date: 06.06.2018

Certificate

This is to certify that the work contained in this thesis entitled **"Impact of Low Illumination and High Noise Level on Occupational Health of Indian Handloom Weavers: Special Reference to Bargarh District of Odisha"** presented herein by Mr. Surendra Kumar (Roll No.126105004) was undertaken under my guidance and supervision. The volume of work submitted for the degree of Doctor of Philosophy of Indian Institute of Technology Guwahati was not submitted by him earlier for any other diploma or degree.

He has undergone four specified courses and secured 9.48 C.P.I. (out of 10). He has fulfilled all the requirements as mentioned in the rules and regulations for submitting the thesis for the PhD degree of the Indian Institute of Technology Guwahati.

Dr. Sougata Karmakar,
Associate Professor,
Department of Design,
Indian Institute of Technology Guwahati,
Guwahati- 781039, Assam, India.

Preface

After food, clothing is the basic necessity of human being. Since the Neolithic period, textiles and clothing have been embraced by the mankind on this globe. Textile Industry of India has been receiving commendation from all over the world. In Indian scenario, handloom industry is one of the most labour intensive small scale cottage production sectors. It is not only one of the important choices of livelihood but has been the guardian / rescuer of varied traditional skills which provide significant employment opportunities to the rural masses at lower capital cost next to agriculture sector. Handloom weaving, which has been inherited by the weavers over generations, is a distinctive and high-skill oriented process for manufacturing the intricate and exquisite products for its survival. Most of the works of the handloom textiles manufacturing sector involve manual labor and this sector is highly fragmented, having the promising growth potential and capabilities for a huge employment generation. This sector contributes a respectable share in the total cloth production of the country and towards the world's hand-woven fabric.

Occupational health is one of the basic critical issues for the handloom sector and ignorance towards these issues is highly prominent. Pervasiveness of occupational health issues (awkward working postures, repetitive activities, cognitive discomforts etc.) due to unfavorable indoor environmental conditions have been reported by various researchers in different sectors including textile and clothing. Moreover, these factors have not been given much thought while installing and commissioning the majority of handloom production units in India which in turn have repercussions on the weavers' well-being. Inadequate attentions have been focused to explore the occupational health related issues in this sector. Owing to global reputation, the growth of this sector is tremendous which is substantiated in terms of output and demand in local as well as in the export market. In recent years this sector has been the victim of many challenges that have cropped up in the context of raw material prices, poor management of time and quality, marketing of finished product and indoor environmental conditions which are continuously affecting the livelihood and overall wellbeing of the weavers. Amongst the aforesaid factors environmental related problems are the most crucial / demanding problems for this sector in today's scenario. Anticipating the remarkable growth potential of this sector in India and particularly in Eastern part of India, it is the right moment to conduct investigations from occupational health perspective in the existing handloom sector.

The study aims to analyze the impact of prevalent illumination and noise level on the occupational health of the weavers and puts forward the possible recommendations to alleviate the problems. This research is based on primary data collected through exploratory-cum-explanatory approach (comprising both qualitative and quantitative techniques) from 480 weavers residing in Bargarh district of Odisha in order to ascertain the influence of prevailing illumination and noise levels on physical, physiological and cognitive attributes of the weavers' wellbeing. The result of this study reveals that the weavers are facing a number of challenges in terms of occupational health constraints and poor working conditions.

Acknowledgement

Primarily I would like to thank 'God Almighty' the giver of life, and the environment in whom we live, move, and have our being. I sincerely express thanks to my supervisor, Dr. Sougata Karmakar (Department of Design) for his constant unwearyingly supervision and continuous advice to me during the entire PhD program. I thankfully acknowledge the precious time, guidance and endeavor rendered by him for the completion of my PhD thesis. Special thanks also are due to my Doctoral Committee members, Prof. Debkumar Chakrabarti (Department of Design), Dr. D. Udaya kumar (Department of Design) and Dr. Sukhomoy Pal (Department of Mechanical Engineering); for their time, detailed observations and helpful instructions during the annual assessments and for granting approval to submit my PhD thesis. Special thanks to Prof. Debkumar Chakrabarti (Department of Design) for his expert suggestions and inputs that helped me to develop the method of measuring "Indoor environmental parameters". My gratitude goes towards Dr. D. Udaya kumar (Department of Design) for his expert advice. I acknowledge contribution of Dr. Sukhomoy Pal (Department of Mechanical Engineering) for his constant support inspiration and noble mentorship. I would also like to extend my gratitude to the entire faculty and staff in the Department of Design, IIT Guwahati and especially Mr. Amitabh Bordoloi, for their encouragement and help in times of need. I would like to express my heartfelt thanks to Dr. Abhirup Chatterjee (Institute Post-Doctoral Fellow, Department of Design), Mr. Thaneswer Patel (Research Scholar, Department of Design) Mr. Anirban Chowdhury (Research Scholar, Department of Design), Mr. Indresh Kumar Verma (Research Scholar, Department of Design) Mr. M. Arunachalam (Research Scholar, Department of Design), Mr. Chirapriya Mondal (Research Scholar, Department of Design), Ms. Sushmita Nath (Research Scholar, Department of Design) and Mr. Gurdeep Singh (Research Scholar, Department of Design) for their assistance through meaningful discussions and friendly support. I also thankfully acknowledge the help rendered by the office of the Director of handlooms, textiles and handicraft, Bhubaneswar; M.D. Sambalpuri Bastralaya, Bargarh; Assistant Director (Textile) office, Bargarh and all the weavers and handloom owners of Bargarh district. I would also like to express my thanks to all the weavers who volunteered during measurement and evaluation process. During my thesis work, I came across, many people who have directly or indirectly helped me a lot. I thank all of them for their support. I express my gratitude to all. I would like to respectfully acknowledge the Development Commissioner for Handlooms, Additional Development Commissioner for Handlooms and all staff members and especially E-II section of the office of the Development Commissioner for handloom, Ministry of Textiles, Government of India for their encouragement and support towards completion of my PhD work. I express my gratitude to all my colleagues, staff members and students of Indian Institute of Handloom Technology, Guwahati (IIHTG) and Indian Institute of Handloom Technology, Bargarh (IIHTB) and especially to Mr. Arbind Kumar (SG-I), Mr. Sidheshwar Deheri for their assistance as and when required during the PhD thesis. I would specially like to thanks my PhD colleagues for their constant inspiration and cooperation in carrying out my thesis.

I would like to dedicate my effort to my father Late Nihal Singh, mother Late Krishna Devi and express sincere appreciation to Dr. P.N.Varma, and Dr. Savitri Varma my in-laws for their inspiration and finally I would also like to express my sincere appreciation to my beloved wife Priti Kumar for her untiring, sacrificial and unconditional help in permitting me to be away from my wonderful children Abishek and Drishti as well as from family responsibilities and remain busy for this research work.

Surendra Kumar

Abstract

Locally designed handloom workstations with indigenously developed accessories are prevalent in Indian handloom and cottage industries. This handloom sector is highly decentralized and covered under the category of the small-scale cottage industry. Recommended standards pertaining to environmental variables are not followed in work-shed of handloom clusters in Indian scenario. Moreover, the weavers were ignorant about the impact of these environmental factors as well as about the use of personal protective devices. Hence, the weavers of small-scale cottage industries or informal sectors suffer from different types of psycho-physiological issues leading to poor occupational health. Following literature review, it is found although a lot of work has been done on the indoor environmental issues including noise and illumination in various industrial sectors including the power-loom but scanty or negligible information is available about the work done with respect to handloom sector. Studies on ergonomic evaluation in terms of occupational health, MSD & handloom modification were carried out in the field of handloom but work on impact of prevalent level of illumination and noise on occupational health of the weaver has never been reported in the context of Indian handloom sectors. Illumination and noise are crucial parameters which might affect the performance, productivity and psycho-physiological wellbeing of the weavers engaged in handloom sector. Among all the environmental variables, noise and illumination are the two key variables which are persistent throughout the year irrespective of seasonal variation. Thus, the current study aimed to investigate the prevailing levels of illumination and noise in handloom workstations and explore their impact on occupational health and wellbeing of the weavers in terms of physical, physiological and cognitive aspects. For conducting the research, it was hypothesised that prolonged exposure to high level of noise and low level of illumination (either solitary, or a combined impact) would significantly affect the physiological and psychological health of the weavers engaged in handloom workstations. In present research, Bargarh district of Odisha was selected as the study location due to the abundance of (8 number. out of the total 18 number) 'A' category handloom clusters here along with the highest production of Ikat sarees. Illumination level was measured using the lux meter whereas noise level by using sound level meter following standard protocol. Questionnaire was developed for collecting the responses of the weavers

against the questions related to their socio-demographic characteristics; impact of noise and illumination level on physical, physiological and cognitive aspects of the weavers. Before administering to the respondents, the reliability of questionnaires was analyzed for validity and test-retest reliability using Cronbach's Alpha (α) and calculated the Friedman's Chi-Squared (χ^2_F) tests for independence of association along with correlation between environmental factors and their subjective perception by using Spearman's correlation coefficient (*r*). After the statistical analysis of the collected data, it was observed that the illumination level in handlooms was significantly poor and far below the recommended standards whereas the levels of noise near the right ear of the weaver was high throughout the year. The results of Spearman's correlation analysis indicated significant correlations between the recorded illumination level and noise levels with perceived job performance. Spearman's correlation coefficient (r) for correlation of illumination level and corresponding subjective responses to questions in the questionnaire on the impact of illumination revealed that there was differential significant ($P < 0.001$) inverse correlation between illumination and the physical, physiological and psychological discomfort factors whereas some physiological discomfort factors such as sensation of light on loom, sensation of light around loom, illumination satisfaction level on loom and effect of light on job performance evinced highly significant ($P < 0.001$) direct correlation. Correlation of noise level and corresponding subjective responses to questions in the questionnaire on the impact of noise revealed that there was highly significant ($P < 0.001$) direct correlation between noise and the physiological and psychological discomfort factors. All the objectives of the research work were fulfilled and the hypothesis was accepted. It is perhaps the first of its kind study to establish impact of environmental factors viz. illumination and noise on handloom weavers' perceived occupational health including physical, physiological and cognitive aspects. Suggestions towards rectifying prevailing level of illumination and noise and to reduce the impact of these factors on the occupational health of the weavers with specific affordable design interventions / recommendations for enhancing illumination level and some general recommendations for controlling the impact of noise in order to improve the overall wellbeing of the weavers has been proposed in the published literature of the present research. Handloom entrepreneurs, cooperative societies, master weavers and handloom workers interested in expanding or establishing new handloom manufacturing establishment at the small scale and village level would find the results of the current research endeavor highly beneficial.

Summary of the research

Introduction

Lack of awareness towards the occupational health is a major concern of the small scale and cottage sectors across the globe. Much thought was not being précised about the location of the workstation, work methods and work environments while commissioning and installing the majority of Indian small scale and cottage manufacturing industries. Ignorance towards occupational health parameters is a major issue. These services are well organized and implemented in the developed countries as compared to under developed or poor countries because of inadequate resources, lack of awareness and due to availability of plenty of unemployed work force which results in providing least priority to occupational health parameters. Moreover due to continuous industrialization in many developing countries of the world this area has not been addressed properly which ultimately resulted into public health problem. Inadequate attention has been focused to investigate the role of environmental aspects on the shop floor of the small scale and cottage sectors. However, the current focus is on increasing the product quality and productivity of the small scale sectors of India in order to enhance the earnings of the workers that too without sacrificing their occupational wellbeing. Hence, the discipline of occupational health and the environmental factors are required to be given due weightage for enhanced safety, comfort and wellbeing of the workers in this sector.

Occupational health is one of the important parameters for the growth and economy of any country of the world. The type and standard of surveillance which is required for a particular target group, decides the occupational health and safety norms. Even though there is growing awareness about occupational health and safety, the rate of accidents in various industries have shown upward trend. It has been ascertained that the workers having prior knowledge about the occupational health and safety norms were less prone to casualty.

Background, Research Gap and Problem statement

Textile Sector employs the largest workforce in the world next to the farming. Handloom sector is recognized as one amongst the most drudgery and uninspiring work. The workforce of this (handlooms) sector earns their livelihood in the most unjust, exploitative conditions having low wages under harsh working conditions. As the weaving activities lead to awkward physical postures and these postures result in physical stress and painful internal disorders.

Several agencies all over the world have taken various corrective measures for uplifting and revival of this sector in terms of improvement of wages, quality of life and life span. But this sector is unable to reflect the positive trend with respect to improvement in production efficiency and quality as well as improvement in physiological and psychological status of weavers. Due to the drudgery nature of work throughout the year, working conditions on the workstations needs to be more rejuvenating and vibrant in order to improve the quality of work, production efficiency besides the quality of life of workers.

India, especially the Ministry of Textiles, is taking aspiring growth oriented steps for the stimulation of handloom sector through its various developmental activities which have been floated in the recent past through its 'Make in India' campaign. For social security such as for their life insurance, accidental insurance and for pension above the age of 60 years of weavers, Government of India has already taken various measures for the weavers. One of the aims of 'Make in India' promotion was to create employment opportunities for the people. Various sectors have been identified for attracting investments. The textile sector and especially the handloom sector is also one of them. Through textile sector skill council, the Government of India is trying hard to incorporate more and more skilled young generation under the realm of textile industries including the handloom cottage industry. Subsequently an emphasis is on the propensity of the young generation towards this traditional manufacturing cottage industry in order to develop huge labor force for this sector.

India's rapid industrial growth has resulted into many environmental issues especially related to indoor environmental factors such as light, noise, relative humidity and temperature and which has drawn the considerable attention from the policy makers, researchers and textile entrepreneurs.

Indian weaves are incredibly rich and recognized as world class heritage. The tacit knowledge of these weavers without any doubt, is a valuable asset and deserves to survive the passing times. Inspite of extreme poverty of the majority of the weavers, this unique heritage is being carried forward by them even during the contemporary global economy.

Weavers distinguish themselves as experts, artists, technologists and innovators. An important insight here is regarding the acquisition and mobilizing of personified tacit craft knowledge, which leads to innovation. Finally, the value of this research to knowledge building itself lies in understanding interaction. It reconnects what became disconnected: the mind and body, science and art, theory and practice, village and city, production and market, means and ends, past and the future, the old and the new, change and stability, thus putting the weaving art further into the toolkit of contemporary knowledge building practices.

India occupies a prominent place in terms of productivity and the number of handlooms and produces 85% of handlooms of the world. Being a global manufacturing hub, it is expected to have tremendous increase in handloom weaving activities in the country. The Indian handloom industries are highly fragmented and unorganized in character which generally falls under the category of cottage industry.

This small scale cottage industry offer huge employment opportunities and significantly contributes to the manufacturing output. The Government is promoting greater manufacturing activities all over India through various policies.

Due to inclination of the weavers towards commercialization of this profession all over India and especially in the eastern part of India, there is an optimistic shift in the number of full time weavers which resulted in more number of working hours on the handloom. Government of India in association with Government of Odisha is also planning to develop a Handloom Park (about 20 km from Bargarh city at Katapali in Barpali district) which is anticipated to give a big boom to numerous handloom weaving units and subsequently expected to increase the pre and post handloom weaving activities with the generation of huge employment opportunities throughout the state of Odisha and especially in the western part i.e. in the district of Bargarh. Most of the weavers (73%) of this district are having pit looms and around ninety percent of the weavers weave sarees. Now-a-days these weavers are facing crisis of declining of the off-springs to adopt and admire this handloom weaving profession as their ancient legacy.

Owing to positive thrust towards commercialization, the weavers find it difficult to bridge the demand and supply gap in order to meet the quality product requirement due to prevailing poor physical and conducive environmental conditions especially illumination and noise on and around the workplace which have detrimental effect on the psycho-physiological inconvenience of the weavers. The indoor environmental conditions for traditional handloom remains unchanged which resulted in deteriorating occupational health conditions of the weavers and need immediate interventions.

Therefore, in this context, investigations into the existing handloom workstations and associated work activities / methods resulting in guidelines for indoor environmental interventions and work methods from an occupational health perspective is sure to benefit the existing cottage handloom industry and the weavers employed in this sector. Additionally such an effort will definitely help handloom houses desiring to set up new handloom manufacturing units to proactively involve the occupational health issues in the workstation designs, thus deriving its associated benefits for all stake holders.

Foreseeing increased handloom manufacturing activities in India and particularly in the eastern part of India, it is the appropriate time to conduct investigations from an occupational health perspective in the existing handloom sector. Following literature review, it was observed that there was scantly or no reported study on investigations concerning the effect of indoor environmental factors on the occupational health of the weavers of the cottage and small scale handloom manufacturing industries all over the world. Ten handloom fabric manufacturing clusters (under the small scale cottage sector) in the western part of the state of Odisha were identified for the present study. Necessary ethical clearance and permission have been obtained for conducting investigations in their handloom houses and manufacturing units. The production processes at the handloom workstations were centered at the front and back side of the handloom weaving machine as well as around and at the center of the handloom workstation.

Aim and Objectives

The present research aimed to investigate the illumination and noise levels in handloom workstations of Indian handlooms located in Odisha (an eastern state of India) and explore their impact on occupational health and wellbeing of the weavers in terms of physical, physiological and cognitive aspects and recommend the remedial suggestions for improving the indoor environmental conditions especially the illumination and noise level conditions that would not affect weavers' health and activities in long run.

The following objectives were framed in order to achieve the stated aim.

1. Assessment of the Illumination level in the handloom throughout the year.
2. Assessment of the noise level in the handloom throughout the year.
3. Explore the effect of prevailing illumination on the physiological and pschycological aspects of the weavers

4. Explore the effect of prevailing noise level on the physiological and pschycological aspects of the weavers through subjective evaluation.
5. Analyze if there were any correlation between the subjective rating with corresponding environmental factors, in order to understand the impact of illumination and noise.

Hypothesis

Initial visits to various handloom clusters were made to observe and understand the prevailing working conditions at handloom workstations. After review of literature and discussions with weavers, hypothesis was formulated for ensuring a proper direction to the research work.

H1: Prolonged exposure to high level of noise and low level of illumination (either solitary, or a combined impact) would significantly affect the physiological and psychological health of the weavers engaged in handloom weaving activities in unorganized / semi-organized handloom sectors

Methodology

The study was based on both primary and secondary data. Primary data was derived from the responses of handloom weavers collected through the questionnaire. Demographic details of the weavers were collected using a personal information questionnaire. Information pertaining to the prevalence of symptoms of physiological ailments was collected using the questionnaire. Direct observations were used to record work activities at the handloom workstation. Work elements (in a work sequence) at the handloom workstations require involvement the use of the entire body, empirical assessments for ascertaining the prevalent value of indoor work environment (illumination and noise level) of the existing handloom workstation, which were measured for one complete year with the aim of identifying location specific and season specific risks. Hand held lux meter / light meter (LM) and sound level meter (SLM) were used for measuring the illumination and noise indoor environmental parameters followed by subjective assessment using the field study questionnaire (Appendix A - F). Discomfort rating using Borg CR 10 (Category Ratio) scale (to understand body parts affected while performing a particular task) and 7 point Likert Scales were marked in the questionnaire. Subjective work load assessment was performed using the National Aeronautics and Space Administration - Task Load Index (NASA – TLX) technique. Statistical analysis of the collected data sets was performed using SPSS v.20 (IBM, USA) software. Proper care was taken to explain the weavers to present the factual information. Secondary data was collected from the websites of the offices of the Development Commissioner for Handloom, New Delhi and Government of Odisha over and above the supporting data was collected from published and unpublished sources like reports, books, journals, periodicals, thesis and minutes of the meetings.

Results and Discussion

Illumination and noise level of the existing handloom workstation were measured for one complete year with the aim of identifying location specific and season specific risks. **Thus the objective – 1 and 2 of the research work is accomplished**.

Symptoms of physical, physiological and pschycological ailments of the weavers working at the handloom workstations were observed. Occurrence of the symptoms of musculoskeletal ailments (discomfort, pain and ache) and pschycological ailments during weaving and pre or post handloom activity were significantly higher for the weavers. Awkward working postures, prolonged work duration and awful workstation environmental conditions especially poor illumination conditions were established as risk factors for the high prevalence of symptoms of physical, physiological and pschycological ailments among the weavers at the handloom workstations. The influence of working postures and environmental conditions on symptoms of physical, physiological and pschycological ailments was found to be significantly ($p < 0.05$) mediated during working on the handloom workstation. It was also inferenced that there was a strong direct or indirect association of the symptoms of physical, physiological and pschycological ailments with illumination as a factor ($0.28 \geq r \geq 0.92$) and ($-0.98 \geq r \geq -0.63$) respectively. Based on statistical evidence it can be concluded that there was a strong association of the effect of poor illumination conditions on the physical, physiological and pschycological ailments. **Thus the objective - 3 of the research work is accomplished.**

Physical, physiological and pschycological ailments indications were also evinced among the weavers at the handloom workstations. The pschycological and musculoskeletal (discomfort, pain and ache) ailments experienced during the weaving and pre or post handloom activity were significantly higher for the weavers due to high level of noise. Uncomfortable working postures, prolonged working hours and high noise level conditions were established as risk factors for the high prevalence of symptoms of physical, physiological and pschycological ailments among the weavers at the handloom workstations. Influence of working postures and noise level conditions on symptoms of physical, physiological and pschycological ailments were found to be significantly ($p < 0.05$) arbitrated during working on the handloom workstation. It was also inferenced that there was a strong association of the symptoms of physical, physiological and pschycological ailments with noise as a factor ($0.47 \geq r \geq 0.96$). Mean weighted ratio of the physical demand was rated very high (79.59) by the weavers due to prevalent of obnoxious noise level conditions. It has been observed that in spite of putting in lots of mental and temporal demand the performance of the weavers was on dismal side. Prevalent noise imposed detrimental consequence on the physiological parameters due to which most of the weavers reported the problem of headache, fatigue, nausea, pain in ear and hearing problem in the scale of medium to high. Subjective responses to questions in the questionnaire on the impact on noise revealed highly significant ($P<0.001$) direct correlation between noise and the physical discomfort factors (such as headache, fatigue, nausea, pain). Strong association of the perception of noise with high level of noise as a factor ($+0.72 \geq r \geq +0.89$) was observed. **Thus the objective - 4 of the research work is accomplished.**

Optimization of illumination and noise level conditions, positioning of illuminating source on the handloom workstation and use of low noise producing material for the handloom accessories with the regulation of working hours on the handloom could be the solution for reducing the occurrence of the symptoms of physical, physiological and pschycological ailments in this cottage handloom manufacturing industries. **Thus the objective – 5 of the research work is accomplished.**

Conclusion

Present research work established that low level of illumination and high level of noise are prevalent at shop-floors of the small and cottage handloom manufacturing sector and such anomalous environmental conditions may be mitigated successfully with the help of suitable suggestions and recommendation of low cost design interventions. These interventions / strategies are practically feasible solutions for extenuating risk factors. Combination of research methods featuring questionnaire study, empirical assessments of indoor work environment (illumination and noise levels) of the existing handloom workstation followed by subjective assessment using the field study questionnaire (Appendix A),measurement of body discomforts using various assessment tools, statistical analysis, direct observation and NASA TLX technique were successful in identifying the symptoms of physical, physiological and pschycological ailments in small scale and cottage handloom manufacturing industries.

The research methodology followed in present research work is perhaps first of its kind towards investigations from an occupational health perspective in small cottage enterprises in India. Research methodology utilized in present research work may be easily adopted by researchers, production supervisors / managers / engineers towards implementing context specific environmental related solutions in the manufacturing handloom sector of industrially developing countries.

Information regarding the poor illumination conditions and abnormal sound level which causes a considerable effect on the quality and efficiency of the handloom production, development from the present thesis can be utilized in the handloom sector in order to facilitate the improvement in quality and efficiency of the system as well as of life of the weavers' and even for further research.

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Nomenclature

Acronyms / Abbreviations

M ± SD	Mean ± Standard Deviation
BMI	Body Mass Index
CFL	Compact Florescent Lamp
° C	Degree Centigrade
dBA	Decibel (A-weighted sound level)
α	Cronbach's Alpha
χ^2_F	Friedman Chi-Squared value
r	Spearman's correlation coefficient
r^2	Coefficient of Determination (CoD)
KS	Kolmogorov-Smirnov value
h	Hours
p	Probability
NS	No significant difference
bpm	Beats per minute
BP	Between People analysis
BI	Between Items analysis
WP	Within People analysis
RNI	Residual component of Non-Additivity analysis
W	Kendall's coefficient of concordance
FICCI	Federation of Indian Chamber of Commerce and Industries
IEF	Indoor environmental factors
BIS	Bureau of Indian Standards
IES	Illuminating Engineering Society
ISO	International Organization for Standardization
SPSS	Statistical Package for Social Science

CIE	Commission International de I'Eclairage
PIB	Press Information Bureau
RPE	Rate of Perceived Exertion
f	Frequency
λ	Wavelength
T	Period
CAGR	Compound annual growth rate
GDP	Gross Domestic Product
MFA	Multi Fiber Agreement
WTO	World Trade Organization
SWOT	Strength Weakness Opportunities and Threat
WMSD	Work - related Musculoskeletal Disorder
NIHL	Noise Induced Hearing Loss
PPE	Personal Protective Equipments

1. Introduction

Food, cloth and shelter are the three basic necessities of the human being and mankind on this planet. Textiles and clothing, which is next to food are one of the cardinal needs; besides serving the everyday requirement of people, it distinguishes individuals in terms of ethnicity, occupation and social status. It also poses real as well as symbolic values. In the social, economic and religious living of communities, textiles play major roles since the time immemorial. The textile art symbolically reflects the richness of the economy and culture of the society. For the demonstration of skills and wealth in many parts of Europe and Asia, young girls spent many months together for preparing clothing and furnishing textiles for their wedding trousseaus.

Textile and handloom Industry is one of the most ancient occupational sectors in many places of the world, India is no exception. The contribution of this industry to humanity in all respects is widely acknowledged. Increase in world population enforced the increase in demand for clothing and related needs which would definitely aid in the exponential growth of textile and allied industry in the coming days. Benefits accrued from this sector reflect in Gross Domestic Product (GDP), industrial production, export earnings and employment of any country in the world. The global textile and clothing industry is worth about US$ 4,395 billion approximately and current global trade in textiles and apparel is about US$ 836 billion (World Trade Statistical Review, 2016).

The textile industry is an example of technological dualism because there is co-existence of a highly modern and capital-intensive organized sector along with a technologically backward, labour intensive unorganized sector which comprises of handlooms, power looms and knitting sectors. This unorganized sector presently accounts for almost 97 % of the total textile output (Arora and Narayana, 2016).

According to International Labour Organization, the unorganized or informal sector is defined as that set of economic dealings distinguished by relative ease of entry, dependence on local resources, the small scale of processes, labour intensive operations, and reliance on skills required outside the formal educational system, unregulated and competitive market. In India this sector constitutes more than 90 percent of workforce and adds more than 60% to the national income (Central Board for Workers Education, 2017) whereas the organized or formal sector is incorporated with the appropriate authority or government and follows certain rules and regulations, the people get assured work and the employment terms are fixed and regular. A number of acts apply to this sector which is regulated and taxed by the government. Sen and Majumder (2015) also estimated the relative efficiency rather than the technical efficiency separately for both organized and unorganized textile as well as garment sectors for 12 major states for the years 2001 and 2011.

Textiles and clothing have played an important role in the gross development of many countries of the world, which indirectly helped their integration with the world economy. The mechanization of textile production in the developed countries had paved the way to prosperity in the early 19th Century. On the other hand, this sector has occupied an important place in terms of its contribution to employment, national output and exports in the developing countries. More than 50% of world exports of textiles and clothing are from the developing countries. World trade report (2006) evinced that the developing countries have the maximum share towards the export of the textile sector and become the manufacturing hubs for textile products which successively attained the capabilities for development of an innovative product with efficient supply chain management (SCM) and enhanced production capacity.

Handloom is an important and primaeval cottage industry in the developing countries like India, Pakistan, Sri Lanka, Nepal, Bangladesh, West Indies, Norway, Indonesia, Myanmar, Iran, Turkey and China where the traditional way of weaving is still practised (Pandit *et al*., 2013). It was estimated that there were about 4.60 million handlooms in the world out of which about 3.9 million were in India (Compendium of Textile Statistics, 2004 and Compendium of International Textile Statistics 2005). Some countries in the world produce the handloom products in a very limited quantity mainly for their internal consumption. The current global garment market is estimated at 1.8% of the world Gross Domestic Product (Corporate Catalyst India, 2015). Due to soft duty norms, India is trailing the share in the international market in the field of textiles and garments in comparison to China and Bangladesh.

India was sensibly recognised as the golden sparrow up till 1600 AD i.e. for over 1500 years and was the economic superpower contributing to 25% – 30% GDP of the world, which declined from 1600 years onwards. During that period Indian handloom was enjoying the monopoly but some weavers during that period revealed the secrets to French priest – which enabled the European textile industry bloom. Later on, Britain became the major manufacturing hub of cotton textiles that reduced India from riches to rags in less than half century.

The strength of the Indian textiles and clothing industry depends on the raw-material base, indigenous innovative design capabilities, presence in the entire value chain, availability of skilled manpower at internationally competitive rates, huge demand in the domestic and external market (Lal *et al.*, 2013).

In Indian scenario, handloom is one of the most ancient cottage industries. Epics of Ramayana and the Mahabharata reveal that the handloom industry might have flourished between 5000 and 3000 BC. Harappa and Mohenjo-Daro civilizations also evinced the use of woollen and decorative embroidery in handloom during that period. Since long the handloom industry is constantly remaining with the rural folk

Since time immemorial handloom is an artefact which needs to be preserved and organized in order to enhance the efficiency of the system which directly or indirectly helps the weavers to earn more wages for their survival and livelihood. Indian Handloom is an age-old source of livelihood for millions of people in the country. This sector constitutes an everlasting part of the rich cultural heritage of India. The characteristic of art and craft present in Indian handlooms makes it a potential sector for the domestic as well as for the global market. According to third National Handloom Census (2010), there were 43.31 lakh weavers in India and even at present handloom sector is the largest employment provider next to the agriculture sector. The study reveals that the handloom industry is not adopting any suitable strategy for procurement of raw material, product planning and promotional activities (Goswami and Jain, 2014) and the sector is inundated with various problems such as unorganized production system, obsolete technologies, low productivity, inadequate working capital, conventional product range, weak marketing link, overall stagnation of production and sales, over and above competition from powerloom and mill sector. The handloom sector up to some extent has been able to tide over these disadvantages by the Government interventions in the form of financial assistance, reservations of certain products and implementation of various developmental and welfare schemes.

Indian weaves are incredibly rich with a world-class heritage. The tacit knowledge of these weavers without any doubt is a valuable asset and deserves to survive the passing times and macroeconomic adjustments. Inspite of the extreme poverty of the majority of the weavers, they carry forward this unique heritage even in the contemporary global economy.

India occupies a prominent position in terms of productivity and the number of handlooms; and produces 95% of handlooms of the world (Annual Report, 2016-17).

This sector contributes nearly 15% of the total cloth production in the country (Kar, 2015; FICCI, 2016). The Indian handloom industries are highly fragmented and unorganized in character which generally falls under the category of small-scale and informal cottage industries, as classified by micro, small and medium enterprises (MSME).

1.1 Environmental factors and occupational health

The existence of living organism on this planet earth is because of favourable conditions which cause expectancy of life under fortuitous circumstances (Slater, 2000). Change in these conditions may create jeopardized situation and these conditions are referred to as environment. It is a nebulous term. The factors which alter this environment are called environmental factors. Both the external and internal environmental factors play a crucial role and inflict a significant dent on the performance and occupational health of the people which may also cause more casualties than malaria or AIDS by 2030 (Lavelle, 2010).

Sutton (2015) stated that the quality of modern life of the contemporary society is affected by the environment. Ability to perform work is intricately linked to the prevailing environmental conditions in the workplace. The human body has an adaptive physiological mechanism that allows us to tolerate a range of physical environmental conditions, but often at a cost to the body. Due to adverse environmental conditions, the capability of adaptive mechanisms of the body is affected which resulted in deterioration of health and, performance. Moreover, in extreme situations, the conditions could even prove fatal.

In this modern world, most of the works are being carried out indoors and 80–90% of the time, the people spends in indoor activity (Arif *et al*., 2016; Höppe and Martinac, 1998). Moreover, indoor physical environmental factors (temperature, relative humidity, lighting, noise etc.) affect the humans' performance and have a detrimental effect on the overall efficiency of the work system. These factors also affect the acceptability and performance of the occupants (Olesen, 1995). The good indoor environment is inevitably necessitated in order to enhance the productivity, satisfaction and overall well-being of the system as well as of the occupants. Working in a comfortable environment enhances the satisfaction level and wellbeing which is indirectly linked to productivity (De Giuli *et al*., 2012). In order to improve the efficiency of the system intervention, efforts are inevitably necessitated. Initiatives have been taken by various researchers for the formation of standards/recommendations which are well suited to the locations/industry and for the projected people.

The contribution of about 80% population of the world is from developing countries (Cullen and Hammer, 2007) and the total workforce of the world is about 2.5 billion persons. The maximum number (61%) of the labour force of the developing countries working in the field of agriculture and cottage industries of the world whereas this number is very scarce (4%) for the developed countries (Dewan, 1998**;** Sousa *et al*., 2014). Occupational health services are well organized and implemented in the developed countries as compared to developing or poor countries because of inadequate resources, lack of awareness and due to availability of plenty of unemployed workforce which results in providing least priority to occupational health parameters leading to at least 2 million estimated death per year due to negligent of occupational parameters (Cullen and Hammer, 2007). Moreover, due to the availability of labour in abundance and continuous industrialization in many developing countries of the world this area has not been addressed properly which ultimately result in the public health problem. Occupational health is one of the important parameters for the growth and economy of any country of the world. The type and standard of surveillance which is required for a particular target group decides the occupational health and safety norms (Harrington *et al*., 1983). Even though there is growing awareness about occupational health and safety, the rate of accidents in various industries still shows upward trend (Sousa *et al*., 2015). It has been ascertained that the workers having prior knowledge about the occupational health and safety norms are less prone to casualty (Ollé-Espluga *et al*., 2015).

With the evidence of increased physical and cognitive problems amongst the working community especially the weavers' all over the world, environmental factors are the important issues where interventions such as self-assessment of environment and study on the effect of various environmental factors especially of low level of illumination and high level of noise on the physical, physiological and psychological conditions of the weavers are inevitably necessitated. Jay (1991) findings suggested four basic principles such as freedom of information, prevention not cure, polluter pays and precautionary approach to developing healthy environment. Moreover, for the protection of environment three aspects such as social, economy and environment require due considerations. More than 25% of the global diseases are due to distressed environmental factors and these factors cause a significant threat to human health (Zahra *et al*., 2015) all over the world.

Environmental factors are the crucial component which affects the productivity, quality, performance, overall well-being of the weaver and the work system. Controlled conditions of these parameters can flourish the whole system which improves the productivity and satisfaction of the worker (Höppe, 1988 and Bauman *et al*., 1995). At the workstations, these parameters required specific consideration in order to satisfy the worker for better quality and output. Thermal conditions at the station are work specific and depend upon the nature of work (Bridger, 2002). The discomfort level of the worker increase when the temperature goes out of control which indirectly affects the performance, efficiency and productivity of the system. Illuminance and illumination conditions have indirect relation with task completion times (Bennett *et al*., 1977). Relative humidity is also an extremely significant environmental factor; the deviation in the value shall cause an unpleasant effect on the physiological condition of the worker which in turn affects the efficiency, productivity and overall performance of the worker (Höppe, 1988). Noise is a very unpleasant sound which upsets the human physically, physiologically and psychologically. It irritates the inhabitants exposed to it and has the negative effect on the working efficiency (Belbin, 1970). Even poor ventilation in the dwelling unit or workstation facilitates the inhabitants to get acclimatized with the inside environment and able to tolerate the temperature up to 34 $^{\circ}$C having 0.6m / sec air velocity without much ventilation (Nicol, 2004).

The purpose of the present study is to explore the effect of indoor environmental factors especially illumination and noise which are deeply associated with the activities of the weavers, on the psycho-physiological condition of the weavers.

1.2 Scenario of environmental research in the handloom sector

The textile industry comprises organized mill sector and unorganized sector. This industry plays a significant role at the global level in terms of total volume of commodities trade across the various countries and over two-thirds of world exports in textiles and clothing is from the developing countries (WTO, 2016; Comtrade, 2015). Under the unorganised and semi-organised sectors handloom industry is also an important cottage industry among the developing world where the traditional way of weaving is still practiced in the countries like India, Pakistan, Sri Lanka, Nepal, Bangladesh, West Indies, Norway, Indonesia, Myanmar, Iran, Turkey and China (Pandit *et al.*, 2013).

In this contemporary world, most of the works are being carried out indoors and, factors such as temperature, lighting, noise, humidity and air flow etc. influence the human performance. Being the indoor activity, it is evident that prosperity of handloom sector as a whole depends on the indoor physical environmental conditions and these factors adjudge a decisive role for better health of the sector in terms of productivity, quality and efficiency. In most of the occasions, these physical environmental aspects were not given due consideration while commissioning the individual handloom workstation in the handloom industry. As all these environmental factors affect the human efficiency and competencies, it is the need of the hours to study the effect of these factors on the human physical, physiological and psychological parameters. A voluminous work has also been done all over the world on indoor physical environment in various industries, offices, residential buildings, aircraft (Koh and Jeyaratnam, 1994; Höppe and Martinac, 1998; Bauman *et al.*, 1995; Bridger, 2002; Oleson and Parsons, 2002; Nicol, 2004; Frontczak *et al.*, 2011; Dianat *et al.*, 2016; Dianat *et al.*, 2013; Hossain and Ahmed, 2012; Huang *et al.*, 2012; Vural and Balanlı, 2011; Morris and Dennison, 1995; Hoffmann *et al.*, 2008; Juslén *et al.*, 2007; Gligor, 2004 and Helander, 1995) and internal air quality and air pollution (Garcia *et al.*,2005, Schwela, 2000; Wang *et al.*, 2014; Mcdowall, 2007; Jones, 1999; Cheremisinoff 2002) but the work done in the field of handloom sector is rarely or scantly reported

India is the second largest producer and exporter of textiles as well as garments in the world (Patil, 2012; Vinayan, 2012; Goswami and Jain, 2014; Corporate Catalyst India, 2015; Comtrade, 2015). Considering the inherent strengths of this textile and handloom industry in terms of a strong raw material base, skilled manpower and low wage costs, this industry has immense potential in the globalised textile economy but encountering tuff competition in terms of low-cost production and free trade with Asian countries. Competition from other low-cost countries like China, Bangladesh, Vietnam and Turkey are posing serious threats to the Indian industry. India is having an appetite for the great demand of textiles due to population size, yet still lagging in terms of per capita consumption when compared with many developed and developing nations. Even though of high production share (59%) of power loom sector in comparison to handloom sector (11%) the contemporary customer has a preference for hand-woven niche innovative handloom products. India produces 85% of the handlooms of the world country and supplied 95% of the world demand for hand-woven fabrics (Annual Report, 2016-17).

India, being the developing country of the world, the environmental issues especially the indoor physical environmental are not being addressed seriously that may be due to lack of awareness or due to the availability of plenty of unemployed workforces. Moreover, due to continuous industrialization, this area has not been addressed properly which ultimately result in the public health problem. In Indian scenario study on the indoor environmental issues including noise and illumination in various industries have been reported (Bennet *et al*., 1977; Belbin, 1970; Nag, 2004; Nag and Patel, 1998; Tiwari *et al*., 1999; Punnett, 1985; Nachemson, 1975; Nehra, 2015; Varghese and Salim, 2015; Bhar, 2016 and Sanjog *et al*., 2013). Moreover, some degree of information is available about the work is done in the field of noise and illumination in textile and hosiery industry (Bhattacharya *et al*., 1989; Uttam, 2015; Shilla, 2014) but the work on the environmental factors (especially in the field of illumination and noise) in handloom is scantly reported.

For the present research, the study on illumination and noise were opted to understand the influence of these environmental factors on the weavers' physical, physiological and cognitive aspects which in turn affect the performance, visual comfort and quality of output. As illumination and noise are the very crucial parameters which are inevitably required as well as persevere at the handloom workstation in all the sessions throughout the year but the work on these environmental factors have not been properly reported especially in the handloom sector.

It is generally observed that there is the prevalence of low level of illumination and high level of noise throughout the year and thus these two crucial environmental factors are affecting the performance, productivity and psycho-physiological well-being of the weavers involved in the handloom sector. Hence, in the present research these two (illumination and noise) important environmental factors are considered among the various others environmental variables which have sufficient influence on health and performance of the weavers.

Outside the northeastern region, 53.1% of households undertake handloom work for commercial purposes in India. Odisha having the highest (77.5 %) handloom owning household outside the northeastern region and have the privilege of producing the maximum Ikat sarees in India Out of the national figure, 80.97 % of weavers' households of Odisha producing the highest number of handloom saris and very few produced other items like dhoti, bed sheets, cloth pieces, towels etc. Odisha enjoys the status of having the highest allied (52.5%) and independent workers (54.8%) as compared to the other states. Also, 87.1% of the weavers in Odisha are working full time for more than 8 h per day for commercial production. Most of the weavers of Bargarh district were engaged in the production of sari (85 %) (Handloom Census of India, 2009 - 2010).

Handloom production of Odisha state for the year 2015-16 was approximately Rs.500 crores and share of the Bargarh district was Rs. 98.42 crores (19.7%). Out of the total handloom Ikat sarees production in Odisha, more than 70% of the Ikat sarees are from Bargarh district which is one of the major revenue generating districts (Indian Handlooms Cluster, 2017), located in western part of Odisha. Bargarh district has been awarded the highest number (8 number. out of the total 18 number) of ‘A’ category handloom cluster (Textile Handloom ImpClusters, 2017). This district is honored to have the highest number of national awardees (51%) and the state awardees (36%) out of the total awardees in the state (Handloom Odisha, 2017). Therefore, as a case study for the current research, Bargarh district in Odisha has been selected.

1.3 Scenario in handloom sector of Bargarh district

Weaving in Bargarh district is being performed on the pit handlooms which are one of the simplest handlooms, fitted onto the pit and the weaver sits on the pit by extending the legs inside the pit for operation of the handloom. The pedals for operating the shedding mechanism are installed in the pit. Most of the weavers were using fly shuttle during weaving on the pit loom with or without dobby machine. It has a sturdy structure comparing to all other handlooms. Firm healds and reeds are provided with fly shuttle sley. Use of fly shuttle increases the production and makes the weaving process further easy. Yardage of the products woven have increased remarkably. A small pit as shown in plan sketch (Fig. 1.1) is engraved in the ground to a depth of about three feet in order to accommodate the treadles. Loom frame structure is built around the pit and a sley is hung from the frame. On conducting the survey of various handloom workstations of Bargarh district region, it was observed that most of the handloom workstations were located inside the household cum workshed having the paucity of ventilation and lighting conditions. Weavers were engaged in manufacturing cotton sarees and shirting fabric using fine count yarn. Ikat designs (preconceived designs) are very intricate design which can be developed by interlacement and with the synchronization of the tie and dyed pattern on the warp and weft yarn in the body of the fabric. This fine quality of weaving requires high level of skill, concentration and clear visibility on the handloom, and especially at the body of the fabric.

Normal shape of a pit **Skeleton of a pit handloom** **Weaver working on a pit handloom.**

Fig. 1.1 Underground Pit Loom (*adopted from Handloom Census Report2009 - 2010*)

The weaving work is monotonous and excruciating in nature and under these adverse conditions, a weaver weaves at least for more than 8 h per day. In case of work pressure during peak season, the weavers have to weave even more than 12 h a day. During field visit, it was also experienced that there was substantial variation in the lighting conditions (illumination intensity) on and around the handloom workstations having low voltage and fluctuation of current voltage. The weavers were using various types of lighting source such as bulb (Incandescent lamp), fluorescent lamps (tube light), compact fluorescent lamps (C.F.L.). Some handloom weavers were using more than one type of source of illumination on the single workstation at different locations. Location of the light source on the handloom as well as the windows and doors of the work shed with respect to the positioning of the handloom were not given specific consideration during erection and commissioning of the handloom at the workstation. The direction of the sun rays was also one of the major factors which influence the illuminating environment on and around the handloom workstation. During daytime the illumination level at the workstation was variable as per direction, the angle of inclination, the intensity of sun rays, glare from the adjacent walls of the work shed or from nearby stagnated water as well as according to the seasons throughout the year. Weavers did not weave continuously they weave in fragments (Weaving timings - 7 am to 8.30 am, 9 am to 12 noon, 1 pm to 4 pm and 4.30 pm to 8 pm) for on an average total time of more than eight hours in a day. During peak season the weaver work on handloom for more than 12 h. They prefer to weave during the daytime rather in the evening or late night hours due to voltage fluctuation and poor electricity supply. As most of the weavers have kuchha (mud) houses, the finishing condition of the wall and roof of the houses also have an impact on the variation of illumination intensity at the handloom workstation. Hence, an attempt has been made to know the inconvenience level of weaving and the problems they encounter and the repercussion on weaving in that prevalent illumination level conditions while working on and off the handloom. This study also aimed to understand the relationship (if any) between illumination and physical, physiological and psychological inconvenience.

Majority of the weavers were having two or more than two handlooms under the same household-cum-workshed. As observed the conditions of most of the handlooms were obsolete. Variation in noise level was observed on and around as well as at the centre of the handloom work shed. Distance from the source of sound leads to variations in the intensity of the sound. The parts or the mechanism which were the main source of noise emission as observed during surveillance were shuttles, beater buckle, slay beating mechanism, movement of jacquard or dobby on the handloom. The main reasons for emission of noise may be due to high friction between the moving parts and the type of material of the moving parts in the handloom. Moreover, during the festival session when there was more work pressure, the noise level was dominant. Even though the weavers weave in the rhythmic movement he frequently overlooks the intensity of sound level produced but it is inadvertently affecting their auditory system.

1.4 Research gap and Justification of the present research

Abundance literature on hand about the work done all over the world on indoor physical environment have been perused (Höppe and Martinac 1998; Bauman *et al*., 1995; Bridger, 2002; Oleson and Parsons, 2002; Nicol, 2004; Frontezak *et al*., 2011; Ashraf *et al*., 2009; Abbasi *et al*., 2011; Roozbahani *et al*., 2009) including noise and illumination in various industries together with textile (Powerloom), offices, residential buildings, aircraft but work on handloom is not well documented.

Studies on ergonomic evaluation in terms of occupational health, musculoskeletal disorder, handloom modification and workstation design, handloom weaver associationism have been carried out in the field of handloom (Sarkar, 2016; Hossain, 2016; Solanki *et al*., 1993; Tiwari *et al*., 1999; Banerjee and Gangopadhyay, 2003; Metgud *et al*., 2008; Nag *et al*., 2010; Goel and Tyagi, 2012; Pandit *et al*., 2013; Meena, *et al*., 2012; Chowdhury *et al*.,2012; Singh *et al*., 2010; Patel *et al*., 2016; Nag *et al*., 2016; Wood, 2014) but work on illumination and noise is reported scantly.

Despite diverse research in different areas encompassing different aspects of environmental, occupational, ergonomics, workstation design, design modification concerns of office, hospitals, industrial manufacturing sector and different other industries, there is still little or scanty information as far as environmental and occupational health are concerned with respect to handlooms (worldwide, especially in India) sector is still unexplored. In India, handloom sector comprises a prime cottage industry among the most ancient Indian industries, thus finding some relevance to explore environmental factor leading to the holistic wellbeing of the Indian weavers.

Habali *et al*., (1989) and Shaikh, (1999) discussed the noise and its effect on working efficiency of the worker in different factories and industrial plants. Mearns *et al*., (2010); Cullen and Hammer, (2007), worked on psychosocial factor in various industries but information on handloom is not well documented.

Hoffmann, (2008); Dianat *et al*., (2016), Sanjog *et al*., (2013) and Dianat *et al*., (2013) suggested that illumination is among the important parameters influencing worker‘s productivity in terms of speed, quality of work, downtime, absenteeism and accident rates but the work on handloom is not well documented. In India lot of work has been done on the indoor environmental issues including noise and illumination (Nag, 2004; Nag and Patel, 1998; Tiwari *et al*., 1998; Punnett, 1985 and Nachemson , 1975; Bhattacharya *et al*., 1981 and 1989; Bhatt *et al*., 1990; Abbasi *et al*., 2011; Nehra, 2015; Varghese and Salim, 2015; Bhar, 2016 and Bhar, 2017) for various industries including textile industry and power loom but very scanty or negligible information is available about the work done in the field of handloom sector.

Hence, in the present research, an attempt has been made to address the identified research gap (as described in Fig. 1.2) by exploring the impact of indoor environmental factors especially illumination and noise which are deeply associated with the activities of the weavers, on the psycho-physiological condition of the weavers engaged in handloom sectors in India. Moreover, it has been planned to document some recommendations for remedial solutions in the current thesis, so that the working conditions of the weavers as well as of the whole system can thrive. This will indirectly improve their financial status.

Schematic Diagram showing the research gap

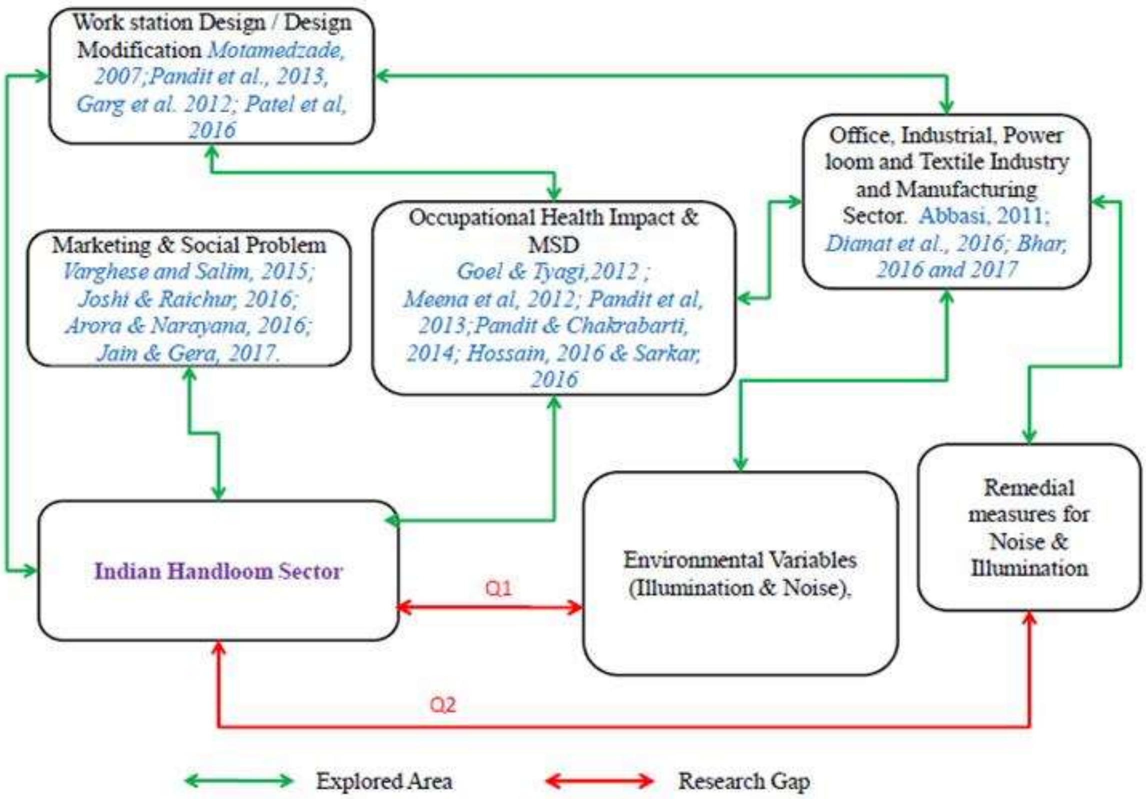

Fig. 1.2 Shows the area of research gap (red arrow lines) where work is required to be done (Mentioned references in the figure are the recent publications related to corresponding research area)

1.5 Research Questions

Following literature survey towards identifying the unexplored area and initial field visits to observe physical environmental conditions prevailing in the handlooms, two broad research questions have been raised:

1. How environmental factors especially illumination and noise affect the physical, physiological and psychological conditions of the weavers engaged in the Indian handloom sectors?
2. What would be the suggestions and recommendations for avoiding adverse consequences on the occupational well-being of the weavers due to low illumination and the high noise environment in handlooms?

1.6 Problem statement

The intention of the research study was to identify and understand the problems encountered by the weavers working on the handlooms all over the world. For this purpose, the researcher initially visited the nearby handloom weaving workstations and understands the problems of the weavers came across on and off the handloom workstations for achieving the desired quality output. Moreover, after browsing the literature and field observations in the handloom sector following problem statements were identified which are enlisted below.

i) Recommended standards pertaining to illumination and noise were not followed in the handloom sector in India and especially in Bargarh district of Odisha.

ii) No standardisation of design and development for handloom workshed. Design variation observed from one workshed to another workshed and from one region to another region. These substandard designs of the sheds affect the occupational health of the weaver

iii) Lack of awareness among the weavers related to the impact of high level of noise and low level of illumination, in which they are exposed to.

iv) Lack of awareness as well as non-affordability of using personal protective devices for protecting themselves from the adverse impact of the environmental variable (noise and illumination) under study.

Aim and Objectives

Plentiful research has been pursued all over the world on the indoor physical environment including noise and illumination in various industries, offices, residential buildings, aircraft etc.; but work on handloom sector/industries is not well documented. Studies on ergonomic evaluation in terms of occupational health, musculoskeletal disorder, handloom modification and workstation design, handloom weaver associationism have been carried out in the field of handloom; but work on illumination and noise is scantly reported. There is also sparse information available on environmental factors with respect to occupational health concerned for handlooms sector worldwide, especially in India; while handloom sector comprises a leading cottage industry in India, among the most ancient Indian industries, thus finding some relevance to explore impact of such environmental factors primarily towards occupational wellbeing of the Indian handloom weavers.

Hence, in the present research, an attempt was made to address the above area (where research is meagre) exploring the impact of indoor environmental factors viz. illumination and noise, which intensely deemed to be associated with the performance and productivity of the handloom weavers (in India), by virtue of their impact on the psycho-physiological state of the weavers. This might contribute directly/indirectly to the gross occupational well-being of the weavers. As per the handloom census of India (2010), the eastern part of the country is reported to have the highest number (77.5%) of handloom owning households next to northeastern region, who were mainly involved in sarees-weaving in India. Amongst the eastern states, Bargarh district of Odisha beholds the maximum number of sarees-weaving handloom workstations – the reason for choosing Bargarh district as a place of experiment.

1.7 Aim

The present research aimed to investigate the illumination and noise levels in handloom workstations and to explore their impact on occupational health and wellbeing of the weavers in terms of physical, physiological and cognitive aspects.

1.8 Objectives

1. Assessment of the Illumination level in the handloom throughout the year.

2. Assessment of the noise level in the handloom throughout the year.
3. Explore the effect of prevailing illumination on the physiological and psychological aspects of the weavers.
4. Explore the effect of prevailing noise level on the physiological and psychological aspects of the weavers through subjective evaluation.
5. Analyze if there were any correlation between the subjective rating with corresponding environmental factors, in order to understand the impact of illumination and noise.

1.9 Hypothesis

Prolonged exposure to high level of noise and low level of illumination (either solitary or a combined impact) would significantly affect the physiological and psychological health of the weavers engaged in handloom workstations in unorganized / semi-organized handloom sectors

1.10 Expected outcome

It was expected that the present thesis would highlight the impact of illumination (under various sources of lights including daylight) and noise conditions (produced by various parts of the handloom or surrounding) prevailing in the handloom workstations, on the physical, physiological and cognitive aspects of the weavers while carrying out the various activities related to weaving.

1.11 Organization of the thesis

A brief outline of the whole work on the subject matter is presented in the following chapters.

1.11.1 Chapter I - Introduction

This chapter focused on highlighting the role and contribution of the textiles and handlooms industry to the community of the whole world, consisting of research problem related to the environmental factors and occupational health of the weavers, scenario of environmental research in handloom sector and the scenario in handloom sector of Bargarh district has been discussed at length. It has also focused and discussed the research gap and justification of the present research, related research questions arrived, the aim of present research endeavor and the objectives towards achieving the aim were pen downed. The hypothesis of the thesis, expected outcome and flow of the research work is also outlined.

1.11.2 Chapter II - Review of Literature

While Chapter II portrays about the importance of environment, environmental factors and scenario of the global textile and handloom industry, over and above entailed the prominence involvement of this sector to the global exports and in the national economy. History and status of this industry during the medieval period and status of handlooms and the handloom weavers as per the handloom census report 2010 has been discussed. Current scenario and strategy for reviving handloom sector and the rural scenario with respect to handloom of eastern states of India with the special focus on Odisha state related to environmental issues have been talked about. The importance of environmental factors and their impact on occupational health, efficiency and performance of the weavers in the textile and small cottage handloom enterprises have also been taken care off. Various ergonomic interventions recommended for improvement of environmental conditions in other sectors have been discussed at length.

1.11.3 Chapter III - Methodology

Chapter III sketches out the selection of location with the reason for selecting the same for study purpose. The sampling of the subjects and the demographic study was carried out on the workers of selected clusters. Research framework and design of the experiment was structured as a guideline for assessment of various parameters related to illumination (Lux), noise (dBA), physiological measurements such as heart rate, discomfort rating using Borg CR10 scale and calculate the cognitive psychological assessment using NASA Task Load Index. Design the questionnaires for assessment of impact of the illumination and noise, the data collection of the weavers was performed using both subjective (questionnaire) and objective (physical measurements of the environmental factors) methods to figure out the prevalence of physical, physiological and psychological problems existing in the present loom conditions. Reliability of questionnaires was examined. Statistical analysis of the collected data sets was performed using SPSS v.20 (IBM, USA) software and calculated the Friedman's Chi-Squared (χ^2_F) tests for independence as well as for association along with the correlation between environmental factors and their subjective perception by using Spearman's correlation coefficient (*r*).

1.11.4 Chapter I - Results

The values of illumination, noise and heart rate were collected and tabulated month wise, season wise and for the whole year through measurement and significance level between group analysis was calculated. Physical, physiological, psychological and discomfort rating parameters of the questions in the illumination and noise questionnaire so obtained were also tabulated and analyzed for significance level. Discomfort levels of various discomfort factors in the questionnaire of illumination and noise were tabulated. Administration reliability of the questionnaire was examined by subjecting them through Cronbach's Alpha ('α') for their reliability and internal consistency of the scales. Friedman's Chi-Squared (χ^2_F) test was performed to ascertain for the association between illumination as well as noise level with psycho-physiological discomforts. Correlation between environmental factors (illumination and noise) and their subjective perception were evaluated by using Spearman's correlation coefficient (*r*). Further, coefficient of Determination (CD, expressed as r^2) was also calculated to examine that to what extent these variables share their variance components. Month-wise representation of correlation coefficient (r) between illumination, noise and questions in the questionnaire was also tabulated and discussed.

1.11.5 Chapter V - General discussion and conclusion of the overall thesis

In this chapter V consolidated findings of the research experiments have been presented and discussed the various issues related to the handloom village and small industries such as lack of research and application of environmental ergonomics in Indian handloom sector; interpretations and inferences of the observations of the present research and fulfilment of the objectives of the present study. Illumination and noise level of the handloom sectors have been discussed in detail. Moreover, evaluation of physiological and psychological cost of illumination and noise on the weavers' health has also been discussed at length. The experimental hypotheses as assumed in the very beginning have been tested, justified and thus fulfilled with the research findings. Salient findings and the key contributions of this current research and proposal towards intervention strategies for improving the illumination level and reducing the noise level in handlooms have also been taken care off. Intervention strategies such as general recommendations for overall wellbeing, specific recommendations for enhancing illumination level and controlling impact of noise in addition to ergonomic / design interventions towards improvement of illumination and protection from noise level in handlooms have been suggested. The conclusion covered the need for research initiatives in Indian handloom sector from environmental ergonomics perspectives; limitations of the present research along with future research scope and contribution of the research findings to the handloom industry have been highlighted prudently.

2. Review of Literature

2.1 Introduction

The existence of living organism on this planet earth is because of favorable conditions which cause expectancy of life under fortuitous circumstances (Slater, 2003). Change in these conditions may create jeopardized situation and truly speaking these conditions in which the living organism exposed are referred to as environment. It is a nebulous term. The factors which alter this environment are called environmental factors. Both the external and internal environmental factors play a crucial role and inflict a significant dent on the performance and occupational health of the people which may also cause more casualties than malaria or AIDS by 2030 (Lavelle, 2010).

The word occupational health came into existence in 1940 during the World War II which made an impact on manpower. Occupational health affected the efficiency of the workforce, changing the attitude of workers, compassion for inducing the sense of caring. Worldwide there are two million causalities every year due to occupational diseases. In order to assess the occupational and environmental health risk, biomonitoring technique has been considered to be an important tool (Manno *et al.*, 2014).

Small-scale industries (SSI) are playing a very important role all over the world and they are one of the main sources of the production house in India and many other countries of the world. Small-scale and cottage industries of India have a significant impact on the economic growth of Asia and play an important role in the Asian economy. India enjoys the status of having the second position in the world in terms of sharing the workforce to the extent of some 500 million people (Sharma, 2012). Small-scale and cottage industries are the driving force for India's economy. Being a highly labour intensive industry it has an appetite for huge labour. Due to low investment per worker, this industry is highly capital productive than various other capital-intensive enterprises of the world (Vidya and Shashidhar, 2007).

Woven textiles are one of the ancient techniques developed by people the world over. Earlier, the woven clothes were dressed in for protecting the body from the heat and cold, which later on developed into a form of attire and expressed the cultural values of the people with their identity. Since the time immemorial, the art of weaving and dyeing of fabrics was practised all over the world including India. It was such an important part of the life of the ancient times that many of its techniques gave the name to philosophical and religious thoughts. The global textile scenario changed and gradually the production base shifted to developing nations due to various reasons. Textile and garment sectors occupy a significant position in the total volume of merchandise trade across countries.

2.2 Textile as an Industry

The textile industry has a significant contribution on the total volume of commodities trade across the various countries at the global level which is growing continuously and amounts to the US $ 836 billion (World Trade Organization, 2016). Over two-thirds of world exports in textiles and clothing is from the developing countries (Dixit, 2015). Being a fast emerging market with more than 250 million middle-income populations, the Indian textile industry would grow, provided it takes competition and innovation in true spirit (Corporate Catalyst India, 2015). Due to increase in wages and other policy changes in the competing countries like China the investors are looking for alternate locations. This development provided an excellent opportunity for India to attract companies which were looking for the alternate source. The textile industry has gained significant momentum in recent years due to advances in computational hardware and software. With the development and advancement of Digital Human Modeling (DHM) technology leads new possibilities to integrate ergonomic knowledge into the design process to solve complicated problems at speeds never imagined in many disciplines of engineering including textile sector.

Handloom industry is an important cottage industry among the developing countries like India, Pakistan, Sri Lanka, Nepal, Bangladesh, West Indies, Norway, Indonesia Myanmar, Iran, Turkey and China where traditional ways of weaving are still practised (Pandit *et al.*, 2013). Some countries in the world produce the handloom products in a very limited quantity mainly for their internal consumption. The handloom industries of Bangladesh, Malaysia and Pakistan contribute to about 5% of the total export of handlooms of the world. Ali and Peerlings (2011) study revealed that while shaping the policies for the promotion of clusters, the local conditions must be taken into account and he observed that clustering in urban is more profitable than rural areas. He also stated that handloom being one of the most important segments of microenterprises in Ethiopia, it supports the lives of more than 227,000 people. Kittipichai et al. (2015)

studied that there were seven factors including the indoor physical environment which influences the overall quality of life including the working posture and psychosocial factors of the Thai workers in textile dyeing factories and was adjudged between moderate to good based on four dimensions such as soul, heart, brain and society.

2.2.1 Global Scenario

In the year 2016, the global apparel market was around 2% (US$ 1.7 trillion) of the world's Gross Domestic Product(GDP) with a projected growth rate of 4% whereas in the year 2014 the global textile and apparel trade was positioned at US$ 820 billion with a compound annual growth rate (CAGR) of 5.6 % over the last decade (FICCI, 2016). Presently the USA and Europe are the prime consumers of textiles and apparel in the world while Asian countries such as China, India (large consumption bases as well), Bangladesh, Vietnam, Sri Lanka, Pakistan etc are the manufacturing hubs (FICCI, 2016). In the year 2005, the textile and clothing industry of the world joined the multilateral trading system. Trade blocs and non-tariff barriers were among the challenges that emerged in the changed market scenario. This industry required to integrate itself and go in for vertical specialization to take on the challenges. Phasing out of multi-fiber agreement (MFA) and functioning of the world trade organization (WTO) are likely to pose new challenges for the textiles, clothing and handloom industry.

Developing countries are the major exporters and the removal of controls under MFA and WTO has increased the competition amongst the developing economies while the developed economies enjoyed the protection over their textile sector. While opening the doors for export of textiles, non-tariff barriers like the ban on child labour and azo dyes and chemicals etc have posed serious depression on export. In today's world, changes relating to globalization have become inevitable and irreversible. World Bank data reflected that globally 600 million new jobs are required to be created over the next 15 years just to keep employment rates constant whereas 175 million is needed in South Asia alone and a large share of the remaining are needed in other developing regions (World development report, 2013).

India was one of the leading textile exporters of the globe in the middle of the nineteenth century. China and Bangladesh emerged as the new players with the enhanced contribution in the world export of handloom and textiles products. Since a long time Banaras was the hub for producing the brocades silk fabric but in the recent past, this sector is in doldrums due to increase in imports from China. Despite imposing anti-dumping duty on the import of raw silk and fabric for protecting the Indian silk industry, the Chinese raw silk makes a headway into Indian market through Nepal and Bangladesh who in turn have the privilege of free trade treaties with India under South Asian Free Trade Area (SAFTA). This industry has significant perspective in the globalised textile economy due to low wage costs, skilled manpower and strong raw material base. But because of strong competition from low-cost countries like China, Bangladesh, Turkey and Vietnam, Indian handloom producers are facing serious threats. The disparities in import duties amongst the South Asian countries have inflicted an adverse effect on Indian handloom and textile industry. Moreover, the Chinese fabrics make backdoor entry from Bangladesh after conversion to garments as SAFTA rules of origin is ineffective (Prasad *et al*., 2014).

2.2.2 Indian Scenario

The supremacy and recognition of the cloth produced in India are well-known for centuries all over the world which needs no reverberation. At the global trade level, the textile and apparel industry of India has a share of 5% (Annual report 2016 - 17; Manoj and Muraleedharan, 2016). The study revealed that even though during the post MFA the compound annual growth rate (CAGR) of Indian textile exports was low but the mean value was on higher side when compared to pre MFA. Indian textile industry is one of the largest, oldest and is highly fragmented, engaged nearly 35 million people. It comprises of two sectors, one is the unorganized sector which encompasses handloom, khadi, carpet, hosiery and knitting, powerloom and readymade garments manufacturing units whereas the organized mill sector consists of spinning mills which have only spinning activities and composite mills which included spinning, weaving and processing activities under one roof. The share of the organized sector in the Indian textile sector was around 97 percent and rest was of the unorganized sector (Manoj and Muraleedharan, 2016). Indian spinning industry is the most modern and competent industry having the world's second largest capacity (Dixit, 2015) in terms of producing the spun yarn ranging from coarse 2 counts to fine 200 counts. Indian textiles sector contributes to 10% of manufacturing production, 2% of India's GDP and to 13 % of the country's export earnings (Annual report 2016 - 17).

Despite the global economic crisis, India is now a fast emerging market with enormous middle-income populations having good purchasing power which echoes the positive indications for the textile sector sooner or later. As long as the Indian economy is growing this sector has tremendous scope for the development, provided it takes competition and modernization critically. India's GDP was US$ 2.1 Trillion and the textile and apparel industry was about US$ 108 billion in 2015 which included both domestic consumption and exports (Singhal ITMF, 2016, Corporate Catalyst India, 2015). Due to close association with the agriculture sector and the rural economy, it is anticipated that one of every six households in the country depends on this textile sector directly or indirectly for their livelihood. This sector has the highest loomage (including handlooms) in the world which accounts to about 61 percent of the world loomage (Strategic Plan, 2012 - 2017).

The Government of India, since independence, has been following a policy of promoting and encouraging the handloom sector through a number of programmes and schemes like cluster approach, high-tech marketing initiative and social welfare measures, the handloom sector has shown positive growth and the income levels of weavers have improved (Garg *et al.*, 2012).

In order to generate awareness about importance of India's handloom industry and its contribution to the socio-economic development, the Government of India has declared 7th of August as the National Handloom Day to mark the respect to the dedicated hardworking weavers of India and national awards are also being conferred upon the master weavers every year in recognition of their excellence and contribution to this sector. Indian handlooms are having a respectable place in the national and traditional design terminology of the world. (Annual report 2016 - 17)

Even though the contribution of the power loom cloth production (59%) was the maximum as compared to the handloom products (11%) to the total cloth production in the country (Fig. 2.1), but the contemporary customer has an appetite for defect-free high quality hand-woven authentic niche handloom products with new and innovative design which in turn will indirectly facilitate to fetch reasonable wages to the weavers in order to lure the younger weaver generation to opt for this occupation.

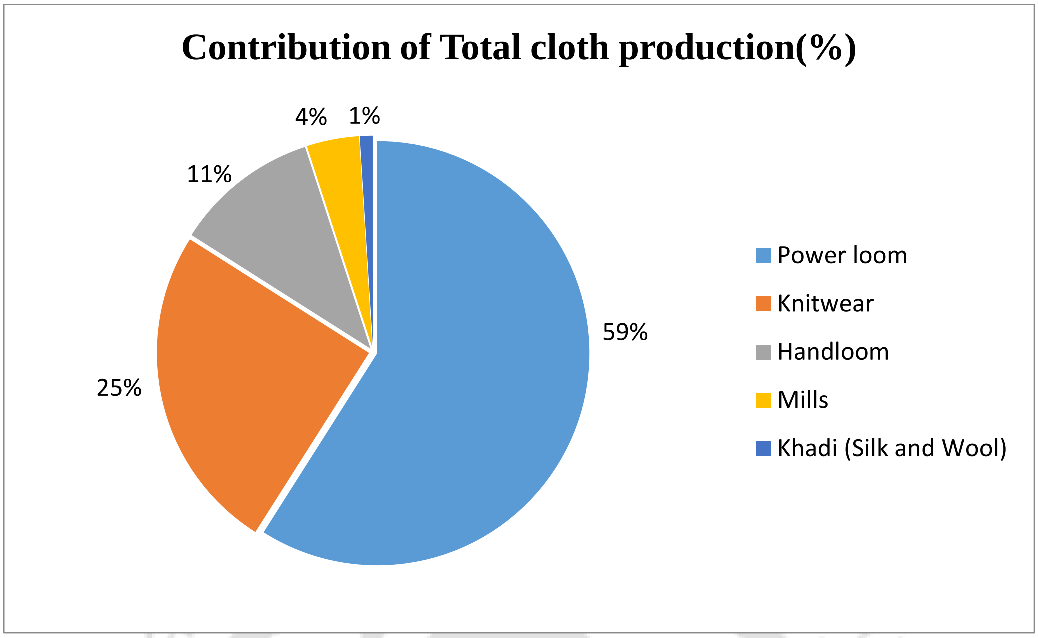

Fig. 2.1 Share of total cloth production (in percentage) by various textile sectors *Source: Textile Commissioner Office, Mumbai (2016)*

India is being viewed as a country, offering an enormous opportunity for increased textile consumption due to very low per capita textile consumption when compared with many developed nations. Per capita consumption of textiles (Fig. 2.2) for European Union was at 729 Sq. M.; the USA at 727 Sq. M.; China at 209 Sq. M. and India at 44 Sq. M.

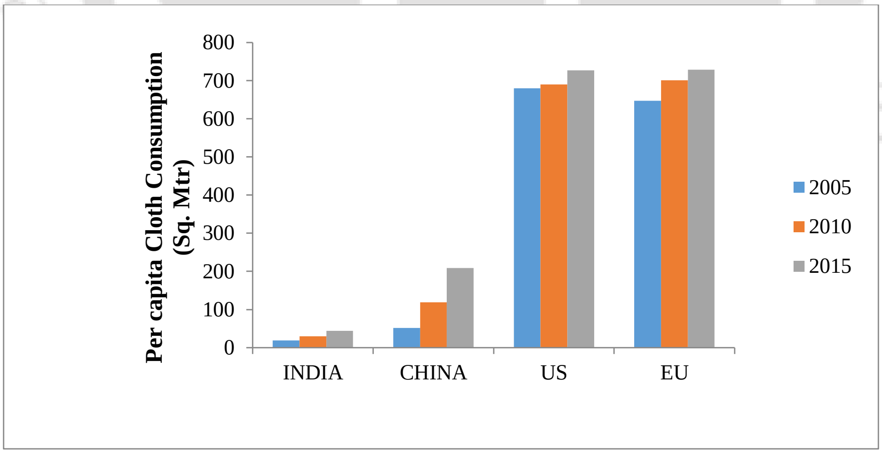

Fig. 2.2 Consumption of cloth in the world (*Source: ITMF*)

(ITMF, 2016; Basu, 2016). Though the per capita consumption of cloth in India has increased by 132% i.e. from 19 Sq. M. (2005) to 44 Sq. M. (2015) but still it was on lower side when compared to European Union, the United States of America and China

(Fig. 2.3). The increase in consumption was mainly due to growth in population and fashion trends in urban areas (Basu, 2016).

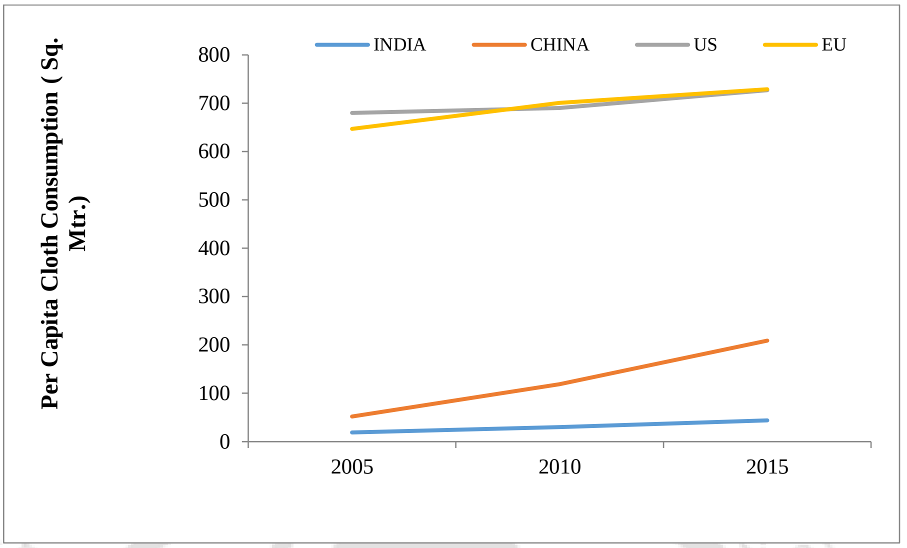

Fig. 2.3 Consumption of cloth in the world *(Source: ITMF)*

2.3 Handlooms in India

India occupies a prominent place in terms of productivity and the number of handlooms and produces 85% of the handlooms of the world (Handloom Census of India 2009-2010; Garg *et al*, 2012). The handloom cottage industry is one of the largest unorganized non-farm economic activities and constitutes an integral part of the rural and semi-rural livelihood (Corporate catalyst India, 2013). It forms a valuable part of the generational inheritance and symbolizes the richness, which has been kept alive by skilled and semi-skilled weavers engaged in the age-old tradition of weaving (Garg *et al*., 2012). Being the decentralised sector, it is a household-based industry having the contribution of the whole family and scattered across thousands of villages and towns in the country. The sector evinced a close medley in terms of managerial base, products, and relations between performers within the organization. The sector is still sustained by transferring skills from one generation to another.

India is known as the custodian of the global handloom. This sector is having the capability of exponential growth. Handloom weaving in India is not only a profession but also a cultural inheritance which symbolizes the bonding of love, care, richness, tradition and respect. The strength of the sector lies due to the unparalleled achievement of the level of artistry, intricacy, innovation and uniqueness of certain weaves/designs in the handloom fabrics which are still beyond the scope of modern machines. This industry has an advantage of being less capital and highly labour intensive, using minimal power, eco-friendly, the flexibility of small production, openness to innovations and adaptability to market requirements. The sector can develop and manufacture the exclusive and exquisite range of fabrics which takes months together to weave and up to the popular items of mass production for daily use.

Handloom industry is the only industry in the world as well as in India which virtually remains pertinent for centuries together and has been surviving since time immemorial. Even though millions have been spent by the various governments in the last 100 years in this sector but this sector has the instinctive perseverance to survive and relevant to the current textile needs of the country (Bhagavatula, 2010).

Being the ancient cottage industry of India, nearly 43.31 lakh handloom households are engaged directly or indirectly in weaving and allied activities on 23.77 lakh handlooms for their livelihood, out of which 87% are located in rural areas and rest in the urban areas. At national level except in northeastern states, the weaving activity was dominated by male weavers (24.3%) than in the allied activities (15.2%). Moreover, the participation of the male worker in weaving activities was also relatively higher in urban areas (57.1%) as compared to rural areas (19.2%) (Handloom Census of India 2009 - 2010).

Besides the direct employment, this sector engages 1.5 persons per weaver indirectly in the production, over and above generates employment for handloom and accessories manufacturers, twisters, dyers, processors, printers and sellers etc. which contributes to 5.5 percent of the employment in the decentralized sector of the country's economy. But due to increase in economic thrust and to support the family income with the urge to become self-dependent more and more handloom weavers' have made headway into various economic sectors to earn their livelihood.

2.3.1 History and Origin of the Handloom Industry in India

Handloom is a symbol of nationalism, equality and self-reliance. Even after almost seven decades of independence the cottage industry in rural India is still to congregate the required momentum. The handloom industry has regained the vitality due to its inseparable links with our ancient cultural heritage which is of traditional significance. Broudy (1993) reported that no one knew how weaving embarked on. A human being might have learned the process of weaving from spider and silkworm. Some literature reveals that Chinese prince wife Si-Ling-Chi invented the loom in 2640 B.C. The earliest cotton weaving has traditionally been associated with India. From the ruins of Mohenjo-Daro in the Indus valley of Pakistan (2500 B.C.), a small piece of cloth and two lengths of yarn, one of 12 ply and other of 24 ply have been recuperated. However, it has already been established that existence of weaving was known about eight thousand years before Christ in the world and handloom weaving might have been started between 5000 B.C. and 3000 B.C. It is also found in Ramayana and Mahabharata that speak about the length of craft (Bansal, 2012; Jain and Gera, 2017).

From history, it is reflected that during the Industrial Revolution (the year 1821) in Britain, due to set up of textile mills in England the position of India in the world trade was dislocated (Das, 2001). British manufacturer acquires the good quality of cotton from India through East India Company, for their rising industry (Buchanan, 2013) which led to the decline in hand spinning of yarn, bound to put out of place the livelihood of millions of spinners in India. The industry fell more and more under the grip of middlemen. Thus the independence of most weavers, who used to produce niche fabrics, disappeared and the majority of them came to work under Mahajan either on the contract or on the wage basis.

Marx also observes that the colonial rule broke up the backbone of the Indian handloom and destroyed the spinning wheel of this sector. They routed the Indian raw cotton after twisting through the European market in India, the quantum of which enhanced stupendously during the year 1824 to 1837 (Buchanan, 2013).

2.3.2 Handloom in India: State-wise scenario

According to handloom census report (2009 - 2010), there was a decline in handloom weavers households from 25.25 lakh to 22.68 lakh but overall households have increased to 27.83 lakh across 29 states and Union Territories of India which substantiate that more number of workers have associated with the handloom and allied handloom activities.

Status of Handloom workers

North-Eastern states enjoy the status of having the highest number (60.5%) of handloom households. In which Assam alone has 44.6% handloom households (Fig. 2.4), whereas Manipur and Tripura have 6.4% and 4.3%, respectively. Other states having comparatively large handloom household concentrations are West Bengal 14.6%, Andhra Pradesh 6.4%, Tamil Nadu 6.8% and Uttar Pradesh 4.0%. There was a considerable increase in the total man-days worked by weavers household from 4977 to 5313 and man-days worked per weaver household during the census year (2009 - 10) from 197 to 234. Moreover, full-time weaving activities have increased from 44% to 64% and the weavers producing less than one meter of fabric per day have reduced to 46% from 68%. The share of the weaver having more than 60% of their total income from the handloom and related activities have also increased from 31% to 35% with a considerable decrease in the share of idle looms to 4% from 10% whereas the idle looms proportion was highest (4.5%) in the North-Eastern states. The trends substantiated that more and more weavers' households were having an orientation towards commercial production. The report also revealed that about half of the handlooms households in the northeastern states were engaged for domestic production (45.9%) which did not support any household income whereas 24.4% handlooms households undertake mixed production and 25.2% of them worked solely for commercial production (Handloom Census of India 2009 - 2010).

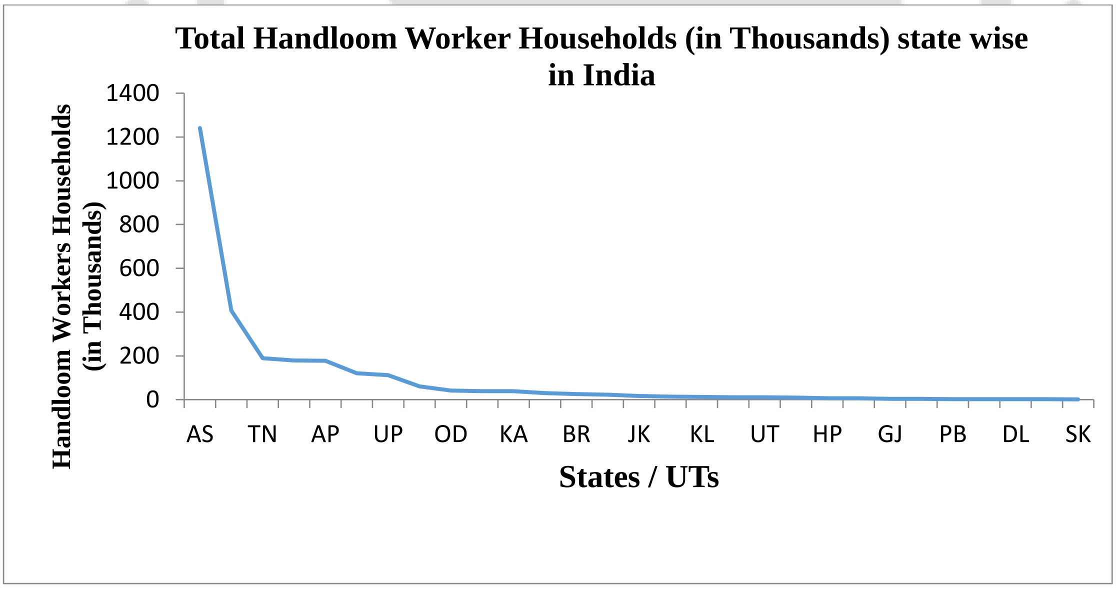

Fig. 2.4 State wise handloom workers households
(*Source: Handloom Census of India 2009-2010*)

Analysis of the state-wise production reflected that except the North-Eastern states, all other states handloom units were mainly engaged into commercial production. In other states, about 53.1% of households were engaged in commercial production, while 15.8% in both domestic and commercial production and rest in domestic production. Maximum handloom commercial production was from the state of Karnataka and Uttar Pradesh whereas in Tamil Nadu, Andhra Pradesh, Odisha and West Bengal the commercial production was carried out in certain pockets and rest handloom households were engaged in domestic or mixed production (Handloom Census of India 2009-2010).

Handloom owning households

Northeastern states having the maximum (80.2 %) handloom owning household and Odisha shared the second place having 77.5 % handloom owning household (Fig. 2.5) as compared to the national average (66.5%) and there 33.5 % households were without handlooms in various parts of the country (Fig. 2.6).

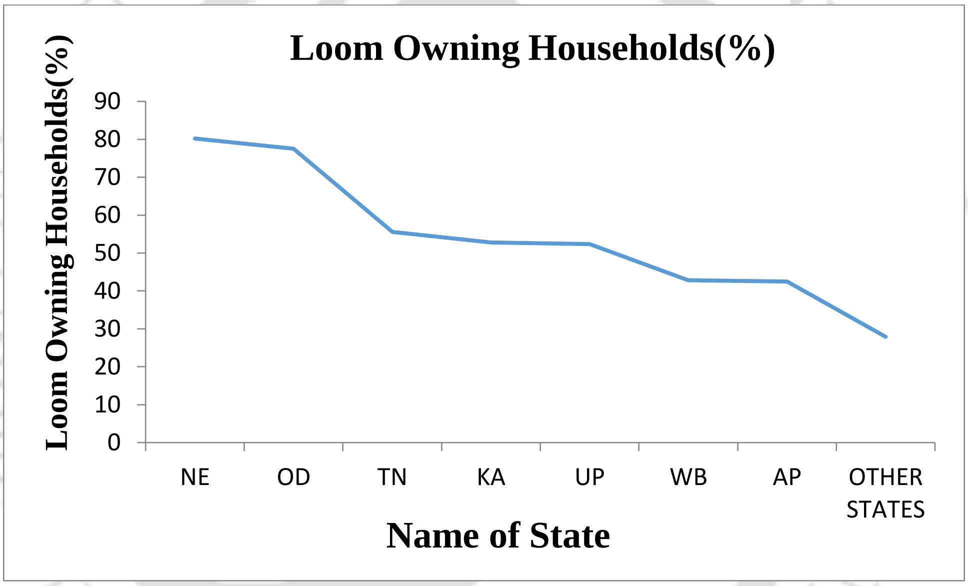

Fig. 2.5 State wise handloom owning households (%) in India
(*Source: Handloom Census of India 2009-2010)*

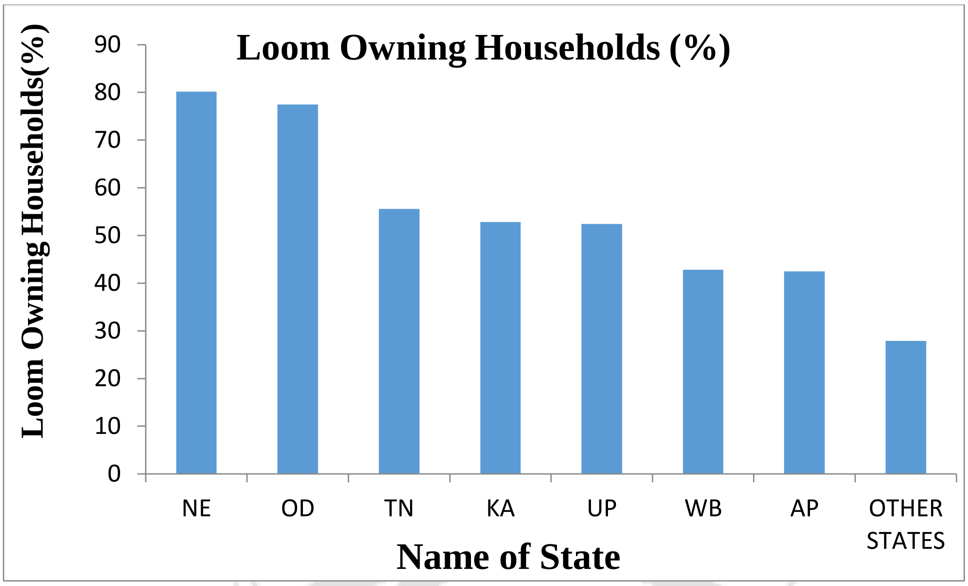

Fig. 2.6 State wise handloom owning households (%) in India
(*Source: Handloom Census of India 2009-2010*)

Handloom Household in terms of Produce

Fig. 2.7 shows the data on the major share of weaver households that reported the production of different type of fabrics by handloom concentrated states.

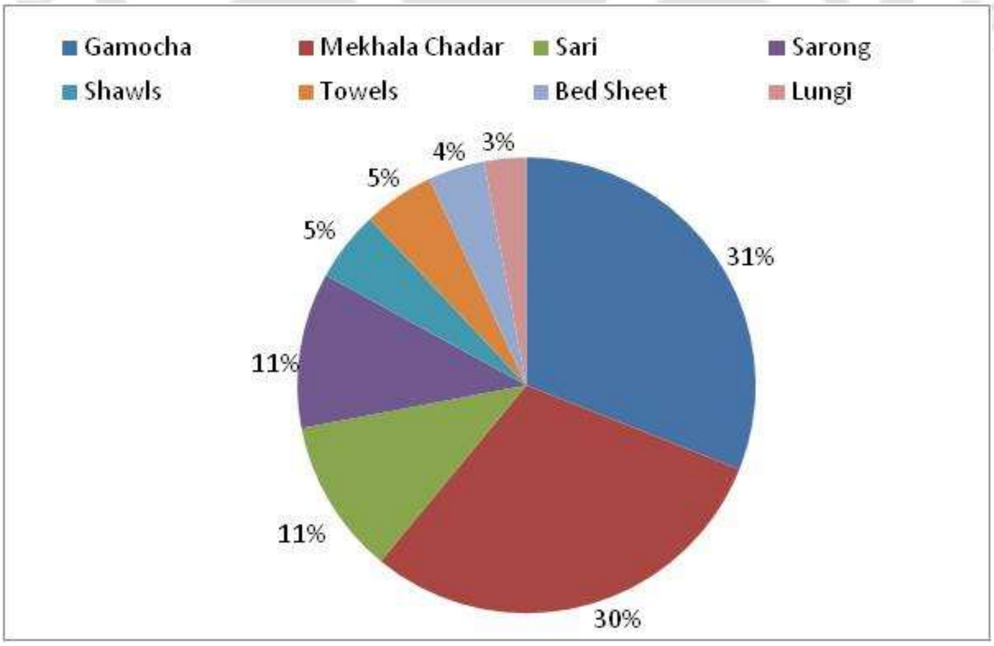

Fig. 2.7 Distribution of Handloom Household in terms of Produce.
(*Source: Handloom Census of India 2009-2010*)

Each region of India has its own cultural identity which is clearly reflected by the regional attire they produce and wear. Varieties of handloom products are being manufactured all over India with regional intricacy, cultural and design. The problems faced by the weavers in this sector are being addressed by the government body in order to make this sector a job oriented and revenue generation village industry by enhancing their capability for competing in the global markets.

In India state wise handloom products are famous such as there are Kani shawls from Kashmir, Phulkari from Punjab Brocades and jacquards from Uttar Pradesh, Tie and dye and Kota Doria from Gujarat and Rajasthan, Chanderi and Maheshwari from Madhya Pradesh, Daccai and Jamdani from West Bengal, Mekhala chadar and Bodo weaves from Assam, Adi and Apa Tani from Arunachal Pradesh, Ikats from Odisha and Andhra whereas Madras checks and Kanchipuram silks from Tamil Nadu, (Handloom.nic.in, 2017). India is known for producing all four commercially known silks variety such as Mulberry, Tussar (Tussore), Eri and Muga in the world whereas Mulberry silk is mainly produced in the states of Kashmir and Karnataka.

2.4 Textiles and Handlooms with respect to the Indian economy

India is the second largest producer and exporter of textiles as well as garments in the world (Patil, 2012; Vinayan, 2012; Goswami and Jain, 2014; Corporate Catalyst India, 2015). The export of textiles and clothing was around 4.72% of the world total exports (Dixit, 2015) which has increased by 3.2% in terms of rupees (Press Information Bureau, 2016).

India's merchandise exports share in the world has increased from 0.5 percent in 1991 to 1.7 percent in 2013 whereas the textile export share of India was 9.7% (US$15 billion) of the total exports in the year 2013-14 with a growth rate of 10% (Prasad *et al*, 2014) which was increased to 12.2% in 2014 (Dhiman and Sharma, 2016). The export of textiles and garment during 2015 - 16 stood at $40 billion (Textiles Sector Analysis Report, 2016).

As per the report of the Ministry of Textiles, the domestic textile and apparel industry of India is growing continuously which may arrive at US$ 223 bn. by 2021 (Textiles Sector Analysis Report, 2016). Total cloth production in India is expected to grow to 112 billion square meters by the financial year 2017 from 64 billion square meters in the financial year 2015 and contributes to 4% share in Gross Domestic Product, 14% of industrial production, 18% of employment and 13% of the country's total exports earnings in 2016 (Jain and Gera, 2017; Arora and Narayana, 2016; Textiles Sector Analysis Report, 2016).

Around 49% of the total textile output produced in India is exported to the world and the share of imports in the total Indian textile supply is 7% according to Compendium of Textile Statistics published by Ministry of Textiles (Arora and Narayana, 2016).

Handloom cottage industry plays a crucial role in the economy of the developing countries like India and is a major source of employment and livelihood to the rural masses next only to farming. The world market is having the huge demand for Indian niche handloom products. This industry plays a vital role in economic development of the rural masses as well as of the Indian economy and has a tremendous scope for expansion both nationally and internationally because of the demand for handcrafted artefacts and unique traditional design. Karur, Panipat, Varanasi and Kannur are the major handloom export centres which focused on the handloom products for export markets and the major importing countries of these products from India are USA, UK, Germany, Italy, France, Japan, Saudi Arabia, Australia, Netherland and UAE (HEPC, 2017).

The creativity and skill contributed to the success in preserving the long tradition of excellence of Indian handlooms. Handloom weavers and fabrics form an integral part of the rich culture, heritage and tradition of India. Apart from providing one of the basic needs of human beings, along with a sizable contribution to GDP and export, this industry provides direct and indirect employment to lakhs of people in the rural and urban areas. The country supplied 95% of the world demand for hand-woven fabrics and contributes to about 27% to India's foreign exchange inflows.

Total cloth production which includes handloom, power loom and mill sector increased to 46,334 million sq. meters in the year 2015 – 16 from 42121 million sq. meters in the year 2008 – 09 (Fig. 2.8) and during the year 2012 – 13, total cloth production was the highest i.e. 61,949 million sq. meters (Kar, 2015; Annual report 2016 – 17).

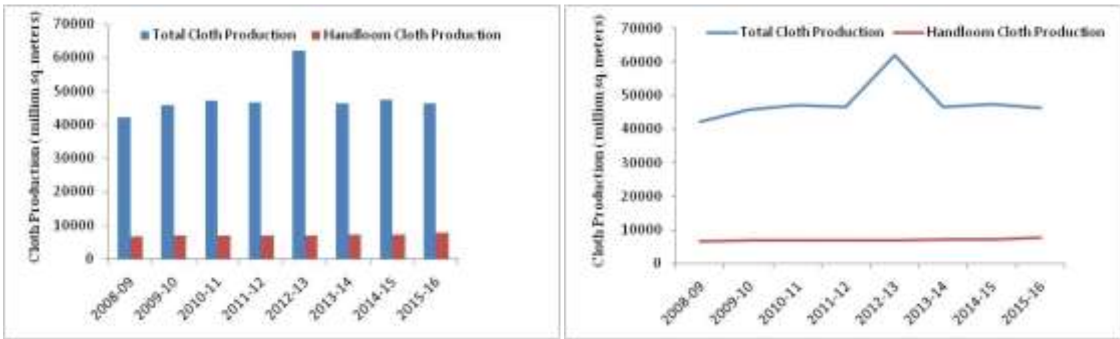

Fig. 2.8 Year-Wise Total Cloth Production includes Handloom, Power loom and Mill sector. (*Source: Annual Report, 2016 – 17*)

Export of handloom products from India stood at US$ 360.02 million in 2015 – 16 and the main importers were US (US $ 106.13 million), UK (the US $ 22.42 million), UAE (the US $ 19.42 million). Italy, Germany, France, Spain, Japan, Netherlands and Australia were also the other export destinations for Indian handloom products. US, UK and UAE account for more than 41 percent of total exports of Indian handloom products (Note on handloom sector, 2015 and Annual Report, 2016 – 17). Some of the leading international players that import Indian handloom products include IKEA, Wal-Mart, Target Corporation, Habitat and Town and Country Linen (IBEF, 2017).

Table: 2.1. Year-Wise production of handloom cloth and export of handloom products:

Year	Production (in million sq. meters)	Growth in production	Handloom exports in crores (US dollar)	Growth in exports
2009-10	6806	1.97%	1252.8 ($241 million)	–
2010-11	6949	2.06%	1574.95 ($303 million)	25.71%
2011-12	6900	(-)0.71%	2623.95 ($505 million)	68.51%
2012-13	6952	7.53%	2811.97 ($521 million)	5.95%
2013-14	7104	2.35%	2233.11 ($372 million)	(-)20.6%
2014-15	7203	1.23%	2246 ($350 million)	5.82%
2015-16	7638	6.04%	2353.33 ($360.02 million)	4.77%

(*Source: Note on handloom sector, 2015 and Annual Report, 2016 – 17*),

The total handloom cloth production of India reached 7638 million sq. meters in 2015 – 16 from 6806 million sq. meters in 2009 – 10 whereas the export of handloom products stood at the US $ 360.02 million (Rs. 2353.33 crores), in 2015 – 16 from US $241million (1252.8 crores) in 2009 – 10 (Fig. 2.9). Even though the number of handlooms and handloom weavers have the waning trend (Handloom Census of India, 2009 – 2010) but the production and export of handloom products reflected (Table 2.1) the increasing propensity.

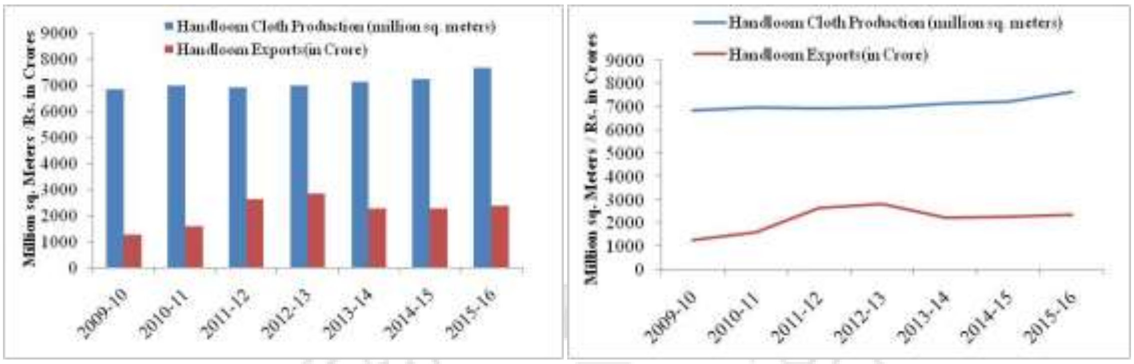

Fig. 2.9 Year-Wise Production of Handloom Cloth & Export of Handloom Products (*Source: Note on handloom sector, 2015 and Annual Report (MOT) 2016 – 17*)

2.5 Current scenario and strategy for reviving handloom sector

77.8% of the total handloom workforce of this sector is from Assam (38.6%), West Bengal (17.3%), Tamil Nadu (8.1%), Andhra Pradesh (8.2%) and Uttar Pradesh (5.6%) (Patil, 2012). Out of four-fifths of the rural handloom workers in India, the state of Assam has 45.1%, West Bengal 16.8%, Andhra Pradesh 5.9%, Tamil Nadu 5.7%, and Manipur 5.3% were having the handloom workforce from the rural sector whereas 82.4% of the total urban workforce of the handloom industry is from Tamil Nadu 21.65%, West Bengal 19.9%, Andhra Pradesh 19%, Uttar Pradesh 16.6% and Manipur 8.2% (NCAER, 2010).

The increase in exports evinces that more weavers are adopting the handloom weaving as the full-time profession having an inclination towards value addition and production of quality handloom products. Many high-end retailers are also focusing on the marketing of the handloom products and numerous special purpose vehicles and self-help groups have come forward for exporting handloom products directly (NCAER, 2010). Goswami and Jain (2014) study revealed that about 54% of the weavers were not aware of the market trend and the use of innovative design. Obsolete technology and poor quality of raw material resulted in poor market response due to low quality and the high price of the end products. Ministry of Textile, Government of India has taken initiatives to facilitate the marketing of handloom products directly from the producer to the user and signed a memorandum of understanding (MoU) with 20 e-commerce companies for providing a platform to artisan and weavers in the different handloom and handicraft clusters across the country for selling their products to the customer (Department of industrial policy and promotion, PIB, union Budget 2017 – 18)

It has been observed that the supply of yarn (raw material) and marketing are the two major constraints for handloom industry. Efforts are being made to develop skilled manpower and entrepreneur in order to facilitate the weavers for adopting this profession on the full-time basis on the commercial scale with full devotion. However, handloom industry needs to reorient itself for meeting the challenges being posed by rapid economic, social and technological advancements.

In the contemporary era, Indian handlooms are going global in a big way and have support from the government as well as from the community world over. Handlooms not just represent a village industry but it is the ancient cultural heritage of India which requires a proper roadmap for its progress and development.

Designers, who facilitate in enhancing the face value of the handloom products, can play a vital role in promoting handlooms. The Indian handloom industry has not fully utilized the indigenous resources to cope up with the changing lifestyles and aspirations and it is a rich and resilient medium of ethnic expression which is being given due respect by the government agencies too.

Handloom industry is facing manifold problems as compared to the other industries. Overall business strategy for the handloom sector (Goswami and Jain, 2014) requires reorientation and marketing of the products was observed to be the important parameter for which three basic approaches such as overall cost leadership through mass production, differentiation through creativity and focus on the targeted group were put forth.

Overall cost leadership strategy cannot work in handloom industry as on one hand the handloom products are priced high and the lower/middle-income groups abstain to buy these products and on the other hand the products are not quality rich to tap the higher class whereas in the case of differentiation strategy which led to creation of something innovative and best suited to handloom industry. Niche and the exclusive product can be developed keeping in view the necessity of the targeted group.

Since handloom industry is a rural-based cottage industry, the labour inclination in pre-weaving and weaving operation is predominant as compared to mechanical operations. The efforts in machinery development for the handloom industry have been oriented to improve machine and labour productivity without sacrificing traditional labour involvement. It is the high time and mandatory to sustain the employment generating potential of this industry. Bortamuly and Goswami (2015) findings reflected that the technology adoption depends on the determinants such as gender, annual income, access to training, age, education, government credit and market vicinity. Hazarika *et al.* (2016) also elucidated that the factors such as finance, education, family stratum and social network are the potent determinants for technology adoption in the nonfarm and informal micro industry in the developing economies.

Subathra (1994) discussed the developmental model based on protection of small-scale domestic industry and other decentralized sector labours against the large-scale capital-intensive industry. Jayakar (1988); Kutty (2000); Mathiraj and Rajkumar (2008) stressed on problems related to the marketing of products, assistance, development of marketing capability and improved marketing channels for handloom products. Maurya (1988) revealed that handloom product should maintain their identity which can overweigh or surpass the sophisticated mill fabric. Das (1986) and Das (2015) articulated the timely introduction of new techniques of production and modernization of the handloom was the need of the hour. Various technological interventions have been put forth in the handloom machine for reducing the fatigue of the weavers and increasing the productivity in order to improve the earnings of the weavers (Pandit, 2015; Garg *et al*., 2012) without compromising with the quality of the products. Access to modern technology appears as the most important factor in the occupational shift from weavers to handloom owners (Borah *et al*., 2013).

Fig. 2.10 Weaver weaving Ikat Sari on the Handloom

2.6 Rural Scenario with respect to Handloom

In rural India, handloom industry is one of the main sources of livelihood and playing a very crucial role in the Indian economy. As far as the number of handlooms and varieties of traditional handloom products is concerned India occupies an important place in the world. This cottage industry is an age-old industry of the world and a large population of rural India directly or indirectly depends upon this industry for their livelihood. Every weaver's household is having handloom at the place where they live and about 75% to 80% of the house of the weaver is occupied by the handloom machine and the allied accessories whereas 20% to 25% was utilized for the housing of households. Weaver's whole family is involved in weaving the fabric and the entire family develops the sari/ fabric like a daughter by the mother which involves love and warmth.

The handloom industry is still surviving despite the development of modern machines in the field of weaving as a result of value addition to the fabric during weaving and these designs cannot be imitated easily by the power loom sector. Handlooms are in existence all over India and each part of India has its own speciality in terms of production of handloom fabric. Inspite of massive production of fabric through power looms the fabrics of handloom origin are being sold at a very attractive and lucrative price because of their own speciality and design identity In handloom there is a trend of mixing old designs with new techniques and create original products.

2.6.1 Handlooms in eastern states of India with the special focus on Odisha state

In the eastern region, West Bengal is having the highest number of handlooms but Odisha enjoys the status of having the maximum handloom owning household. Even though the reduction in the number of handlooms, there is increase in yardage on an average from fifty meters per month to fifty-four meters per month with an increase in annual income Rs. 37546/- to Rs. 59229/- (Handloom policy Odisha, 2016). The gross state domestic product (GSDP) of Odisha was US$ 51.30 billion over 2014 – 15. Odisha stands at 7th in rankings among Indian states based on ease of doing business and reforms implementation, according to a study by the World Bank.

Handlooms of Odisha have established a pride of place in the domestic as well as in the international market due to exquisite craftsmanship having the specialities of tie and dye method of colour combination along with unique traditional design and superior quality. Even though, having a good reputation, this sector is still in the most dismal condition in Odisha due to the steady decline of the functional performance of the weavers' co-operative societies and production centres with the advent of organized modern textile industries. Majority of the weavers switched over through master weavers or through direct marketing due to which the socioeconomic condition of the weaving community is deteriorating continuously. The weaver encountered various hurdles engaged with this profession due to global market competition which led to low level of income, the poor market price of the finished commodity and inability to reach the buyers while facing the poor indoor physical environmental conditions. According to Subhajit (2006), the functions of the co-operative societies and production centres have drastically reduced to a very low level, despite that some of the handlooms remained unaffected by the globalization of textile industry. This industry provides employment to 4% of the state population (Basu, 2016).

Out of the national figure, 80.97 % of weavers' households of Odisha producing the highest number (85%) of handloom Ikat saris (Handloom Census Report, 2010) and very few produced other items like dhoti, bed sheets, cloth pieces, towels etc (Fig. 2.11). In terms of productivity, most of the handlooms undertaking commercial production (93.5%) in the state of Odisha are located in rural areas.

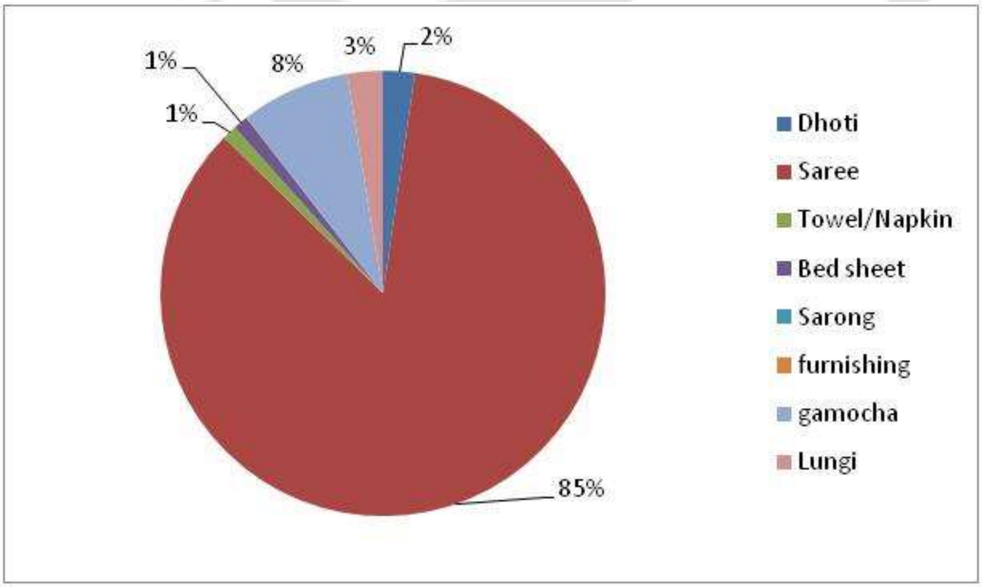

Fig. 2.11 Production of major fabrics in Odisha. (*Source: Handloom*

Census of India 2009 – 2010)

82.2 % of the handloom workers households were weaver households in Odisha out of which (85%) are male weavers (Fig. 2.12) and irrespective of less number of handlooms, average earning per weaver is higher to many other states and next to Delhi and Haryana(Handloom Census of India, 2009 – 2010).

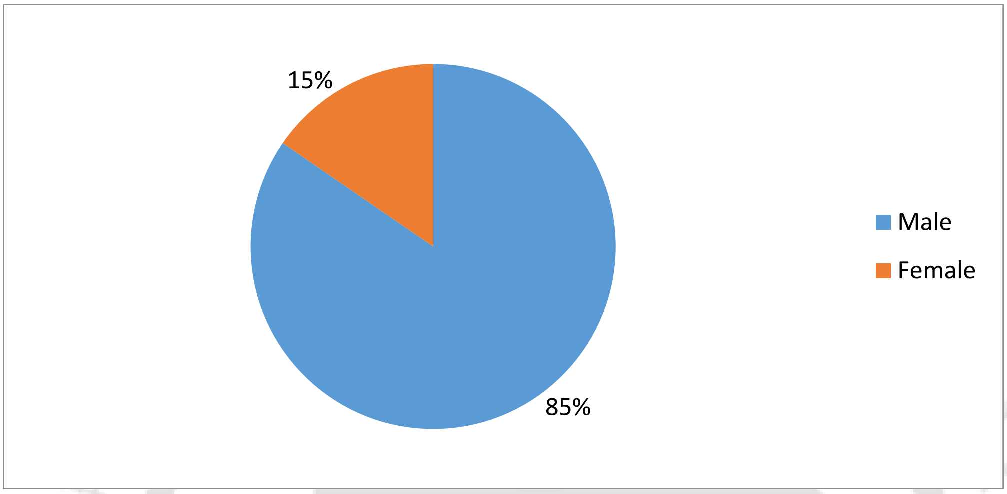

Fig. 2.12 Gender wise involvement of weavers in handloom activity in Odisha state. (*Source: Handloom Census of India 2009 – 2010)*

Even though of increasing trend of export, the earnings of the weavers are not remunerative i.e. total income of a handloom weaver varies between Rs.29300 to Rs.57, 232/annum/weaver on an average at the national level whereas in case of Bargarh district of Odisha, the income of the weavers have shown an increasing trend in the year 2016 i.e. by 10% to 64,800/annum/weaver or Rs. 5400/- per month (Handloom policy Odisha, 2016).

Traditional garments are the part of the enriched culture of Odisha state and are being draped in various styles. Sambalpuri cotton saris are one of the ancient and famous handloom miracles of Odisha culture and a symbol of tradition and civilization (Mishra, 2016). It has been an important part of the ethnic Indian female attire in the western Odisha society. There is a huge demand for Sambalpuri saris all over India and overseas.

Small weavers, master weavers and co-operative societies are the main actors of the clusters. Majority of people are working under the master weavers who in turn provide raw materials and other necessary inputs in term of dyes, chemical, handloom accessories, market trend and demand to the weavers. It was observed that most of the handloom weavers' co-operative societies were running in a loss as a result of which they were unable to take proper care of its weaver members.

Table: 2.2 Year-Wise Total Production of Handloom Products of Odisha state and Bargarh district (Rs. in lakh)

Year	Odisha	% Growth in production of Odisha State	Bargarh	% Growth in production of Bargarh District
2013-14	26080.00	-	7440.55	-
2014-15	36372.56	39.46 %	10582.44	42.23 %
2015-16	37806.79	3.94 %	9191.49	- 13.14 %
2016-17	36018.21	- 4.73 %	9828.18	6.93 %

(*Source: Handloom policy Odisha, 2016 and Data collected from State handloom department, Govt. of Odisha, Bhubaneswar, 2017)*

Production of Handloom Products of Odisha state data reflected that there was progressive growth of fabric production up to the year 2015-16, then the fabric production decline by 4.73 % in the year 2016 – 17 (Table 2.2) due to dip down in sale by 3.58 % in the domestic as well as in the international market (Handloom policy Odisha, 2016). Similarly as per the statistical report acquired from the director of handloom and textile, Government of Odisha, Bhubaneswar, the total production of Bargarh district also followed the same trend, initially there was progressive growth in the production of fabric of the district up to the year 2014 – 15, then the fabric production declined by 13.14 % and followed by upsurge by 6.93 % in the year 2016 – 17 (Fig. 2.13, Fig. 2.14) due to remarkable appreciation in total sale of Bargarh district products by 17.1 % despite of sharp decline in the state production and sale.

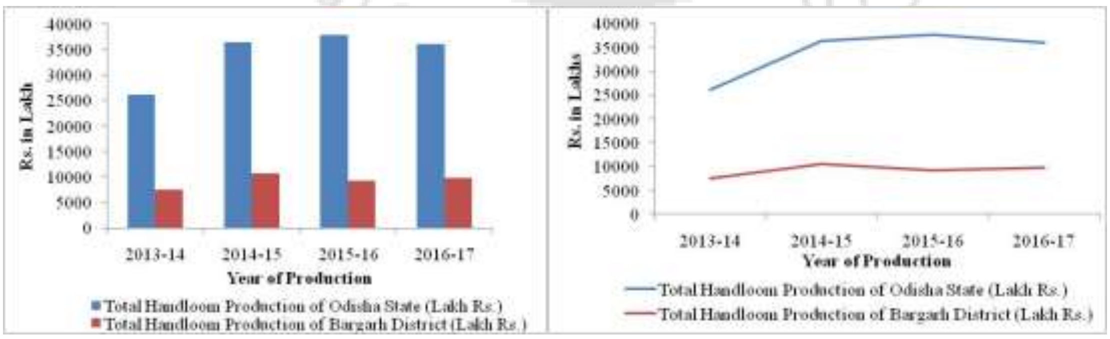

Fig: 2.13 Total Handloom production of the Odisha state and Bargarh district in lakh Rs. (*Source: State handloom department, Govt. of Odisha, Bhubaneswar, 2017*)

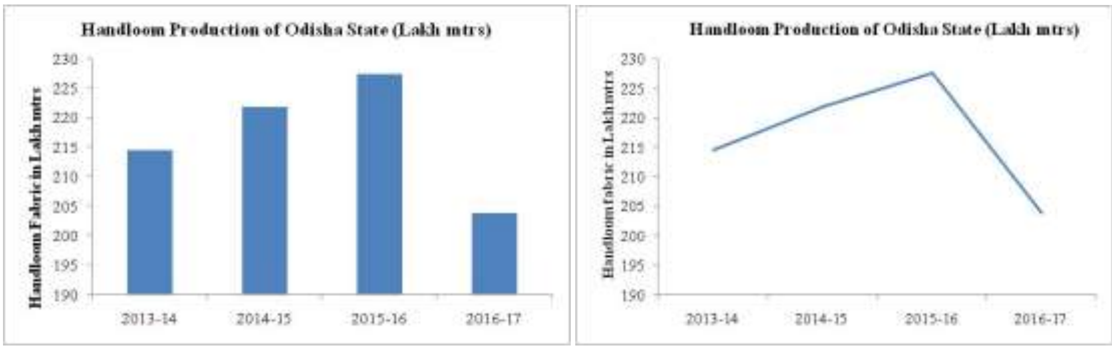

Fig. 2.14 Total Handloom production of the Odisha state in lakh meters.
(*Source: State handloom department, Govt. of Odisha, Bhubaneswar, 2017*)

Handloom can be used as a tool to fight poverty and it plays an important role in the socio-economic development of the weavers as well as of the country. Handloom enhances the source of income with an increase in weavers' pride. Odisha state is having the highest percentage of allied (52.5%) and independent workers (54.8%) as compared to the other states. Also, 87.1% of the weavers in Odisha are working full time for more than 8 h per day for commercial production (Handloom census of India, 2009 – 2010).

For the social security of the weavers, Government of India has initiated various schemes such as Jandhan Yojana, Prime Minister Jeevan Jyoti Bima Yojana for life insurance, Prime Minister Suraksha Bima Yojana for accidental insurance and Atal Pension Yojana for the pension of weavers above 60 years of age. Srinivasulu (1994) experienced that due to change in the government policies there was a sharp rise in yarn and dyes prices which led to deprivation in the economic status of most of the weavers.

Indebtedness was one amongst the major problems and serious issue of the handloom weavers which was because of low income, poverty, lack of education and excess expenditure in social customs. Observations reflected that out of the total average income of each household, the weavers spending nearly about half the income on their food followed by clothing. Most of the weavers were not having any agricultural land as their secondary source of income.

In Bargarh district majority (96%) of weavers are working under the control of the master weavers and rest (4 %) working as an independent weaver. The master weavers provide the raw materials and pay the wages towards the conversion charges. Most of the weavers of Bargarh district which accounts approximate one-third populations of the handloom weavers of the state as per the director of handlooms and textiles report were engaged in the production of sari (85 %). With respect to the number of working days per month, the majority (54 %) of weavers are working for 26 to 30 days supported by their family members.

The study reveals that the handloom industry is not adopting any suitable strategy for procurement of raw material, product planning and promotional activities (Goswami and Jain, 2014) and there is a gradual shift of this highly skilled occupation to other private, contractual and government services because of the uncertainty and drudgery that lies in this sector besides lack of attention of the various agencies towards the excruciating and downtrodden condition of traditional weavers. In the recent past the governmental organizations have become more vibrant and taken various constructive steps to float various digital based activities right from the procurement of raw materials and accessories for the handloom sector up to marketing of the finished product in order to get access of the important requirements for the survival and development of this sector and to facilitate the weavers to have prompt supply of standard quality of raw material at reasonable prices and suitable market for selling of their products which shall be a crucial step in the direction of improvement in the productivity as well as financial conditions of the weavers.

Livelihood

Handloom industry is facing manifold problems which other industries do not have and in order to make the industry profitable, the problems prevailing in the handloom sector are required to be identified and addressed properly. SWOT analyses should be estimated and the weavers facing problems regarding raw material supply and marketing of products (Goswami and Jain, 2014) are required to be addressed seriously. For a weaver, handloom is the only source of income on which the whole family depends and survives. Current scenario of the contemporary practice of the handloom industries reflects that design of the fabric, its development and marketing have the influence of the designer, entrepreneurs, government, nongovernmental organization (Hani and Das, 2017).

Tradition

Since time immemorial handloom is an artefact which needs to be preserved and organized in order to enhance the efficiency of the system which directly or indirectly helps the weavers to earn more wages for their survival and livelihood. Indian Handloom Industry is an ancient cottage industry under decentralized sector. It is an age-old source of livelihood for millions of people in the country. This sector constitutes an everlasting part of the rich cultural heritage of India. The characteristic of art and craft present in Indian handlooms makes it a potential sector for the domestic as well as for the global market. However, the sector is inundated with various problems such as unorganized production system, obsolete technologies, low productivity, inadequate working capital, conventional product range, weak marketing link, overall stagnation of production and sales, the threat from cheap imports, over and above competition from power loom and mill sector. The handloom sector up to some extent has been able to tide over these disadvantages by the government interventions in the form of financial assistance and implementation of various developmental and welfare schemes. The presence of art and craft elements in the handloom weaving has cropped up the Indian handlooms to the global level (Sudalaimuthu and Devi, 2011). The systematic approach to the development of tools and process leads to advance productivity and quality in a cost-effective form (Chaudhary and Saha, 2005). Handloom sector is playing a vital role in the manufacturing of intricate fabrics which indirectly leads to the contribution in the economy of the country (Kondaiah, 2010). For streamlining the various activities related to the handloom production and for justification of the handloom weaver's work, the role of the master weaver who acts as a backbone for the weavers as well as a successful entrepreneur is of paramount importance (Bhagavatula, 2010).

2.7 Different types of looms used by Indian weavers

It is not known with certainty when weaving was first adopted by our ancestors. However, it has already been established that weaving was known about eight thousand years before Christ. It is a matter of controversy whether wool, linen, silk or cotton was first used as raw material for weaving. It may be assumed that human beings, encouraged by nature and compelled by necessity, sought a better kind of material than barks or leaves of trees or hides of animals to protect their bodies from the inclemency of the variable weather. It is highly probable that fleece attracted their first attention. In the Vedic age, we find a remarkable understanding of spinning and weaving of linen, wool, silk, cotton. In the ages of Ramayana and Mahabharata, the art of weaving reached a high standard of perfection and beauty.

The appreciation of fine arts and textiles of the Hindus met its climax during reigns of Mughal emperors. Dacca muslin and silk dictated the fashions of the Asian and

Europian aristocrats till the end of the eighteenth century. 400^s or higher counts of cotton yarn were recorded to have been spun by ladies by using a small instrument called "Takli".

Despite the traditional background of highly developed artistic weaving with an extra weft in the country, it was surprising that weaving machine was short of mechanical details till the introduction of the fly shuttle loom and jacquard machine. Since the invention of the sley and fly shuttle loom in the thirteens of the eighteenth century there have been rapid improvements in loom mechanism.

2.7.1 Loom: Definition and Type

In technical terms loom is a weaving machine in which interlacement of two threads takes place, out of which one single thread of warp is known as an 'end' and other of weft is called 'pick'. Looms are of two types Non- Mechanized hand operated (Handloom) and mechanized power operated (Power loom).

Handlooms

Handloom is a non-mechanized hand operated machine in which yarn or thread in the form of warp and weft is interlaced at the right angle by using the shuttle or wooden/ bamboo sticks and woven into fabrics by the crossing of vertical and horizontal threads by the process known as weaving.

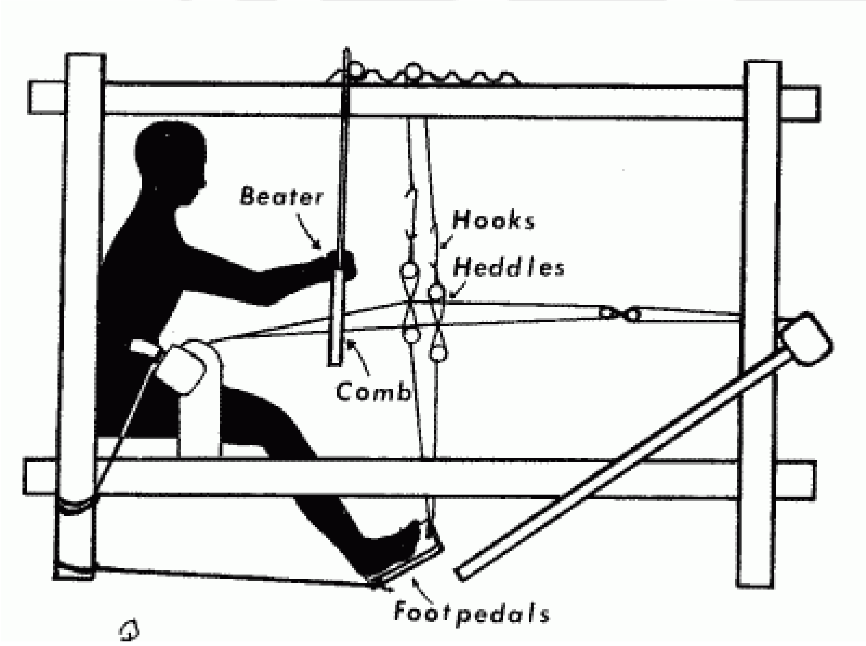

Fig. 2.15 Skeleton diagram of frame handloom (*Source: Banerjee, 1982*)

It is recognized to be one of the oldest ongoing crafts in the world. In the present era of mechanization and standardization, the handloom sector provides a unique richness of varied manual skills, representing the cultural and traditional art forms. A person is required to operate each handloom (Fig. 2.15). It involves the high amount of physical stress, a lot of time consumption in the manufacturing. Handlooms are generally classified either on the basis of the loom structure, the development of end product and its laying position on ground or place of its origin (India. The Factories Act, 1948).

In handloom weaving, expert weavers are the key persons, facilitate in transforming the fabrics as per the demand of today's world. This sector represents country's traditional art form that has been supported and encouraged since time immemorial.

Handloom industry is highly labour intensive sector. In order to save the time, energy and human efforts, technological intervention is inevitably required. Various Research & Development works have been carried out in the handloom industry in order to reduce the drudgery of the handloom weavers and improving their productivity.

Various types of handlooms machines are available all over the world such as

- ***Primitive Looms***
- ***Pit Handlooms***
  - *Throw shuttle pit looms*
  - *Fly shuttle pit looms* a) Underground pit loom b) Raised pit loom c) Pit looms with dobby/jacquard.
- ***Frame Loom-*** light weight and heavyweight frame looms
- ***Loin looms***
- ***Other looms*:** Vertical loom, Semi-automatic and automatic dobby/ jacquard looms, Pedal loom, Banarasi loom, Manipuri loom, Rajasthani loom, Kashmiri looms, Chittaranjan looms, Ichalkaranji looms, Modernized Malabar looms, etc.

Power looms

Various types of powerloom machines are available all over the world such as

- **Conventional or shuttle looms**
  - *Over pick power loom*
  - *Under pick power loom*
- **Shuttle less looms**
  - *Sulzer or Projectile loom*
  - *Rapier loom*

- *Airjet loom*
- *Waterjet loom*
- *Multiphase loom*

2.7.2 Motions of Weaving

Motions of weaving

- **Primary motion**
  - Shedding
  - Picking & Beating – up
- **Secondary motion**
  - Let off & Take up
- **Auxiliary motion**
  - Temple motion
  - Terry motion
  - Drop Box motion
  - Warp stop motion

The weaving of the fabric is carried out by using various motions such as **shedding, picking and beating up** in a sequential order.

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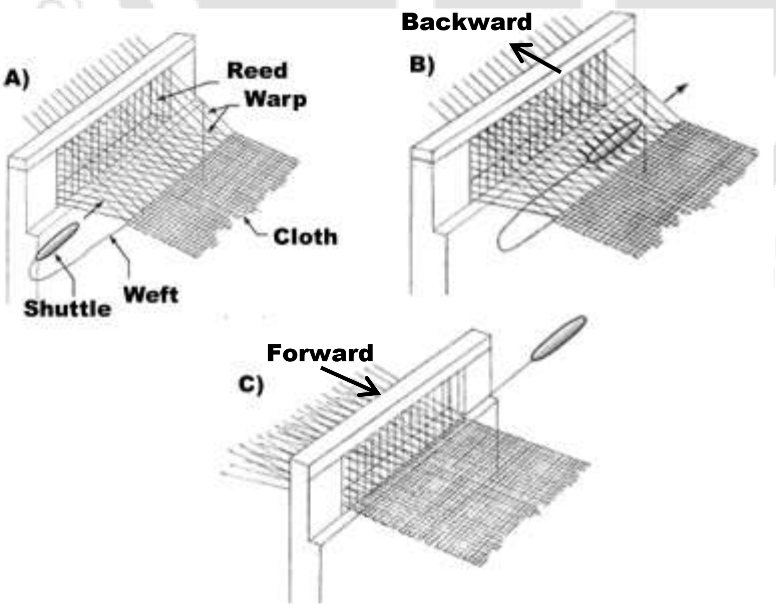

Fig. 2.16 Primary motions of weaving: (A**)** Shedding, (B**)** Picking, (C**)** Beating

Source: *Textile Innovation Knowledge Platform, Textile Center of Excellence (UK*).

Shedding is the first primary motions of weaving in which the warp is divided into two layers one above the other for the passage of the shuttle with a pick of weft using heald frames (Fig. 2.16 'A'). This motion is produced by treadles, dobbies and jacquards or other mechanisms.

Picking is the motion of propelling the shuttle at high velocity with the help of picking handle connected by cords with pickers on both sides of the sley frame, which move the shuttle to pass across the shed over the race from one shuttle box to another with the weft yarn (Fig. 2.16 'B'). Besides the shuttle, there are other appliances such as rapier, miniature shuttles, Water force and air force, which are being used in shuttle less looms.

Beating up is a motion of beating up the last pick of weft to the fell of the cloth with the help of the reed in the sley. The sley swings forward to beat up the last pick of weft (Fig. 2.16 'C').

2.7.3 Yarn Path through the Handloom

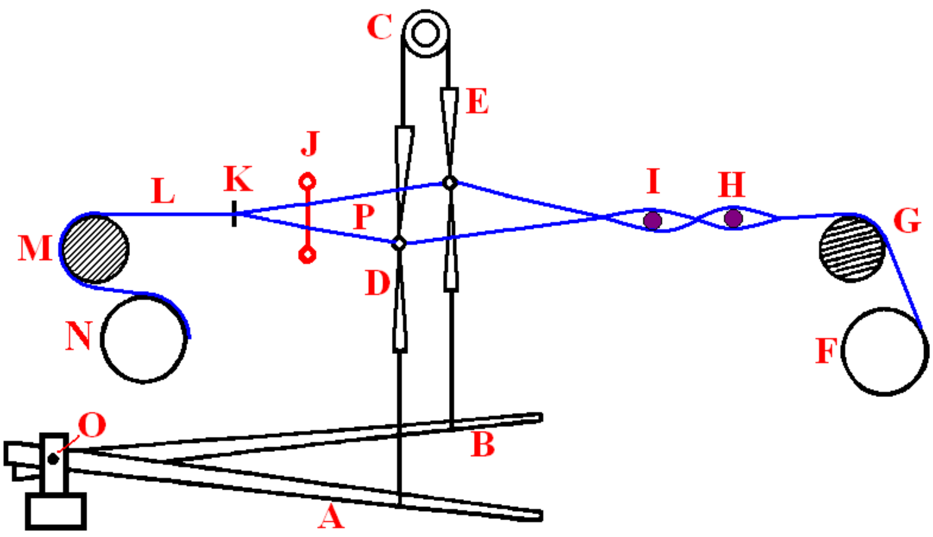

Fig. 2.17 Yarn Path of the Yarn through the Handloom (*Source: Banerjee, 1982*)

Warp beam → Back rest→ Lease rods → Healds →Reed →Front rest→ Cloth roller (A-Treadle, B-Treadle, C-Shedding roller, D-Heald shaft, E-Heald shaft, F-Warp roller, G-Back rest, H-Lease rods, I-Lease rods, J-Reed, K-Fell of the cloth, L- Cloth, M-Front rest, N-Cloth roller, O-Treadle stand pin)

Warp yarn is passing from the warp beam over the backrest through the lease rods, reed and healds over the front rest roller and finally wrap on the cloth roller or take up roller (Fig. 2.17)

2.8 Environmental Factors and its impact on occupational health

Ergonomics is considered as one of the crucial factors for making the function of any system easy and successful. Moreover, it is a human Engineering and there is a need for efficient ergonomic intervention. Several research papers have been published on the issues related to the ergonomics problems in the small scale as well as in cottage industries and especially of the weavers working on the handloom, regarding work related musculoskeletal disorders (Pandit and Chakrabarti, 2014; Motamedzade and Moghimbeigi, 2012; Nag *et al.*, 2010; Choobineh *et al.*, 2007; Smith *et al.*, 2006; Banerjee and Gangopadhyay, 2003; Bernard and Putz-Anderson, 1997; Solanki *et al.*, 1993); workstation design (Pandit and Chakrabarti, 2015; Motamedzade *et al.*, 2007; Corlett, 1999 and Das, 1990); Ergonomic problems (Pandit *et al.*, 2013; Metgud *et al.*, 2008); Occupational health (Goel and Tyagi, 2012); sitting posture (Banerjee and Gangopadhyay, 2003) and various other studies at micro level.

Ergonomics can play a very crucial role in the enhancement of handloom productivity, the efficiency with quality without affecting the work-related musculoskeletal disorder (WMSD) to the weaver. Various works which were being performed on and off the handloom during preparatory and weaving operation were of repetitive in nature. By adhering to the ergonomics parameter weaver - handloom interaction could be optimized to a maximum extent in order to induce a weaver's work friendly environment and to reduce the WMSD. Hence, at every stage, one must consider the micro or macro ergonomics in and around the workstation in order to improve the overall efficiency of the work system.

Due to drudgery and excruciating nature of work new generation is reluctant to come forward for the revival of this rich Indian cultural heritage. In order to make this sector more vibrant, it is essential to have ergonomics interventions for providing new dimensions to this ancient cottage industry. Weaving on the handloom requires patience and working for a long time in one particular posture which may lead to various work-related musculoskeletal disorder (WMSD). The other factors and activities which proliferate these WMSDs are the poor indoor physical environment, the physical and psychological stress of work, poor machine design, lack of skill required to perform the job, repetitive treadling, piecing of yarn through various reeds and healds eyes (effect on neck, lumber, hand) etc. Motamedzade *et al*., (2007); Arphorn *et al*., (2008) and Nurmianto, (2008) illustrated that ergonomic intervention at the workstations has helped in reducing workers discomfort and fatigue, which facilitates an increase of productivity and reduction in MSDs. Hiremath et al. (2014) stated that respiratory problem was the common issue amongst the textile workers which led to the eye and musculoskeletal problem. Meena *et al.* (2012) stated that the awkward working postures at the workplace in the handicraft industry upshot high rate of absenteeism which indirectly affects quantity and quality of the production.

Finished goods are the outcome of the manufacturing process which transforms the raw materials into the final product in order to meet the specifications or customer's expectations. In the labour intensive countries like India, the focus is on increasing employment opportunities for the huge population. In order to optimize the human-machine interaction for enhanced safety, comfort and well-being of workers and for increasing the efficiency and productivity of work system especially in handloom manufacturing sector, application of ergonomics is inevitably necessitated.

Investigations from an ergonomics perspective have been carried out in Indian manufacturing industries like transformer manufacturing industry (Wanave and Bhadke, 2014); pump assembly work (Nishanth *et al*., 2015); Steel plant (Pachal *et al*., 2005 and Ray and Tewari, 2012); welding work (Chaudhary *et al*., 2013); cast house work station (Kumar and Das, 2012); small scale casting (Singh, 2012); brick manufacturing (Pandey and Vats, 2012); assembly workstation in a welding shop (Shinde and Jadhav, 2012); small scale aluminum casting works (Biswas *et al*., 2012); pedestal oil-lamp manufacturing (Senthil and Vadivel, 2012); small scale forging firms (Singh, 2010); foundries (Mohan *et al*., 2008; Kundu *et al*., 2005); lock manufacturing (Muzammil *et al*., 2005) and electronic component manufacturing (Fernandez and Uppugonduri, 1992)

Ignorance towards ergonomics was noticed across all industries in Indian scenario including the handloom sector. It is being observed that inadequate measures have been taken to explore ergonomics aspects in the production sector (Sanjog *et al*., 2013). There is a paucity of field studies in industrial ergonomics research (Singh *et al*., 2014). Much thought was not given to ergonomic aspects while installing and commissioning majority of production units (large, medium, small, and micro) in India which resulted in the poor human-centric approach of the manufacturing industries in India and thus affecting the workers' well-being (Sanjog *et al*., 2013). Various initiatives have been taken by India to improve its manufacturing sector. The focus in India is shifting towards a labour intensive manufacturing sector with the aim to make India a global manufacturing hub through the ambitious national campaign called “Make in India” (Mehta, 2014). Such start-ups are expected to enhance employment in the manufacturing sector to 100 million workers by the year 2025 (McCormack, 2011) and this forecast must be taken into consideration by the practitioners/researchers, of the ergonomics discipline in India.

Developing countries contribute to about 80% population of the world (Cullen *et al.*, 2005) and the total workforce of the world is about 2.5 billion persons. The maximum numbers (61%) of the labour force of the developing countries are working in the field of agriculture and cottage industries of the world whereas this number is very scant (4%) for the developed countries (Dewan, 1998; Sousa, *et al.*, 2014).

Occupational health services are well organized and implemented in the developed countries as compared to underdeveloped or poor countries because of inadequate resources, lack of awareness and due to availability of plenty of unemployed workforce which resulted in providing least priority to occupational health parameters leading to at least 2 million estimated death per year due to negligent of occupational parameters (Cullen *et al.*, 2005). Moreover, due to continuous industrialization in many developing countries of the world, this area has not been addressed properly which ultimately result in the public health problem. Occupational health is one of the important parameters for the growth and economy of any country of the world. The type and standard of surveillance which is required for a particular target group decide the occupational health and safety norms (Harrington *et al.*, 1983). Even though there is growing awareness about occupational health and safety, the rate of accidents in various industries still shows an upward trend (Sousa *et al.*, 2015). It has been ascertained that the workers having prior knowledge about the occupational health and safety norms are less prone to casualty (Ollé-Espluga *et al.*, 2015). These days inherent occupational health is the main issue for occupational hazards which needs special focus (Ng and Hassim, 2015; Bouhuys, 1969).

Manothum *et al* (2009) evaluated the implementation of an occupational health and safety management model for informal sector workers (Handloom weaving) in Thailand and it was observed that workers had improved to meet necessary standards. Schilling (1981) concluded that rapid development in occupational health leads to improvement in efficiency, attitude, compassion and increase in the competence of health and safety at the workplace. By putting into action the on hand understanding and with some efforts occupational health in the informal sector can be improved in order to deal with the causal risk environments (Loewenson, 2002).

The study reveals that poor ambient environmental conditions have the detrimental effect on the physical and occupational health of the workers working in the small-scale steel manufacturing industries (Chohan and Bilga, 2011) and glass manufacturing unit (Bhanarkar *et al.*, 2005; Srivastava *et al.*, 2000). Being a developing country, occupational health and safety issues in India require structural changes in various fields from a historical perspective so that workers can have a safe and healthy working environment. Goel and Tyagi (2012) suggested several remedial measures to identify the occupational health hazards.

Concern over the quality of modern life is a characteristic of the contemporary society which is indirectly related to the environmental factors (Sutton, 2015). Ability to perform work is intricately linked to the prevailing environmental conditions in the workplace. The human body has adaptive physiological mechanisms that allow us to tolerate a range of physical environmental conditions, but often at a cost to the body. When conditions exceed the capabilities of the body's adaptive mechanisms, then performance and health deteriorate, and in extreme situations, conditions could even prove fatal.

While considering the environmental issues, over all wellbeing of the people is the main priority in order to enhance the efficiency and performance of the system. The continuous existence of life on the planet can be ascertained by the quality of the environment. Change of environmental factors influences the internal metabolic activities of the human being which in turn affect the occupational health of the worker. Interaction with environmental factors not only affects attitude and emotions but also action and well-being. Maintenance of optimum level of environmental factors may fetch the maximum output. In order to accomplish better productivity, satisfaction and overall well-being of the inmates, the good indoor environment is advantageous. According to Colovic (2014), the unhealthy and unsafe environment attracts various health issues in the garment industry in order to maximize the productivity, analysis of workplace is inevitably required. While ascertaining the work-life quality, besides considering the method used during the work, all the physical as well as psychosocial factors, are required to be evaluated scientifically (Kaya, 2015).

Environmental factors are playing a decisive role in various industries of the world especially the health institutes, textiles, mining and micro industries which underscore the various issues ultimately results in the drop of the efficiency of the system (Wong *et al*., 2010). Environmental issues also affect the occupational health in various industries such as wool, hemp, rock and glass wool industry of the world. Indoor environmental determinants such as thermal, visual, noise, air flow and air quality affect the human comfort (Frontczak and Wargocki, 2011).

Human body's response to different environmental conditions depends on a number of environmental factors which led to various physical, physiological and psychological disparities (Parsons, 2000). Therefore, it is inevitably required to carry out the study in the context of handloom sector in order to see how these factors will affect the inhabitants in that occupation. With the evidence of increased physical and cognitive problems amongst the working community especially the weavers all over the world, environmental factors are the important issues. Here, interventions such as self-assessment of environment and study on the effect of various environmental factors especially illumination and noise on the physiological and psychological conditions of the weavers' are inevitably necessitated. Berthe and Elie, (2015) suggested that for protection of environment three aspects such as social, economy and environment have the decisive role which entails due considerations. Gehle *et al.* (2011) reported that more than 25% of the global diseases are due to environmental factors and these factors cause a significant threat to human health (Zahra *et al*., 2015) all over the world. Earlier studies have also revealed the significance of the environmental conditions in workplace assessments (Räsänen *et al*., 2000; Dawal and Taha, 2006; Kahya, 2007; Newsham *et al*., 2009; Lundh *et al*., 2011; Nazari *et al*., 2012 and Dianat *et al*., 2013).

In this modern world, most of the works are being carried out indoors. Moreover, indoor physical environmental factors (temperature, relative humidity, lighting, noise etc.) affect the humans' performance and have the detrimental effect on the overall efficiency of the work system (Butt, 2012). These factors also affect the acceptability and performance of the occupants (Olesen, 1995). The good indoor environment is inevitably demanded in order to enhance the productivity, satisfaction and overall well-being of the system as well as of the occupants. Working in a comfortable environment enhances the satisfaction level and wellbeing which is indirectly linked to productivity (De Giuli *et al*., 2012). In order to improve the efficiency of the system intervention/efforts are inevitably required. Initiatives have been taken by various researchers for the formation of standards/recommendations which are well suited to the locations/ industry and for the projected people.

Roja *et al.* (2012) study revealed that indoor climatic parameters such as light, noise, vibration and dust affect the tailor's work efficiency due to psychological discomfort. Çınar and Ağlargöz (2011) stated that music was an important tool for mood regulation which caused positive benefits on employees' well-being in the modern factory. Anjum and Ullas (2010) findings reflected the psychological stress on the workers due to time and work pressure leading to sleep disturbance and skin disease amongst the weavers. Fortuitously, the faulty ventilation system causes poor indoor air quality having airborne pollutants which encapsulate all the inorganic, organic and biological contaminants (Godish, 2016). In Gold mining industries of Ghana, mercury pollution amongst the workers is the major issue (Paruchuri *et al.*, 2010).

Economy and environment run parallel to each other and are the two sides of a coin (Yin, 2016). All over the world, small-scale industries contribute a significant thrust to the economy of a country besides entailing an enormous load of occupational health on the system rather than the large-scale industries (Thomas R, 2015). Mbuligwe (2015) elucidated on the environmental conditions and its implications for occupational health and safety in small-scale industries. Moreover, he analyzed the environmental management practices which have been embraced by that sector. Hashim and Boffetta (2014) observed that due to industrialization and population growth, the outdoor and indoor air pollution exposures in the low to middle-income group countries causes a high risk of lung cancer especially amongst the women folks in comparison to high-income countries. Managing of after-effects of tsunamis, hurricanes, floods, and drought is a core public health function which causes huge economic and societal effects (Tulchinsky and Varavikova, 2014). The use of obtainment technology in small-scale industries units have led to positive net return and benefit to the society as well as the environment at large due to additional investment on control devices (Chakrabarti and Mitra, 2005).

Small-scale industries play a significant role in India as well as many other countries of the world. In Asia's economic growth, India plays a pivotal role and is the second largest in terms of the workforce of the world with some 500 million people (Sharma, 2012). As we know that micro, small-scale and cottage industries play a very crucial role in the development of India's economy and this industry uses a huge amount of human resource and is highly labour intensive sector (Vidya and Shashidhar, 2007). Due to low investment per worker, this industry offers higher productivity of capital than capital-intensive enterprises. This industry is considered as the primary source of employment throughout the world (Chen, 2001). In India, construction is an extremely risky work system. Due to improper design and unsafe practices prevalent among Indian construction workers, this task is very exacerbated. Unsafe environment or working conditions may lead to long-term illness or even death in this sector.

Indoor environmental quality is interrelated with people's health. Due to poor housing indoor environmental conditions, the people especially of lower economic strata, are more prone to carcinogens (Rajer *et al*., 2014). A plethora of information is available in various research papers related to internal air quality and air pollution in textile Industry (You *et al*., 2009; Smith, B. (1986); Mahajan, 1985; Müezzinoğlu, 1998; Smith and Bristow, 1994; Chen and Burns, 2006; Schwela, 2000; McDowall, R. 2007; Jones, 1999; Cheremisinoff 2002; Kiurski *et al*., 2013; Choudhury, 2014; Karthik and Gopalakrishnan, 2014). Due to excess infrastructural activities, the environmental protection lags behind the economic growth.

India's rapid industrial growth has resulted into many environmental issues especially related to indoor environmental factors such as light, noise, relative humidity and temperature and bottleneck over these factors have gained a significant attention from the policymakers, researchers and textile entrepreneurs.

It has been ascertained that unsafe environment or working conditions may result in instant death or long-term illness (Tulchinsky *et al.*, 2014). It has also been observed that when the illumination, noise and even temperature goes out of acceptable range then the whole environment is considered as unacceptable by the inmates (Huang *et al*., 2012). All occupations including textile attract health and safety risks (Cullen *et al*., 2005) in all part of the developing world. Methods of environmental assessment of the human activities are inevitably necessitated in order to reduce the environmental impact.

Handloom weaving involves the number of steps and this process occupies over 50% of the work cycle time. On handloom except weaving the rest other activities are not repetitive in nature but are difficult in actions which require lots of posture buckling (Banerjee and Gangopadhyay, 2003). Various pre-loom and post-loom processes are involved in the production of handloom cloth such as yarn dyeing, sizing, winding, warping, beaming and weaving which are the pre-loom activities while bleaching, dyeing, printing, calendaring and finishing are the post-loom activities, which have to be carried out in a sequential manner. The weaving on handloom is a tedious as well as monotonous nature of work which requires continuous efforts in order to meet the production demand of the handloom fabric. During weaving, there are the various processes involved in which the weaver has to perform the activities with much attention, care and patience. A minor negligence can spoil the material within no time. Further, in order to perform the weaving task, favourable climatic conditions are inevitably required otherwise it might deteriorate the quality as well as the quantity of the product. The production and quality of handloom fabrics show its due influence and impact on the socio-economic lives of the poor weavers.

In a study, it was found that worst environmental conditions caused wrong body posture which resulted in higher quality deficiency than good posture. Working posture is highly dependent on environmental conditions prevailing on the workstations as well as up to some extent on workstation design, if it is not properly addressed, leads to physical symptoms (Lu and Aghazadeh, 1996). Body pain, absenteeism and job turnover are indications of the poor environmental conditions at the workstation. Error rates of work increased with body discomfort and pains on poor workstation conditions (Grandjean, 1988; Corlett and Bishop, 1976; Eklund, 1995) leading to decrease in production with poor quality output and loss of income or even job, this situation adversely affects workers physiological and mental health status.

Price of handloom products depends upon its aesthetic value which indirectly depends on the artistic sense of the weavers and gets transformed on fabrics in the form of motifs. Weaving on poor handloom conditions will cause discomfort and strain which in turn deteriorates quality performance due to loss of concentration, poor visibility and high disturbance. The ultimate goal of ergonomist is to provide the conducive environmental conditions at the workplace so that it prevents from adverse effects of stress/strain, muscular pain, resulting in poor quality performance. Well-functioning working environment makes the task better adapted to the abilities and limitations of the humans, less stressful eliminates fatigue, discomfort and imposes fewer risks performance.

In spite of all these studies still, there is the gap in performance of the work system which leads to decrease in the efficiency and productivity of the overall system due to non-synchronization of various activities of the work system. For improvement of overall efficiency including production, indoor physical environment plays a very pivotal role.

Abundant information and work has been reported all over the world on indoor physical environment especially in the field of noise and illumination in various industries, offices, residential buildings, aircraft (Höppe and Martinac,1998; Bauman *et al*., 1995; Bridger, 2002; Oleson and Parsons, 2002; Nicol, 2004; Frontezak *et al*., 2011; Dianat *et al*., 2016; Dianat *et al*., 2013; HOSSAIN and AHMED, 2012; Huang *et al*., 2012; Vural and Balanlı, 2011; Morris and Dennison, 1995; Hoffmann *et al*., 2008; Juslén *et al*., 2007; Gligor, 2004; Helander, 1995).

Besides the work on musculoskeletal disorders, workstation design, ergonomic problems, occupational health and sitting posture it is being observed that a plethora of work has also been carried out on the handloom workstation in the field of marketing and social problem (Mezzadri and Srivastava, 2015; Arora and Narayana, 2016 and Jain and Gera, 2017) as well as on the influence of designer, entrepreneurs, governmental and nongovernmental organization in shaping the handloom environment (Hani and Das, 2017). But the work on the environmental factors in the field of handloom is scantly reported.

In India lot of work has been done on the indoor environmental issues including noise and illumination for various industries (Bennet *et al*., 1977; Nag, 2004; Nag and Patel, 1998; Tiwari *et al*., 1999; Punnett, 1985; Nachemson, 1975; Nehra, 2015; Varghese and Salim, 2015; Bhar, 2016; Sanjog *et al*., 2013; Belbin, 1970) and but very scant or negligible information is available about the work done in the field of noise and illumination in textile industry (Bhattacharya *et al*., 1989; Uttam, 2015) and especially for the handloom sector for assessing the illumination and noise conditions and their effects on the physiological and psychological conditions of the weavers.

2.9 Environmental Issues in Handlooms Sector

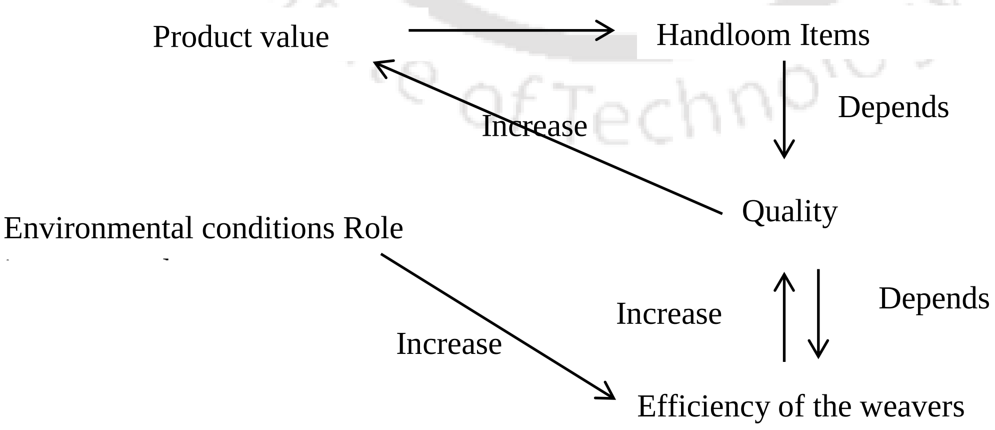

Fig. 2.18 Role of environmental conditions in Handloom industry

The product value of handloom items depend on the quality of the product and quality of the product invariably depends upon the efficiency of the weavers which is associated with the psycho-physiological discomfort (Fig. 2.18). Various studies have been carried out which clearly reflected the relationships of the effect of environmental factors on quality performance by humans (Sanders and McCormic, 1993; Smith and Jones, 1992). Error rates of work increase with body discomfort and pains on poor workstation conditions (Grandjean, 1988; Corlett and Bishop, 1976; Eklund, 1995) which in turn decrease production, poor quality and job loss. The situation gets even more exaggerated with long duration of poor workstation conditions usage

Price of handloom products depends upon its aesthetic value which indirectly depends on the artistic sense of the weavers which get transformed on fabrics in the form of motifs. Weaving on poor handloom conditions will cause discomfort and strain which in turn deteriorates quality and performance due to poor visibility, the high disturbance resulted in the loss of concentration. The ultimate goal of ergonomist is to provide the favourable environmental conditions at the workplace so that it prevents from adverse effects of stress/strain, muscular pain, resulting in poor quality performance. Well-functioning working environment makes the task better adapted to the abilities and limitations of the humans, less stressful, eliminates fatigue, discomfort and impose fewer risks performance.

Handloom is an independent environment-friendly and autonomous technology. Energy impacts are almost zero. The sector thus lends itself to sustainable development policies aimed at reduction of negative impacts on environment and ecology. In spite of rural base, the environmental factors impose a significant dent on productivity, satisfaction, overall well-being of the weaver and the work system. The environmental factors such as temperature, relative humidity, lighting, noise, the airflow which needs to be addressed properly.

Temperature

Indoor environment affects workers' satisfaction which ultimately influences the productivity also. The ability to work in heat is influenced by, individual characteristic of the worker, thermal environment and the requirements of the task. The thermal regulation system of the human body is very complex which maintains a comparatively constant internal temperature of around 98.6°F ± 1.8°F (37°C ± 1 °C). Thermal comfort and control facilitate the enhancement of productivity and satisfaction of the occupants (Höppe and Martinac, 1998 and Bauman *et al*., 1995). Thermal conditions depend upon the nature of work; the thermal comfort zone for inactive office work is from 19.4 °C to 22.8 °C, for light work is from 15.6 °C to 20 °C, and for active factory work from 12.8 °C to 15.6 °C. The ideal temperature ranges between 19 °C to 23 °C with 40% – 70% of Relative Humidity was found acceptable by most of the workers (Bridger, 2002). Tanabe *et al.* (2009) reported that raising the indoor air temperature by 1.0 °C, from 25.0 °C to 26.0 °C, would lead to a reduction in performance of 1.9%. According to Frontezak *et al.* (2011), the women and men differ in their rating on thermal condition. Respondents rating varied according to the nature of indoor environment such as workplace, duration of stay, education level, peer relationship and time as well as the ranking varies from country to country. Four environmental conditions such as air temperature; humidity; air flow; and wall temperature affect the heat exchange process and have complex interaction.

Relative Humidity

Relative humidity is the most ubiquitous measure of the indoor ambient air (Nicol, 2004). The recommended range of relative humidity is between 30% – 70% for indoors. Any deviation from the recommended value may attract either dryness, prone to infection or wetness, attract development of moulds. According to Höppe (1988), the variation in the value of relative humidity causes an adverse effect on the physiological condition of the worker. Tsutsumi *et al.* (2007) reported that as per the ASHRAE Standard 62–2001 the recommended value of relative humidity for office environment should be between 30% – 60% and the humidity sensation varies with exposure time. Nicol (2004) reported that humidity has been investigated in a number of field surveys in hot climates and was found to have a significant effect on comfort temperature.

Illumination

Lighting is an important factor which facilitates in humanizing the efficiency, health and safety of workers at the workplace. This factor affects the effectiveness of the worker in terms of speed, quality of work, downtime, absenteeism, and accident rates (Hoffmann et al., 2008). Bennet *et al.* (1977) stated that illuminance and task completion times have the strong relationship between them. As per IS-3646 (Part I) -1966 the required level of illumination could be achieved through a combined usage of the natural daylighting and the artificial lighting. Artificial lighting supplement the natural light which augmented both quantity and quality resulted in the advancement of interest and avoid monotony. Health, job performance and safety of the inhabitants at a workplace were adversely affected by the poor lighting conditions of work environments (Aarås et al., 1998; Knez and Kers, 2000; Van Bommel, 2006; Juslén et al., 2007; Drebit et al., 2010). As per EN 12464-1 (Light and lighting – lighting of workplaces, Part 1 indoor work places) for performing visual tasks efficiently and precisely, sufficient and proper lighting is inevitably required

Noise

Noise is an unpleasant sound which disturbs the human being physically and physiologically headway to environmental pollution by destroying environmental properties (Melnick, 1979). Being a global occupational health hazard factor, noise imparts a significant indentation on the social and physiological parameters including noise-induced hearing loss (NIHL). Noise annoys the inhabitants exposed to it and has the negative effect on the working efficiency (Belbin, 1970). Excessive occupational exposure to the noise causes hearing loss to the worker (Ashraf *et al*., 2009; Belbin, 1970).

Even though the decrease in noise level as compared to past situations in the office environment, still the noise emitted from the office gadgets was beyond toleration and caused the subjective and behavioural effect on human health (Kjellberg and Landstrom, 2000). Arezes (2012) developed the improved procedure for assessment of occupational daily noise exposure. Lu (2008) stated that noise was found to be associated with hearing loss. Studies also revealed that in the landscaped offices about 90% of the workers were disturbed by the noise out of which 35% were severely affected (Nemecek and Grandjean, 1973). Brookes (1972) enunciated that 62% of the mentioned noises were the most disturbing aspect of their working environment. Dissatisfaction with the noise conditions have the considerable impact on the general satisfaction with the job and working environment, according to Sundstorm (1986) general job satisfaction increases with increase in noise from people talking, telephones and typewriters otherwise was the reverse effect. The highest correlation was observed between the general satisfaction and the office environment (Klitzman and Stellman, 1989).

Airflow

Air movement is one of the important deciding parameters which determines that a person will feel hot, cold or comfortable (Belbin, 1970) and amongst the primary factors affecting thermal comfort (Atmaca *et al*., 2007). This parameter is concerned with the measurement of the thermal environment (Bridger, 2002). Air movement is the Operative temperature (average of air temperature and radiation temperature) which can be investigated by means of measurement (Isaksson and Karlsson, 2006). Modern heat stress monitors use thermistors (electrical transducers) to measure the air movement (Bridger, 2002). As reported by Nicol (2004), the workers work in the free running dwelling can acclimatize and tolerate the temperature between 30 °C to 34 °C with 0.6m / sec air velocity without much ventilation.

2.9.1 Illumination: definition, types, measurement and health impact

Illuminance is defined as the amount of light falling on a surface or in other words we can say that illuminance is the luminous flux per unit area at a point on a surface. Illuminance may also be defined as the number of lumens falling on per unit area of the surface. The unit is lumens/m^2 (or meter-candle or lux) or lumen/ ft^2 (or foot-candle).
Luminous flux as a quantity of radiant flux (watt) which expresses its capacity to produce the visual sensation (in lumen).

1 foot candle = 1 lumen/ ft^2 = 10.76 lux or meter-candle

Definitions Commonly Used Terms and Types

Lux is the luminous flux produced from a source of one candlepower at a distance of one meter falling on one square meter surface perpendicular to the rays of light everywhere.

Foot-candle is the luminous flux produced from a source of one candlepower at a distance of one foot falling on one square foot surface perpendicular to the rays of light everywhere.

Lumen (lm): It is also a unit of luminous flux and defined as the flux emitted by the point source of one candela with a uniform luminous intensity within a unit solid angle.
1 watt = 683 lumens at 555 nm wavelength.

The difference between lux and lumens is that the lux takes into account the area over which the luminous flux is spread whereas 1000 lumens, concentrated into an area of one square meter, give an illuminance of 1000 lux and the same 1000 lumens when focused over ten square meters it produces a poor illuminance of 100 lux only.

Two lighting sources are chiefly available in the textile industries i.e. Natural light (such as daylight) and Artificial light (tube lights, lamps etc.).

Natural light

During daytime natural light is the major source of light which is being used in various industrial buildings but has the following inconvenience

i) Difficult to regulate the intensity of light which varies from time to time within the day, day to day, within the year

ii) Varies as per the conditions of the weather (sunny or cloudy).

iii) Also varies with the size and positions of the doors and windows

Artificial light

Artificial light is used in the areas which lack in illumination even during daytime. It is the main source of illumination in the textile industries. There are various type of light sources.

a. ***High Temperature type:*** These illuminating sources are of gas, oil or incandescent filament type lamps. They emit light when heated to high temperature.

b. ***Fluorescent type:*** These illuminating sources have the phosphor-coated tube filled with inert argon gas at low pressure and mercury vapour gas fitted with tungsten electrodes on both side inside the tube. On heating, the mercury vapour ionise which cause the electron in the gas to emit photons at UV frequency and convert into visible light when exposed to phosphor coating inside the tube.

c. ***Gas discharge type:*** These illuminating sources generate light by passing electric current through an ionised noble gas or metal vapour, which emit visible radiation e.g. sodium and mercury vapour lamps.

d. ***Electroluminescent type:*** LED (Light Emitting Diode) is an electroluminescent source. It can convert electric energy to visible light it is energy-saving and environment-protecting. Besides, it has fine spectrum performance and contracted beam. It has other advantages, such as easy being controlled, safe, reliable, durable, and flexible. As a result of these, it is an ideal lighting appliance and radiant semiconductor device compared with incandescent lights, low-pressure mercury lamps, high-pressure mercury lamps and other light sources (Tianhua and Hailiang, 2011)

Good lighting should have the sufficient intensity for a particular job, should be bright, diffused and should not glare, dazzle and not allow marked shadows.

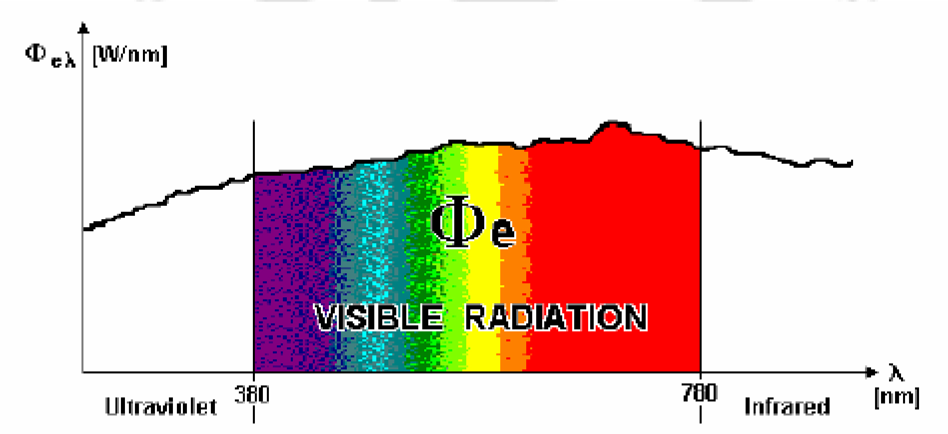

Fig. 2.19 Range of Visible Radiation (*Source: Bureau of Energy Efficiency, 2005*)

Instruments used for measuring illumination

Photometry is a science dealing with the measurement of light. Light meter / Luxmeter is used for measuring illuminance

Photometer*:* A photometer is an instrument which measures lighting intensity or optical properties of solutions or surfaces (Fig. 2.20). It measure: Illuminance irradiance, light absorption, the scattering of light, reflection of light, fluorescence, phosphorescence and luminescence.

Fig. 2.20 Luxmeter (Light meter) (Source: https://en.wikipedia.org/wiki/File:Fotometer.jpg

In this contemporary world, most of the activities are being carried out in the indoor physical environment. The factors that govern this environment are noise, illumination, temperature and humidity (Sanjog *et al*, 2013). Being dependent on circadian rhythms, light is an essential component for the human in order to execute the wide variety of tasks efficiently and effectively. Moreover, human behaviour and performance heavily depend on the internal physical environment in which the inhabitant is exposed. These indoor environmental factors have the detrimental effect on the human health and on their work efficiency (Yu *et al*., 2009). Besides the role of light in visual processes, light plays an important role in a wide variety of non-visual processes also (Hanifin and Brainard, 2007). Report evinced that the people in the developed countries all over the world spend 80 – 90% of their total time in the indoor environment (Höppe, 2002; Yu *et al*., 2009; Wargocki, 2013) and 85% of the rural population of the world has scarcity of electricity (Lavelle, 2010). Insufficient light levels over the workplace and non-uniform illuminance distribution due to use of improper solar shading create the problem in work. It has been ascertained that even 400 lux of illumination level is sufficient to carry out the indoor activities (Tsushima *et al*., 2015) moreover under the bright light the participants felt less sleepy, more vital and happier.

For the purpose of giving a description of lighting quality necessary to perform the task in a work situation, horizontal illuminance is used. New perspectives on lighting design (more light is not necessarily better light), and a pronounced trend toward more precise focusing of light on specific tasks (task lighting over ambient lighting). The current tendency among countries is towards a convergence at levels significantly lower than in recent decades (Mills and Borg, 1999). Singh *et al.* (2010) measured the indoor and outdoor illumination level at two different locations in all seasons and derive six formulae which have correlation coefficient value above 0.96 for the whole monitoring period. In order to facilitate our cognitive performance refinement of illumination parameters and subsequent exploration of cognitive modulation are inevitably required. The appropriate illumination conditions in terms of quality as well as the quantity of lighting for the production units, are inevitably the need of the hour (Hossain & Ahmed, 2012).

Bennet *et al.* (1977) stated that there exists a strong relationship between illuminance and task completion times. Tsushima *et al.* (2015) findings revealed that in the indoor environment the illuminance level reduced to 400 lux from 750 lux after the 2011 earthquake. Höppe (1988) reported that lighting of neon lights mounted on the ceiling often caused a headache, eye strain and fatigue. In a field study it has been observed that acceptable level of illumination in the office premises was above 300 lux, moreover, the survey report depicted that the illumination intensity ranged from 93 lux to 1424 lux at the workplace (Huang *et al*., 2012).

Different type of visual tasks such as rough work, medium work, fine work, very fine work in an assembly and inspection line require different range of lux value of 200, 400, 900 and 2000 lux respectively according to the nature of work [Belbin (Chapter 10), 1970]. Bureau of Indian Standards (BIS) has published various recommendations for lighting.

IS: 3646 (Part I): 1992, Reaffirmed 2003 (BIS, 2003) briefly precise the code of practices to be followed for interior illumination for various type of indoor working activities whereas IS: 6060:1971, Reaffirmed 2004 (BIS, 2004) specified the Code of practices for factory daylighting to be applied for the process and industrial buildings.

Experts of various illuminating societies have the difference of opinions about the standard values for a specific task such as for a particular task IES recommendation differs from the European guidelines which suggested higher illumination levels. Moreover, it is clearly evident from the fact that IES (Illuminating Engineers Society) recommends 3000 lux for precise assembly works whereas German DIN prescribes 1000 lux for the same (Helander, 1995).

Poorly designed and maintained lighting can result in glare and flicker that may cause vision problems. When the lighting meets both quantity and quality needs, it adds better working performance and productivity (NEEPI, 2000). The luminous environment acts through a chain of mechanisms on human physiological and psychological factors, which further influence human performance and productivity (Gligor, 2004).

Eye work under inappropriate illumination conditions can attract sick building syndrome (SBS) which leads to eye discomfort, eye strain and fatigue (Morris and Dennison, 1995 and Vural and Balanlı, 2011). Braun et al. (2009) informed that artificial lighting is not only considered as unpleasant but even as health-impairing.

Sinoo et al. (2011) observed that lighting conditions in the nursing home were poor and below 750 lux threshold and was on the higher side near the window zone. Aizenberg (2014) observed that in the Moscow schools 80 – 90 % of classrooms rooms and 100 % of classrooms blackboard did not meet the standard illumination requirement conditions.

Rosenthal and Grundy (1980) ascertained that the levels of illumination were found between 130 lux and 590 lux in various existing visual display unit workstations even though a lighting level of 500 lux – 1000 lux has been recommended by the Illuminating Engineering Society for various office tasks. Hasan et al (2011) stated that the effect of illumination on the spontaneous eye blink rate was significant in the age group of 31 – 40 years having internet exposure for more than 2 h / day.

Hawes *et al.* (2012) suggested that blue Light Emitting Diode (LED) lighting system has the low colour temperature in comparison to traditional fluorescent technology which supports positive mood, improve wakefulness, and expedite performance on both visual perceptual and cognitive tasks, it also indirectly affect worker mood and cognition. Braun et al. (2009) stated that the narrow spectrum of white light (LED) increase hyperactivity, exhaustion, excitability and attention deficits whereas glaring cause inner tension and psychological fatigue. The melatonin hormone gets suppressed and the circadian activation is at maximum level due to the blue light (464 nm) which helps in counter the tiredness and performance (Hawes *et al.*, 2012; Cajochen, 2007 and KULLER, 1986).

Literature citations on colour preference indicate that office workers prefer a light blue-green office colour (Brill *et al.*, 1984 and Brill *et al.*, 1985). Natural light even affects vital functions of the human organism. Lighting influences productivity factors such as output, errors and accidents (Bommel *et al.*, 2002; Volker, 1999). Illuminance increases the work output and decreases errors or rejects, as a function of task illuminance. A literature search yielded several field studies in which lighting change effects have been measured in an industrial environment. Tedder (1968) stated that superior illumination level brings many settlements such increased safety and reduced fatigue in the industrial plant. According to Staley (1960) with the increase of illumination level the time taken to see the vital details decreases.

Recommended lighting levels have been published for various tasks by Commission International de I'Eclairage and Illuminating Engineers Society which are given below (Table 2.3)

Table 2.3 Illuminance Levels for different areas of activity

	Illuminance level (lux)	**Examples of Area of Activity**
General Lighting for rooms and areas used either infrequently and/or casual or simple visual tasks	20	Minimum service illuminance in exterior circulating areas, outdoor stores, stockyards
	50	Exterior walkways & platforms.
	70	Boiler house
	100	Transformer yards, furnace rooms etc.
	150	Circulation areas in industry, stores and stock rooms.
General lighting for interiors	200	Minimum service illuminance on the task
	300	Medium bench & machine work, the general process in chemical and food industries, casual reading and filing activities.
	450	Hangers, inspection, drawing offices, fine bench and machine assembly, colour work, critical drawing tasks.
	1500	Very fine bench and machine work, instrument & small precision mechanism assembly; electronic components, gauging & inspection of small intricate parts (may be partly provided by local task lighting)
Additional localized lighting for visually exacting tasks	3000	Minutely detailed and precise work, e.g. very small parts of instruments, watchmaking, engraving

(*Adopted from: Energy Efficiency Guide for Industry in Asia, www.energyefficiencyasia.org*)

Bhattacharya *et al.* (1989) examined the lighting conditions in a weaving shed of power loom weaving and suggested that the illumination levels at the workstation of weaver were very low compared to an Indian standard and the Illuminating Engineering Society (1973) standard. Many weavers had no visual comfort at work and expressed their preferences for higher illumination levels for comfort, safety, and optimum work performance. Ramdass (2013) enunciated that the garment worker requires perfect eye vision in order to avoid accident for which more natural light was found suitable as compared to fluorescent tubes. Loe and McIntosh (2009) stated that illumination has the influence on the visual environment for enhancement of human stimulation and pleasure.

Luminous Performance Characteristics of Commonly used Luminaries for various tasks are given below (Table 2.4).

Table. 2.4 Luminous Performance Characteristics of Commonly Used Luminaries

Type of Lamp	**Lum / Watt**		**Color Rendering Index**	**Typical Application**	**Life (Hours)**
	Range	**Avg.**			
Incandescent	8-18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

(*Adopted from: Energy Efficiency Guide for Industry in Asia, www.energyefficiencyasia.org*)

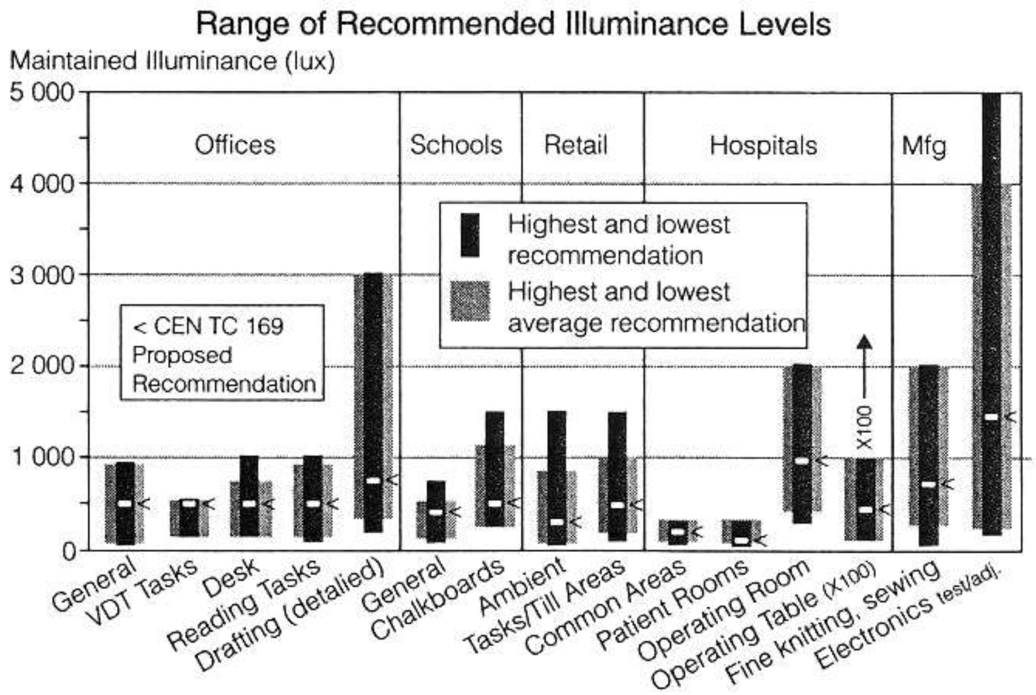

Fig. 2.21 Recommended horizontal illuminance levels for work conditions in 19 Countries (Figure adopted from Mills & Borg, 1999). Values for hospital operating tables have been compressed by a factor of 100 to fit in the graph. Values of the black bars reflect the extreme high and low endpoints of all national recommendations for a given task. The shaded bars indicate the average values of recommendations when they are expressed as the range.

Impact of illumination level on health, efficiency and performance

In 1879, Thomas Edison's incandescent light bulbs first illuminated a New York street (Wurtman, 1975). Light is a necessity for the visual system to operate but on the other hand, it is injurious to health if provided in the wrong way. Light is emitted in the form of radiation. Peter (2009) stated that eye and skin of the person can be affected by the exposure to the ultra-violet, visible and infrared radiation through both thermal and photochemical mechanisms. Light influences sleep patterns and may cause breast cancer to the workers working in night shift. The UK Health and Safety Executive recommend that a person should not be exposed to more than two hours a day with unfiltered tungsten halogen lamps task lights located within 0.6m of the user or with CFLs for more than one hour at distances of less than 0.3m. The most common effect of lighting on health is the eyestrain. The symptoms of eyestrain are irritation and inflammation of the eyes; breakdown of vision, evident as blurring or double vision which causes headaches, indigestion, giddiness etc. Falchi *et al.* (2011) reported that one should avoid using higher lighting levels than the requirement for a particular task. Most polluting are the lamps with a strong blue emission, like Metal Halide and white LEDs. Chepesiuk (2009) studies show that exposure to light during the night can disrupt circadian and neuroendocrine physiology, thereby accelerating tumour growth, the disruption of the circadian cycle can cause a lot of health problems. Juslén *et al.* (2007) signified that the speed of production increased with increase of lux value from 800 lux to 1200 lux. The speed of work was higher in winter as compared to summer which evinced that the other environmental factors affect the physical, physiological and psychological parameters.

Boyce (l981) pointed out that lighting makes details easier to see without producing discomfort which the workers can use to enhance the output. Lighting affects the visual aspects of a task which can be performed with the combination of visual, cognitive, and motor components. He further added that visual performance can be improved by changing features of the task (i.e., size or contrast). Boyce (1988) inferenced that based on the performance of a single task it would not be wise to generalize the effects of lighting. Stenzel (1962) stated that change in illumination from 350 lux to 1000 Iux has enhanced the output in a leather factory. Knave (1984) also enunciated that increasing illumination improved visual acuity in a field setting (a foundry).

Workers working under poor lighting conditions have the detrimental effect on their visual comfort which in turn influences the human behaviour and ultimately jeopardize the work efficiency (Hossain and Ahmed, 2012). Hoffmann *et al.* (2008) stated that illumination is one of the important parameters at workplace and is a decisive factor in humanizing the efficiency, safety and health of the workers in terms of quality of work, speed, downtime, absenteeism, and accident rates. Juslén *et al.* (2007) reported that output levels of the workers provided with controllable task lighting were improved extensively. It is fascinating to know that when the people were exposed to the new lighting system it enhanced their performance in terms of visual comfort, visual performance, interpersonal relationships, visual ambience etc (Juslén and Tenner, 2005). Edwards and Torcillini (2002) reported that poor lighting in the dwelling units may lead to physiological and psychological problems and decrease the production efficiency besides increasing stress whereas natural light increases the productivity and improve the health besides reducing stress level. Uttam (2015) highlighted the importance of illumination in textile mill/industries and concluded that human health is exaggerated adversely due rarity of illumination at the workplace which in turn affect the production and product quality which may upshot the accidents and safety problems. The subjective workload assessments have been performed to ascertain the effects of task demand, the workload on mental workload investigations on young Indian adults for selection of optimum font type and size during onscreen reading task performance. Kuller (1986) stated that people were influenced extremely by the total visual environment and also concluded that daylight tube hinders the production of melatonin hormone than the white fluorescent tube. Moreover, the window-less shed has an influence on stress hormones cortisol and the brain's electrical activity was influenced by the colours and patterns.

Ergonomic interventions for improvement of illumination conditions

Ergonomics (or human factors) is that branch of science which explore to turn human-machine antipathy into human–machine synergy (Hancock, 1997) and concerned with understanding the interactions among humans and other elements of a system, and applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (International Ergonomics Association, 2014). In other terms, it is the practice and research of the interaction between the human and the physical environment with the goal of optimizing human well-being and overall system performance. Leheto and Landry (2012) suggested that maintenance and placement of light sources is an important contribution to facilitate the uninterrupted supply of illumination on the workstation. Moreover, selection of paints and finishes on the walls, ceilings, floors, and work surfaces can also facilitate the improvement of lighting conditions. The reflectance value of white painted surfaces is around 90%, bare concrete is about 50% and of dark painted surfaces is up to 5%. Placement of light on the workstation at the better location is also a very imperative factor. They mentioned that lighting affects the human performance, morale, and safety disapprovingly.

Robert and Brangier, (2009) proposed to structure ergonomic activities around corrective, preventive (design) and prospective ergonomics. Prospective ergonomics represents a huge potential for the advancement and evolution of ergonomics and for the achievement of its full maturity. For public health ergonomics programs, the major goal is the prevention of work-related musculoskeletal disorders (MSDs). These prevention efforts encompass many different areas of ergonomics and public health disciplines ranging from engineering to epidemiology. Comprehensive approaches to physical ergonomic interventions work best to reduce the incidence of work-related MSDs.

The human factor is concerned with the study of man-machine interfaces, primarily expected to optimize human well-being and to improve the all-round system performance (Chowdhury *et al.*, 2012). Ergonomics plays an important role in the design of all kinds of systems like work systems and product/service systems, involving people (Dul *et al.*, 2012). Ergonomists harmonize the man, machine, environmental parameters and the whole system at the workplace in order to make them attuned to the limitations, needs and abilities of humans (International Ergonomics Association, 2014). Physical ergonomics discusses the human anatomical, anthropometric, physiological and biomechanical characteristics which include working postures, material handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health (International Ergonomics Association, 2014). Better visual working environment led to improved safety and a reduction in the number of accidents that could arise from poor visual environments and standards of lighting (Rushworth, *et al.*, 2001). Cognitive ergonomics have extensive roles which affect the interactions of humans with other elements of a system (International Ergonomics Association, 2014). Boyce (l981) reported that illumination simplifies the details which can be differentiated without producing discomfort or disturbance leading to enhanced output. He further noticed that instead of increasing the illumination level even by changing features (i.e., increasing its size or contrast) of the task there was the improvement in visual performance which was at parity when the illumination level was increased at the visually difficult task (small size, low contrast).

2.9.2 Noise: Definition, Types, Measurement, Health impact

Definitions, Commonly Used Terms, Units and standards

A sound wave is a pattern of compression and rarefaction caused by the propagation of energy travelling through an elastic medium (such as air, water, or any other liquid or solid matter) as longitudinal waves away from the source of the sound.

Noise is termed as unwanted sound.

A simple sound wave is characterized by some generic terms of variables such as Amplitude, *Frequency, Wavelength, Period and Intensity.*

Amplitude The maximum displacement of the molecules measured from the equilibrium position is known as amplitude.

Frequency (f) It is defined as the number of oscillations per second or the number of back-and-forth oscillations of a particle in the medium per unit of time. The unit for frequency is the Hertz (Hz).

The *wavelength* (λ) is defined as the distance between the two compressed regions of the air molecules or It is also represented by the distance between the two peaks or a disturbance travels along the medium in one complete wave cycle. It is measured in meters

The term *'period'* (T)can be defined as the number of seconds per oscillation/cycle or the time required for the completion of one cycle of wave motion. It is measured in seconds

The *intensity* of a sound wave is defined as the average rate at which sound energy is transmitted through a unit area. The unit for measuring the intensity of sound is known as decibel (dB).

Acoustics is the scientific study of sound which includes the effect of various parameters such as reflection, refraction, absorption, diffraction and interference

Instruments used for measuring the noise

Sound level meter (as prescribed by International Electrotechnical Corporation and BIS, 2005)

It is an instrument used to quantify the sound pressure level used for the measurement of different kinds of industrial noise (Fig. 2.22).

There are three types of sound level meters

a) Integrating-averaging sound level meter that measures time-average sound level,

b) Conventional sound level meter that measures exponential time-weighted sound level,

c) integrating sound level meter that measures sound exposure level.

Noise dosimeter (instrument worn by the worker)

A noise dosimeter (American) or noise dosimeter (British) is a specialized sound level meter designed exclusively to measure the noise exposure of a person integrated over a period of time (ANSI, 1991).

Octave noise analyzer (capability to read output noise levels in dBA and availability of different weighting built-in filters) ***and Noise spectrum meter*** (Huang *et al*, 2012),

Weighted Scales

Sound level meters have four types of weighting the sound which is known as A, B C and D scales of which dBA scale (or weighting function) is widely used in industries (Helander, 1995).

dB(A) is A-weighted decibel − a measure of sound levels as experienced by humans, calculated using a spectral sensitivity factor (A-filter) that weights sound pressure levels by frequency to correspond to the sensitivity of the human ear.

Four weighted scales i.e. A, B, C and D were developed to match the responses for sounds of low, medium, high and very high intensity.

A-frequency-weighting meant for sounds in the region of 40 dB sound pressure level (SPL), but it is now authorized for all levels.

B scale designed to match the equal loudness contour at 70 dB, but B-frequency-weighting - a halfway house between 'A' and 'C' has almost no practical use.

C scale for a flat rating across the frequency scale and is still used in the measurement of the peak value of a noise in some legislation.

D-frequency-weighting was designed for use in measuring aircraft noise.

For all civil aircraft noise measurements, A-frequency-weighting is used as is mandated by the ISO and ICAO standards.

Fig. 2.22 Sound level meter (*Source: http://www.industrybuying.com/testing -and-measuring-instruments-2324/sound-level-meter-1833/*

The vibration can be described as the oscillations of an object about an equilibrium point. Some objects that cause disturbance to the surrounding particles in the medium; those particles disturb the next and so on is known as vibration. When the sound travels through the gas, liquid or solid it exhibits as a pressurized longitudinal wave in which the particle displacement is parallel to the direction of wave propagation (Fig. 2.23) whereas the in the case of transverse wave the particle displacement is perpendicular to the direction of wave propagation

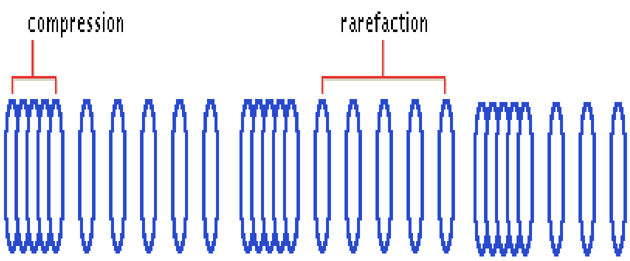

Fig. 2.23 Longitudinal waves of sound
(*Source: http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l1b.html*)

The compression and expansion of the air molecules produce differences in air pressure and this difference of pressure in the air move away from the source surface like ripples in a pond, creating a sound wave. This is how the source produces a sound that we can hear.

Sound can be generated by a vibrating source such as the tuning fork. When vibration is given to the source it vibrates and displaces adjacent particles in the medium and permits them to vibrate back and forth. Their vibrations cause more distant particles to vibrate, and so on. The sound which is audible is made up of tiny vibrations of air molecules, transmitted to our ears. This transmission of vibrations (Fig. 2.24), starting from the source and continuing from one molecule to the next, is how sound travels through a medium. It should be noted that air cannot sustain any form of shear stress so sound can only be transmitted as a longitudinal wave.

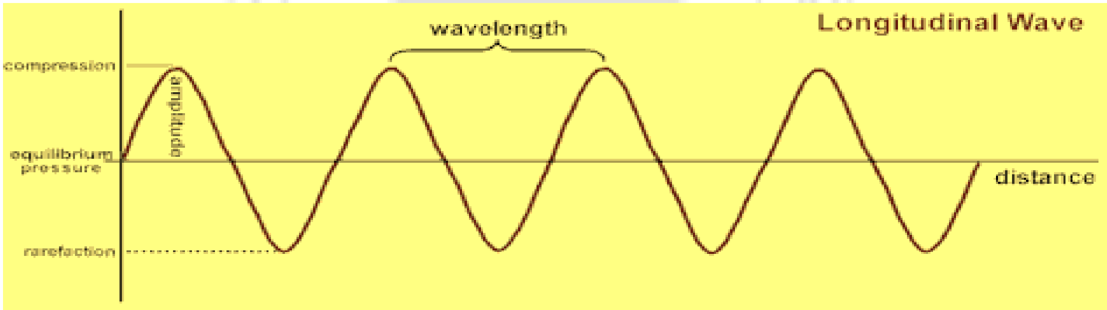

Fig.2.24 Sound wave Propagation (*Source:http://www.kemt.fei.tuke.sk/Predmety /KEMT320_EA/_web/Online_Course_on_Acoustics/index_acoustics.html)*

For measuring the noise exposure of different intensity a formula has been developed by OSHA, a regulatory body in the USA (Helander, 1995). Eleftheriou (2002) reported that reliability of the different exposure limits of noise is argued among the scientific association of United States of America and Greece where it has been resolved to limit the noise exposure to 90 dBA for an 8 hour period in USA while it is recommended that 80 dBA exposure dose is harmless while 85 / 90 dBA is termed as guide number. In Greece (whereas ISO recommended the maximum acceptable noise level between 85 to 90 dB for an 8 hour period 5 days/week exposure time (40 hours/week) (Habali *et al*, 1989; Shaikh, 1999).

Haider *et al*. (2008) studies reflected that most of the textile workers were over exposed to noise (86 dBA – 95 dBA) in the knitting and dyeing section leading to hearing loss. Atmaca *et al*. (2005) findings reflected that noise level in the textile industry was found in the range of 75 dBA – 99 dBA and more than three fourth (77.78 %) of the workers in this sector were having annoyance due to noise which caused nervousness (64.29%) and hearing problem (25.97 %) to the workers. Noweir and Jamil, (2003) inferenced that textile industries are the most noisy industries due to high speed, high production machines. Perlikowski (2005) findings showed that by encapsulating the textile machines in sound insulating casings with an air ventilation installation having noise suppressors can reduce the noise level up to 5 dBA. Yildirim *et al*. (2007) derived a relationship of noise with the oxidative stress and hearing loss which substantiated direct correlation. Moreover poorer hearing threshold was noticed amongst the textile workers due to high frequencies (4 – 6 kHz) and duration of employment (5 – 8 yr). Shah *et al*. (2013) observed the significant association between the hearing loss and duration of exposure at low level of noise (< 80 dBA) in both the ears among textile workers whereas the high level of noise has strong association with the left ear.

Shaikh (1999) suggested the sound level limit of 88 dBA for the industrial plants in developing countries working for 8 h/day and 6 days/week which he claimed to be consistent with ISO specifications. Bedi (2006) ascertained that in various departments such as loom shed, spinning, ring frame and two for one (TFO) area the noise level was higher than the OSHA standard of 90 dBA for 8h exposure due to high sound level frequency of 4000Hz as compare to other departments led to hearing loss. IS 15575 (Part 1): 2005 (superseding IS 9779:1981) specify the electro acoustical performance specifications for three type of sound level meters in India and these specifications were identical with International Electro technical Commission [IEC 61672-1 (2002)] (BIS, 2005). Procedure for measurement of airborne acoustical noise and for evaluation of its effects on worker was taken from BIS standards IS: 9876 – 1981 (Reaffirmed 2001) by obtaining necessary assistance from ISO 2204-1973 (Guide to the measurement of airborne acoustical noise and evaluation of its effects on man), (ISI, 2001).

Measurement methods of the machines noise were taken from IS: 4758-1968 (Reaffirmed, 2002) which follow the indication made by ISO (495) which deal with the general necessities for preparation of test codes for machines noise measurement (BIS 2002).

Nelson *et al.* (2005) reported that all over the world about 16% of the disabling hearing loss in adults is due to occupational noise, which varies from 7% to 21% in the various sub regions. The males are found to be more prone than females due to differences in occupational categories, economic sectors of employment, and working lifetime, which is still higher in the developing countries. Occupational noise is the major cause of hearing loss amongst the adult. Abbasi *et al*. (2011) observed that due to exposure to the high intensity noise originated from power loom, weavers were facing various mental and physical problems (physio-psycho problem).

Alessandro *et al.* (2015) elucidate that the leaves of Boston fern and Baby tears plants can be used to reduce the noise level for the indoor application or acoustic quality can be improved in the indoor environments and it has been observed that leaf area density is related to flow resistivity. Choi *et al.* (2015) revealed that the road traffic maximizes the stress level of the occupants. Office space played an important role while considering the noise and illumination factors (Nemecek and Grandjean, 1973). Dianat (2016) and Dianat (2013) reported that recommended level of noise, illumination and WBGT were not met in half of the workstations surveyed in the manufacturing plant which led to the pernicious effect on the job performance, safety and health of the worker. Raja *et al.* (2012) reported that permissible level of noise for sewing industry was taken 80 dBA.

Table: 2.5 Noise Level of Various Looms

S.No.	**Name of Loom**	**Noise Level (dBA)**	**Weaving Insertion Rate per minute**
1.	Chitranjan Loom	80-85	80-85
2.	Shuttle Loom	92-107	650
3.	Rapier Loom	87-100	1000
4.	Projectile Loom	90-100	1500
5.	Airjet Loom	97-99	2890-3860
6.	Water Jet Loom	82-92	2600
7.	Multiphase Weaving Loom	97-99	5500

Source: Eleftheriou, 2002.

Impact of noise level on health, efficiency and performance

Noise is a sound pressure level (SPL) which varies directly with the frequency of sound. Workers experienced heavy hearing loss due to excessive occupational exposure (93.3 dBA) to noise (Ashraf *et al*., 2009). Talukdar (2001) confirmed that high level of noise causes psychological effect and physical damage such as irritation, loss of concentration, anxiety and increase in pulse rate and ascertained that one minute exposure to a sound level over 100 dBA can cause permanent hearing loss. Choi *et al.* (2015) also reported that stress level increased with increase in decibel level. Mechanization of the textile process has deteriorated the environmental conditions (Bhar, 2016) in terms of producing heavy noise and dust. Most of the European countries are suffering from residential noise problem (Rypkowska and Schreider, 2011) and the poor quality of neighborhood is health damaging.

Nandi and Dhatrak, (2008) ascertained that occupational noise added by various industries including textile industry, contribute to 16% of the disabling hearing loss worldwide which cost up to 2% of GDP of the developed countries. Weinstein, (1977) reported that noise of 68 dBA – 70 dBA significantly impaired the knowledge or cognitive based task such as identification of grammatical errors during proofreading but observed no adverse effects on the ability to detect spelling errors which cause more imperfections during work lead to poor outcome in terms of competencies, efficiency and performance. Padmini and Venmathi (2012) findings revealed that the overcrowded work area, poor workstations design, improper illumination and noise conditions that too without proper personal protective equipment led to deteriorating occupational health and safety conditions, were the major problems faced by the workers in garment industries. Singh *et al.* (2009) stated that in most of the sections of the forging industry the noise level was found more than the recommended OSHA norms which resulted in speech interference and other occupational discomforts as most of the workers working on overtime up to 24 hrs per week led to high noise exposure than the USA and European countries.

Goswami and Swain (2012) findings reflected that the workers of stone crusher industry were prone to noise induced hearing loss (NIHL) due to high noise level and were working without personal protective equipment (PPE) during forenoon time. Fernández *et al.* (2009) stated that about 70% of the construction workers were exposed to a noise dose higher than the recommended noise levels at the construction site. Gomes *et al.* (2002) Stated that noise level was more than 90 dBA at all places except the fabrication workshop which resulted into visual defects and muscle cramps due to non-use of PPE and poor occupational hygiene. Jayawardana *et al.* (2014) concluded that noise level inside a textile factory is well above the limits specified by NIOSH and it amounts to be hazardous.

According to Zytoon (2013), the noise level on the fishing vessels was on the higher side than the recommended NIOSH exposure limit of 85 dBA which led to high risk of NIHL and attract suitable interventions for hearing protection. Singh *et al.* (2010) affirmed that majority of the workers in the small and medium scale industries were exposed to high noise level for 60 h – 72 h per week that too without personal protective equipment (PPE), headway to noise-induced hearing loss (NIHL).

Table: 2.6 Noise Level at Various Places

Particular	Decibel Level	Pressure $N^{-2}m$	Intensity wm^{-2}
Hearing Threshold	0	0.00002	10^{-12}
Conversation	65	0.04	$3x10^{-6}$
Town Traffic	80	0.2	10^{-4}
Workshop	100	2	10^{-2}
Jet Take Off (60 m away)	125	36	3
Pain Threshold	140	200	100

Source: *Eleftheriou, 2002.*

Ergonomic interventions for reducing the noise level or exposure to noise

Noise is an insidious environmental outcome of today's industrial world. There is no issue that high noise levels pose serious threats to our audible range but the effects on performance are not clear-cut. Noise can be minimized by various ergonomics interventions such as by reducing the noise level of the source by enclosing the source inside the soundproof box. Place sound-absorbing and reflecting barriers in the noise path which will reduce the sound level energy hence, attenuate.

Use of earplugs and earmuffs protect from extreme exposure to noise and are made out of soft materials, such as cotton, wool, plastic, or wax. (Leheto and Landry, 2012) when the wearing plugs having the Noise Reduction Rating (NRR) 10, is used in a 90 dBA noise environment, would reduce the exposure to 80 dBA. Berger et al. (2003) also reported that the combination of a low NRR (17) insert the device with a moderate-NRR (21) muff device give a relatively high level of protection (NRR = 29). Olayinka and Abdullahi (2009) reported that on adopting the noise control measures, the noise level on the average has reduced by 2.52 dBA.

Leheto and Landry (2012) also articulated that physical environment of a workstation should be designed by using appropriate ergonomic interventions in order to improve the untidy, uncomfortable thermal conditions, noisy environments or poor lighting conditions which in turn affect task performance cause safety problems and ultimately reduce morale in many unwanted ways. The outcome of physiological damage is the permanent hearing loss to the mechanisms of the ear. The change in path length from the source to the receiver fluctuate the noise levels, doubling in distance from a source resulted in a 6 dBA reduction in the noise level.

Noise has little effect on sensory functions such as contrast discrimination, visual acuity, the speed of eye movements and dark vision accommodation (Smith, 1989). The noise has detrimental effects while the tasks performed without rest pauses between responses (Davies and Jones, 1982). Determined efforts to deal with the noise problem and to have an active awareness about it shall assure a future of peace which will be a landmark for the progress of the community all over the world.

2.10 Status of handloom sector in Odisha with reference to environmental issues

Handloom, an ancient cottage industry is the backbone and the most prevalent economic activity of the rural masses of India and has significant existence in the state of Odisha State. As most of the small units in handloom sector in this state have abreast the weaving on a commercial level and mostly men weavers (85%) are associated with weaving as a part-time or full-time profession (Handloom Census of India 2009 – 2010). As most of the weavers of this region have adopted this profession as their full time job, the working hours spent on the handloom in commercial weaving is quite more as compared to that of traditional weaving, many a times, even extending beyond 8 hours of work schedule as laid up in the Bureau of Indian standard norms. Total working hours per week of handloom weavers are about 20% more than those in the USA or European countries (operating 40 h / week) (ISO 1990; ISO 1997). The time hours and the environmental conditions required for commercial purpose are different from that of domestic weaving. But, inspite of their changing requirements, neither the task scheduled nor the workstations modified from the micro as well as from macro ergonomics point of view. The indoor environmental factors for traditional handloom remains unchanged which inevitably require ergonomic interventions

For improvement of overall efficiency including production, indoor physical environment plays a very pivotal role. A plethora of information and work have been done all over the world on indoor physical environment especially in the field of noise and illumination in various industries, offices, residential buildings, aircraft [Abbasi *et al*., 2011; Abdul and Ahmed, 2011; Agarwal and Yadav, 2013; Bauman *et al*., 1995; BIS, 2002; Frontczak and Wargocki, 2011; Hoppe, 1988] and based on these researches recommendations have been specified. Isaksson and Karlsson (2006) reported that in various research studies much thought has been given to indoor environment conditions in offices with an attempt of increasing productivity and evaluation of indoor environmental quality by grades (e.g. quite satisfied, just satisfied, just dissatisfied, and quite dissatisfied) and not by numerical value.

Bennet et al. (1977) reported that there is close relationship between illuminance and task completion times in various industries. Huang et al. (2007) surmise that for arriving at satisfactory conclusions indoor environmental conditions are required to be measured throughout the year.

Peeterset et al. (2009) stated that adaptation of inhabitants depend on various factors such as social condition, genetic factors, acclimatization, habituations (building design, building function),their experiences, season, climate, semantics, demographics (gender, age, economic status), adjustment (personal, technological, environmental) and cognition (attitude, preference, and expectations).

Djongyang et al. (2010) reported that comfort judgment is a cognitive process which besides the factors of mood, culture, individual, organizational and social, is also influenced by physical, physiological and psychological factors.

Even though this sector has respectful share in the GDP of the nation but is not well organized and Government of India is trying hard to develop this sector by floating various schemes through cluster approach (Nehra and Suman, 2015).

In present scenario, the major problem the weavers encountering is the poor efficiency and quality of the produce on handloom which may be due to poor indoor physical environmental conditions. In order to enhance the efficiency of the system it is obligatory to improve the indoor physical environmental conditions especially the illuminating and noise conditions around the men and handloom workstation.

Pandit *et al.* (2013) reported that the handloom activity in the N.E. region is a part time house hold activity and weavers are unwilling to work for a longer period and even during night time also. This activity shall take time for gradual transformation to commercialization in that region. The employment opportunities in the region were very scant. Due to part time house hold activity environmental factors does not play significant role on their activities.

Pondering on the gravity of the situation it is inevitably necessitated to study about the effect of disgraceful illumination and noise level conditions on the occupational health of the Indian handloom weavers who have been constantly working under the nonstandard environmental situations.

In Odisha, mostly men weavers (85%) are associated with weaving as a part-time or full-time profession. (Handloom Census of India 2009 – 2010). The weavers of this area have adopted this profession as their full-time job. Out of the total handloom Ikat saris produce in Odisha, more than 55% are from Bargarh district (Handloom policy Odisha, 2016). The weavers of this district are having the capacity as well as competency to excel in the field and also the economy of the district is supported with micro-level involvement of weavers but due to poor working environmental conditions the backbone of their occupational health has shattered due to which they are unable to stretch their working timings beyond a certain bench mark and this ultimately led to drop in production as well as of quality of the products.

Owing to the positive thrust towards commercialization there is the optimistic shift in the number of full-time weavers which results in more number of working hours on the handloom. In turn, the weavers find it difficult to bridge the demand and supply gap in order to meet the quality product requirement because of poor physical and conducive environmental conditions especially illumination and noise prevailing on and around the workplace which have the detrimental effect on the psycho-physiological inconvenience of the weavers. These poor physical environmental conditions are silently hollowing the health of the weavers. This clearly depict that neither the indoor physical environmental conditions on and around the workstation nor the standard illumination and noise parameters is well adopted according to their physical and cognitive activities. The indoor environmental factors for traditional handloom remains unchanged which inevitably require ergonomic interventions. As far the studies depict that no work has been carried out to address the issues related to illumination and noise on the handloom all over the world therefore, the final study has been concentrated to Bargarh district of Odisha in light of the background of the facts. In the present research, an attempt has been made to evaluate the effect of low illumination and high noise on the occupational health of the handloom weavers and to investigate the contributing factors.

3.0 Methodology

In this contemporary world, most of the works are being carried out in the indoor physical environment. There are various physical factors of indoor environment such as temperature, lighting, noise, humidity and air flow etc., which influence the human performance in terms of quality and productivity. For most of the instances, these physical environmental aspects are given seldom consideration while the individual is working at the handloom workstation. As all these environmental factors affect the human efficiency and competency, it is the need-of-the-hour to explore the effect of these factors on the physical, physiological and psychological parameters of human being. Sufficient work has been done on indoor environmental factors in various industries (Koh and Jeyaratnam, 1994; Höppe and Martinac, 1998; Nazari *et al*., 2012; Vahedi and Dianat, 2013; Frontczak *et al*., 2011; Dianat *et al*., 2016; Dianat *et al*., 2013; Hossain and Ahmed, 2012 and 2013; Vural and Balanlı, 2011; Morris and Dennison, 1995; Juslén and Tenner 2005; Juslén *et al*., 2007; Gligor, 2004) and internal air quality (Garcia et al., 2005 and Jones, 1999) but report of such experiments on the cottage handloom industry is literally very meager. For this reason, research on illumination and noise as indoor environmental factors were opted to comprehend the influence of these factors on the physical, physiological and cognitive aspects of the weavers, which might, in turn, affect the performance, visual comfort and quality of output. As illumination and noise are the crucial parameters which are inevitable for any handloom workstation (across all the sessions throughout the year) but no work have been properly reported so far on these environmental factors in respect of the handloom sector. Hence, in the present research these two (illumination and noise) important environmental factors were considered among the various others environmental variables which have sufficient influence on occupational health and performance of the weavers.

3.1 Location of the Study

The eastern part of India having mostly men weavers (85%) is associated with weaving activity as a part-time or full-time profession. Odisha state takes pleasure in the status of having the 2nd highest (77.5%) handloom owning households after the North-East region (80.2%), which is also over and above the national average (66.5%). That means most of the weavers have their own handloom workstations. Moreover, this state also enjoys the position of producing the maximum number of Ikat sarees in comparison to rest of the states in India (Handloom Census of India 2009 – 2010).

The work-hours spent on the loom in commercial weaving are more prolonged as compared to that of traditional weaving. Out of the total handloom produce in Odisha, more than 55% of handloom production is from Bargarh district and it is one of the major revenue generating districts, situated in western part of Odisha (Fig. 3.1). Bargarh is accredited with 'A' category handloom cluster district, having more than 1000 handloom in working condition. Therefore, this research was undertaken at Bargarh (Fig. 3.2) district only.

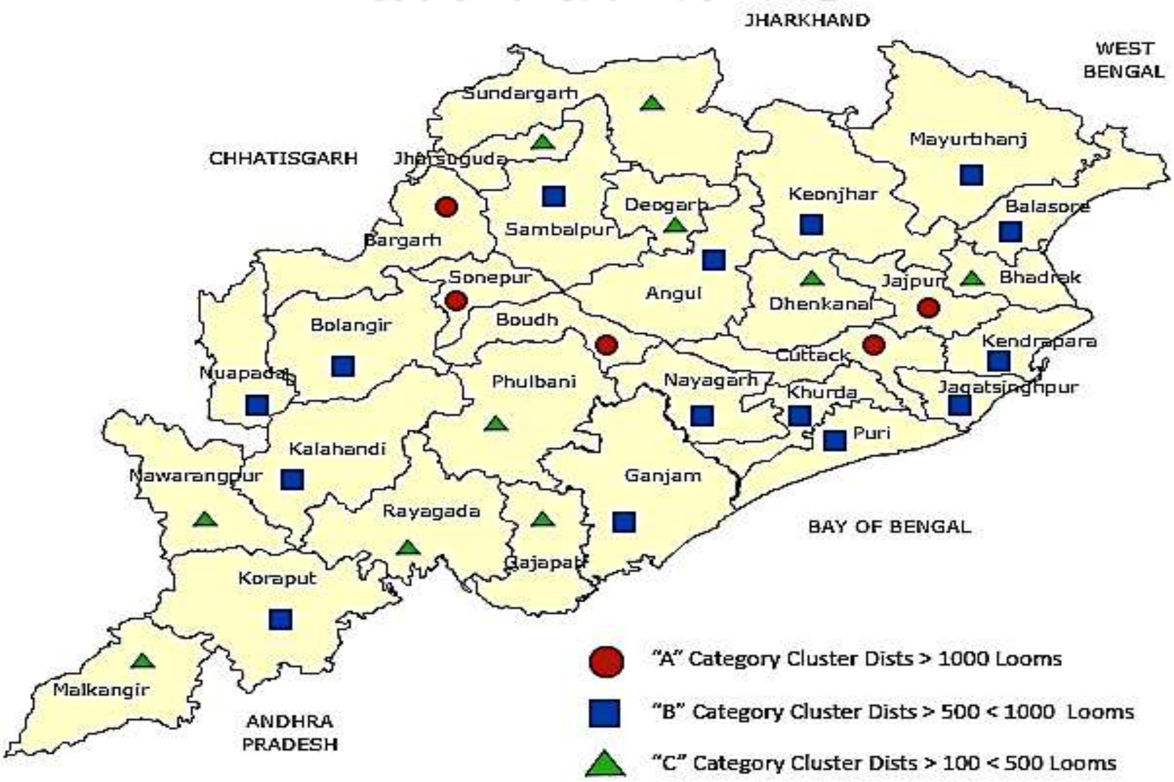

Fig. 3.1 Handloom clusters distribution on the map of Odisha (*adapted from Government of Odisha Website http://www.odisha.gov.in/textiles/index.htm visited on 06.03.2017*).

Fig. 3.2 Map of Bargarh District (*adopted from http://www.onefivenine.com/india/village/Bargarh, visited on 06.03.2017*).

3.2 Sampling

From the handloom perspective the districts of Odisha have been divided into three categories of clusters (Fig 3.1) – (a) Category 'A' handloom clusters district with more than 1000 live handlooms, (b) Category 'B' districts with 500-1000 live handlooms and (c) Category 'C' districts with less than 500 live handlooms. Out of total 18 'A' category clusters in Odisha, 08 clusters are in Bargarh district. All these 'A' category clusters have been included for study, besides two block level clusters (Table 3.1). Bargarh district of Odisha has the highest number of live handloom clusters including the block level clusters.

Among total 15 blocks in the district Bargarh, 10 blocks were earmarked for conducting the research work (Fig 3.2, Table 3.1). All the 8 'A' category handloom clusters along with 2 block level clusters were taken for sampling. From each of the 10 blocks, using purposive (non-probability) sampling technique, 50 handloom workstations were selected randomly. Bargarh district was preferred purposively of having the highest number of commercial production handlooms. A list of villages condensed under various clusters was prepared on the basis of the concentration of handlooms households with the help of the Assistant Director of Handlooms and Textiles, Bargarh.

Table 3.1 Villages selected from eight 'A' category handloom clusters and two block-level clusters of Bargarh district, Odisha.

Sl. No	Name of Block	Name of the Village	Total Number of weavers available	Number of weavers selected for the study	Total weavers selected from the block
1.	Bargarh	Bargaon	64	11	50
		Gudesira	59	11	
		Sahajbahal	33	6	
		Bardol	64	11	
		Katapali	64	11	
2.	Attabira	Tope	50	7	50
		Rangatikra	25	3	
		Singhpali	150	20	
		Banahar	35	5	
		Lurupali	111	15	
3.	Bhatli	Kesaipali	38	7	50
		Hatisar	77	13	
		Bhatli	78	13	
		KusanPuri	55	10	
		Kharsal	37	7	
4.	Bheden	Jandol	90	8	50
		Bheden	115	11	
		Chichinda	140	13	
		Remunda	130	12	
		Talmenda	71	6	
5.	Barpali	Kusanpuri	189	12	50
		Bagbadi	206	14	
		Barpali	210	15	
		Bandapali	44	3	
		Phulapali	86	6	

6.	Bijepur	Jaring	116	6	50
		Bijepur Village	323	18	
		Para	228	13	
		Laumunda	220	11	
		Barkani(Badkani)	35	2	
7.	Padampur	Phulmatipur	68	07	50
		Padampur City	67	6	
		Khairapali	247	25	
		Guthurla	42	4	
		Dahita	87	8	
8.	Sohella	Birjam	23	03	50
		Sarkanda	200	28	
		Nuagaon	37	6	
		Beherapali	44	6	
		Barihapali	48	7	
9.	Gaisilat	Baidpali	21	06	50
		Kujamunda	25	8	
		Gudarpali	40	12	
		Khalabahal	34	10	
		Ainlabhata	45	14	
10.	Ambabona	Ruchida	99	24	30
		Dwari	10	3	
		Sountamal	10	3	

Finally, a total of 480 weavers were selected as shown in Table 3.1. Weavers selected were all right limb dominant, apparently healthy without any specific physical problems. The sample population has the inclusion of independent weavers, master weavers, and weavers under middlemen, co-operative weavers and labour weavers. In the present study, only male weavers have been considered as they are principally associated with the main weaving activity (85%) in Bargarh area (Handloom Census of India 2009 – 2010) and have adopted this activity on the commercial scale.

It was difficult to find out male workers/ individuals with the work of similar nature and of with the same demographic and socioeconomic features. Weavers' family members who work outside the work shed of the handloom were undoubtedly exposed to higher level of illumination and lower level of noise but their activities (such as winding, warping, packaging, preparation of raw materials for dyeing etc. and household work like cooking, cleaning etc.) were completely different from weaving activities. Thus, these inhabitants could not be considered for control group. Moreover, it was also found that the weavers who worked on the handloom were also engaged on other ancillary work outside the handloom. Therefore, in the present research the control group was not adopted. To establish the problem statement of sufferings of the weavers due to exposure to higher level of noise and low level of illumination, instead of comparing experimental group (weavers) with control group, statistical correlation technique was adopted.

3.3 Subjects

A total of 480 weavers voluntarily participated in the experimental study with age ranging between 18 to 45 years. Male weavers were selected as participants, as per the following preset inclusion criteria like having work experience of minimum 3 to more than 25 years of uninterrupted work (in the present occupation) and being in good general health, having no medical record of any chronic ailment (no visual and hearing related problems). The subjects were informed about the study, the experimental procedure and their role in the research in vivid details. Written informed consent for participation in the study was obtained from each of them before involving in the experiment and the entire data collection was performed in accordance with declaration of Helsinki (World Medical Association, Helsinki, 2001). Since most of the subjects were not well-versed with English, they were explained the questions in their vernacular language and data were filled in by the interviewer. Personal information (native state, dominant working hand, use of corrective lens for the eyes, educational status, etc.) of the weavers was collected (with confidentiality assured thereto) as a part of the questionnaire only (adopted and modified after Ostrom, 1993; Engels *et al*., 1996; Chiu *et al*., 2002; Choobineh *et al*., 2004; Choudhury, 2014 and Bhattacharyya, 2011)

3.3.1 Demographic exploration

The average age of the participants was 32.68 ± 8.14 years and had been in their weaving profession for 11.49 ± 9.5 years. The height of the weavers varies in the range 164 ± 5.32 cm with weight in the range of 57.7 ± 7.98 kg with an average BMI of 21.4 ± 2.5, all the above data expressed as M ± SD. All the weavers had their own handlooms. Some of the weavers produced the sarees for selling directly to the market; while others operated the handloom on job basis, working for the cooperative society or some private handloom buying house. All the handlooms were installed in the weaver's houses only, who adopt this profession as their full-time activity. On an average the weaver's working hour spanned for 10.47 ± 1.8 h per day extrapolated to 22.82 ± 2.1 days in a month, all data expressed as M ± SD. Maximum weavers used 2/120s double cotton yarn besides 2/100s and 2/80s for the fabric production and producing mainly sarees of maximum double Ikat variety. All the weavers used Pit looms with maximum 8 treadles. In a month on an average a weaver weaved 53.5 ± 20.49 meter of fabric. The handlooms of most of the weavers were operative in Kuchha houses. More than 44% of the weavers used incandescent lamp (bulb), CFL or both. About 19% of the weavers were using the artificial light even during day time due to inapt illumination conditions prevailing during the daytime. Demographic and job characteristics of the weavers were given below in Table 3.2.

Table 3.2 Demographic and job characteristics of weavers (N=480; Literacy rate 63.99% and 50.4% preferred incandescent lamp i.e. bulb as artificial light).

Characteristics of Weavers	Mean	Range
Age (years)	32.68	18 – 45
Years of engagement	11.49	3 – 27
Working hours (h / day)	10.47	4 – 15
Monthly Income (Rs)	7291	1600 – 27200
Fabric Production (m / week / HL)	49.5	11 – 165

3.4 Research Framework

The research aimed at understanding the influence of illumination and noise on the psycho-physiological conditions of the weavers. The data was required in order to understand the problems encountered by the weavers while working on the handloom. The research used an exploratory-cum-explanatory approach (comprising both qualitative and quantitative techniques) to look at the influence of illumination and noise on physical, physiological and cognitive attributes of the weavers' wellbeing (Fig. 3.3.).

Fig. 3.3 Research Framework.

Odisha state is characterized by a tropical climate with semi-dry summer and cold winter; the average rainfall is 1500 mm, the maximum and minimum temperature of 35° C – 40° C and 12° C – 14° C respectively. Climate of Odisha is categorized into three distinct seasons, namely summer (Mar–Jun), rainy (Jul–Sep) and the winter season (Oct–Feb) (Climate in Odisha, 2014). Recorded data were grouped under three climatic seasons (summer, rainy and winter). Comparison of observations for identifying season specific risks (Deb and Ramachandraiah, 2010; Wani and Jaiswal, 2011; Wani and Jaiswal, 2012) and location-specific risks (Biswas *et al.*, 2012) was performed.

3.5 Design

The physical survey was conducted in different handloom units located in and around Bargarh for the detailed experimental study to understand the problems encountered by the weavers due to various environmental issues, especially to prevailing illumination and noise issues in various handloom workstations.

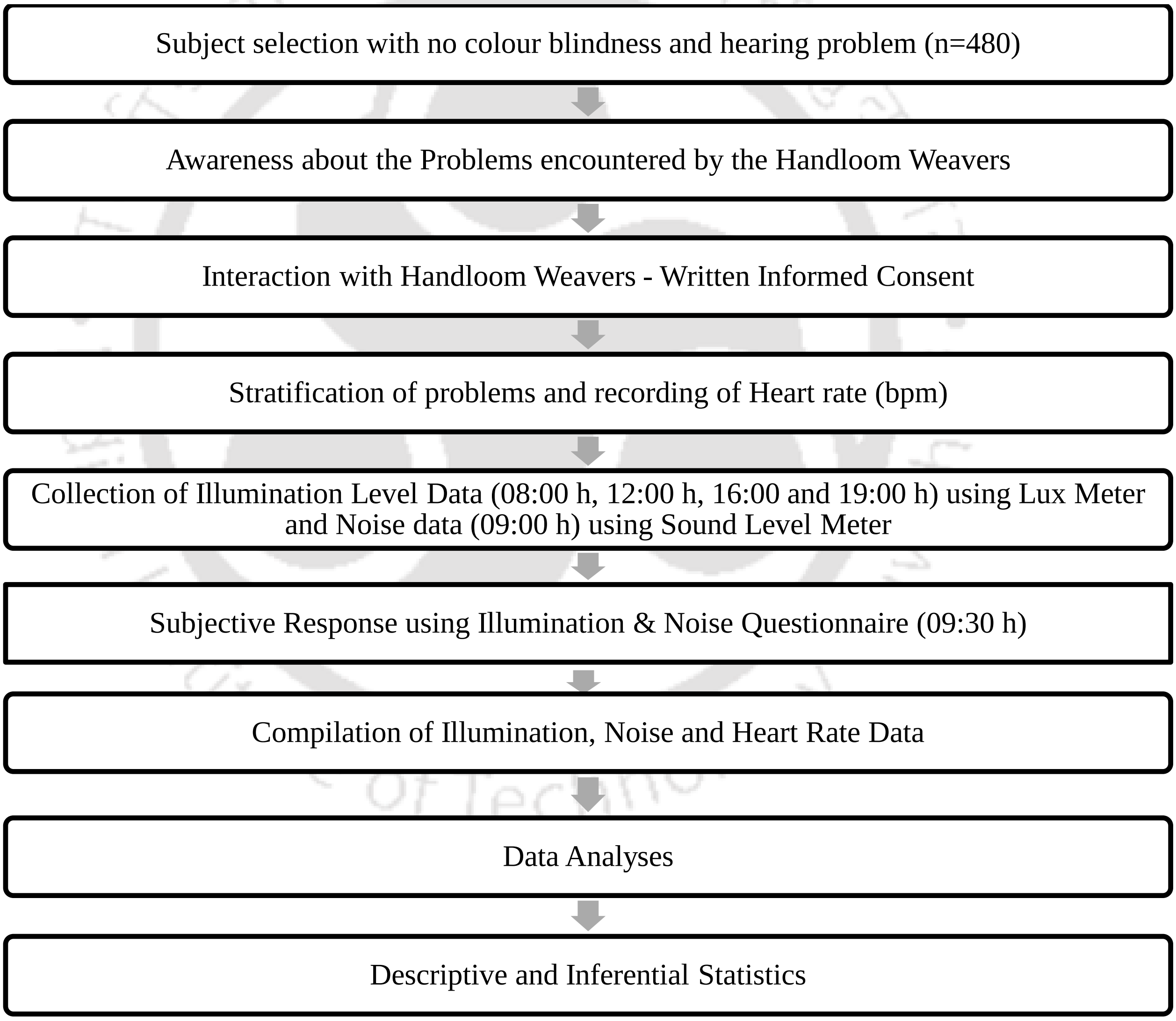

Fig. 3.4 Experimental Design

Ten handloom production blocks out of fifteen, having the highest concentration of weavers, were earmarked for conducting the experiment. Performance, illumination and noise related issues were also documented through the relevant questions. The weavers in the clusters were gathered for data collection in such a way that at least minimum 30 weavers could be covered every day of the month in order to cover the sample size of 480. The entire experimental design consisted of the following steps as shown in Fig. 3.4.

3.6 Parameters

3.6.1 Assessment of Illumination (Lux)

The illumination measurement procedure was followed as per the studies conducted by Dianat, 2013 and Küller *et al*., 2006 and illumination level on the handloom units was measured using standardized methods (Chengalur *et al.*, 2004; Padmini and Venmathi, 2012) in accordance with task, working plane, point of operation using the Auto Digital Lux meter [Model No. 1010A, Make M/s Sigma, 2011]. Data was recorded in the sheet to observe the lux value which has been measured during the whole day for four times at an interval of four hours at four locations (i.e. three points on the front side of the handloom and one point on the back side; Fig. 3.5) in the prevailing working illumination conditions on each handloom (Fig. 3.6) every month for 12 months. During measurement of illumination value the subjects were asked to weave on the handloom as per with their daily prevailing illumination conditions and light sources.

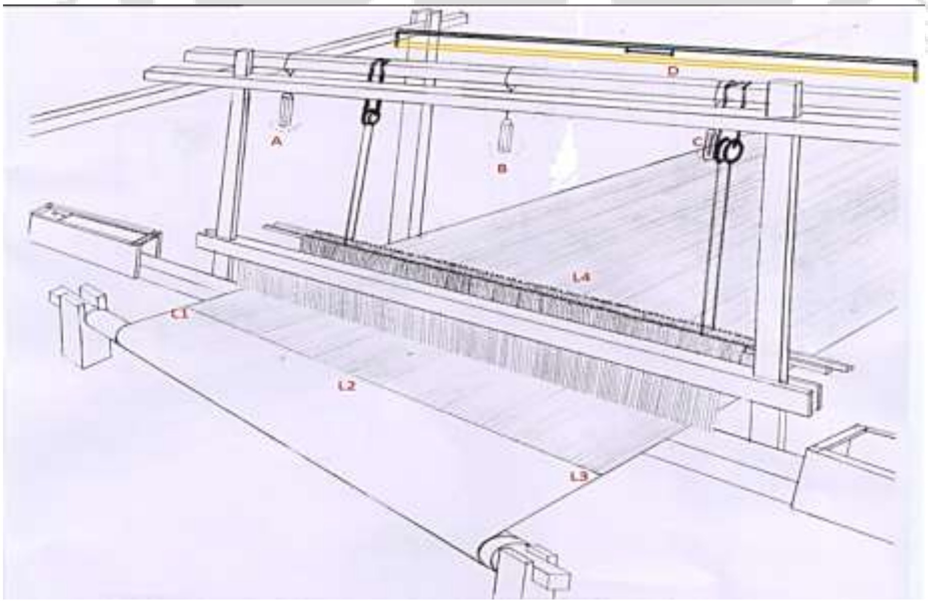

Fig. 3.5 Sketch diagram of handloom depicts the locations for measuring the illumination values at four points.

Fig. 3.6 Original loom image signifies the positions L_1, L_2, L_3 and L_4 for measuring the illumination values.

3.6.2 Estimation of Noise (dBA)

The noise level (A-weighted sound level) on the handloom units was measured within worker's hearing zone (Bureau of Indian Standards, 2005a); Chengalur *et al.*, 2004; OSHA, 2013; Bridger, 2002; Singh *et al.*, 2009 as prescribed by International Electrotechnical Corporation) using sound level meter [Model KM 929, Make M/s Kusam Meco, 2014] in worker's working position operating the handloom. The noise level (in dBA) was measured at two different locations, one near the right ear of the weaver and another at the centre of the shed every month for the whole year on each handloom. For each point, two readings i.e. Maximum and Minimum were taken. There are four types of weighting the sound which are known as A, B, C and D scales in the sound meter out of which dBA scale (or weighting function) is widely used in industries (Helander, 1995). Hence all the values were measured in 'dBA'. Noise level was measured on the handlooms which were in operation.

3.6.3 Physiological Measurements

Heart Rate. The heart rate of the weaver was measured by counting the pulse of the dominant hand of the weaver at supine rest before they started working on the handloom as per their daily routine.

Measurement of discomfort rating using Borg CR 10 scale. Discomfort rating of the weavers was evaluated by using the Borg CR10 (Category Ratio) scale. The exact site of discomfort is specified using the body map (Corlett and Bishop, 1976), which is divided into different segments (Fig 3.7). Depending on the region of discomfort, pain is mapped in that segment. Borg CR10 scale (Borg, 1982a, 1998,) is used to rate the level of discomfort in terms of pain from Grade 0 (No pain) – Grade 10 (Excruciating / *Extremely Strong*).

Borg CR10 scales:

0 *Nothing at all*	**0.5** *Extremely Week*	**1***VeryWeek*
2 *Week*	**3** *Moderate / Mild*	**5** *Strong*
6 *Moderate Strong*	**7** *Very Strong*	**10** *Excruciating / Extremely Strong*

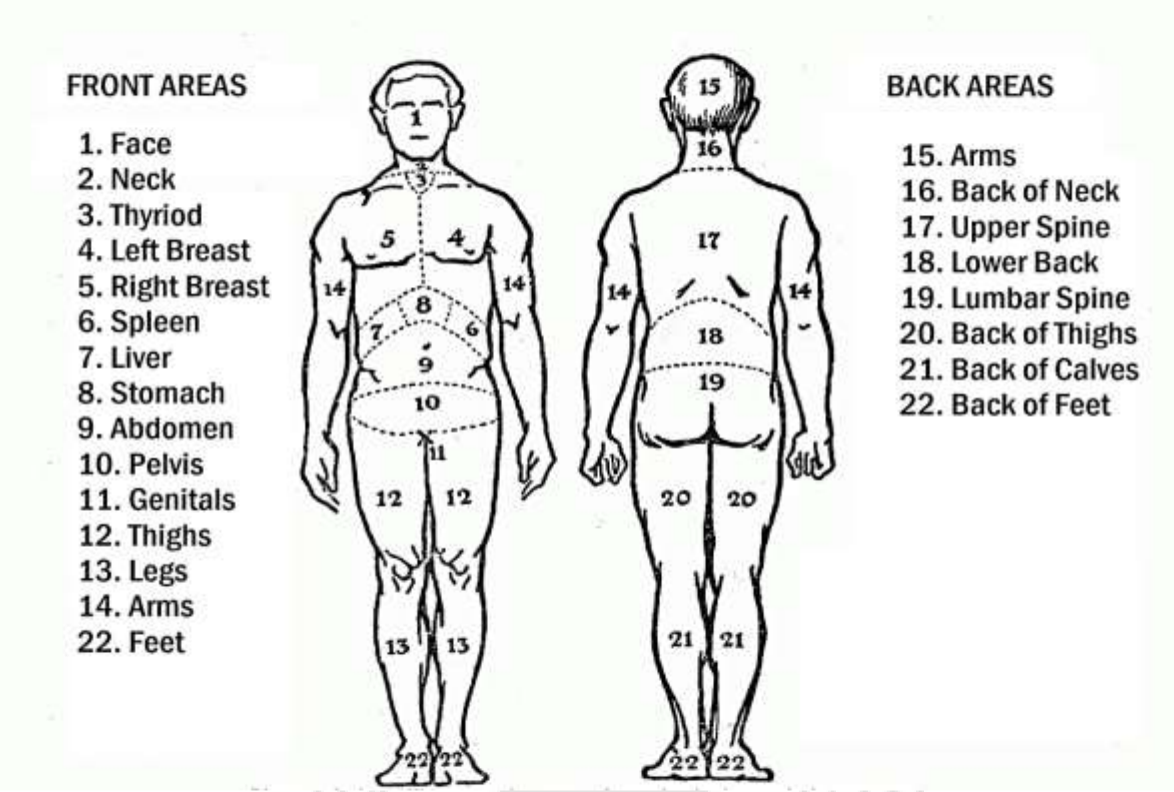

Fig. 3.7 Body map for identification of areas of discomfort for rating on Borg's scale.

3.6.4 NASA Task Load Index for Cognitive Psychological Assessment

NASA Task Load Index (TLX) is the most widely accepted subjective multidimensional tool for assessing subjective workload on the operator(s) working with various human-machine systems (Hart and Staveland, 1988). This tool is used to rate perceived cognitive workload on 6 different subscales such as (1) mental demand, (2) physical demand, (3) temporal demand, (4) performance, (5) effort and (6) frustration, and thus determine an overall workload score, based on the weighted average of the ratings using these subscales. The reliability of the NASA TLX scale is very good (r = 0.83; Singh *et al.*, 2005). Based on a weighted average of ratings the NASA TLX scale provides an overall workload score (Singh *et al.*, 2005; Singh *et al.*, 2010 a).

3.6.5 Questionnaires for the assessment of impact of illumination and noise

Two Questionnaires were designed after reviewing and consulting several available questionnaires, journals, publications, research papers, literature and established parameters compiled by various standard organizations. The *7-Point Likert Scale* is a psychometric response scale primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements. This is a non-comparative scaling technique and measures only a single trait. Respondents are asked to indicate their level of agreement with a given statement on an ordinal scale. Borg's CR10 Scale Rating is also used in the questionnaire to ascertain the perceived exertion of various discomfort factors. The 7-point Likert scales are advantageous because they are simple to construct, likely to produce a highly reliable scale and easy to read and complete for participants. Using such a 7-point Likert scale (where 1 depicts very low, 2 low, 3 moderate, 4 medium, 5 moderate high, 6 high and finally 7 represents very high), weavers rated their reactions to the prevailing illumination and noise conditions on the workplace.

Questionnaire on the impact of illumination.

The questionnaire to evaluate illumination contained 60 questions framed considering demographic, physiological and psychological aspects. Questions related to demographic parameters have been adopted from the publications of earlier researchers (Wargocki *et al.*, 2012 and Toftum *et al.*, 2012). Questions on physiological aspects prepared with the help of various publications, literature and research papers (Sanjog *et al.*, 2013; Howarth, 2005; Cameron, 1996; Borg, 1982; Agarwal and Yadav, 2013; Borg, 1998). Questions related to psychological measures were constructed after various publications and standards (Parsons, 2005; Howarth, 2005; Wargocki *et al.*, 2012; Pejtersen *et al.*, 2006 and Simone *et al.*, 2012).

Questionnaire on the impact of noise.

A total of 43 questions were designed considering all the aspects as in case of questionnaire for light, viz. the demographic, physiological and psychological components. Questions related to demographic parameters had been constructed in light of previous works (Eleftheriou, 2002; Cheung, 2004; Öhrström *et al*., 1979 and Zytoon, 2012). Questions on physiological aspects have been comprehended after Öhrström *et al*., 1979; Agarwal and Yadav, 2013 and Borg, 1998. Psychological components were fabricated after consulting existing reports (Eleftheriou, 2002; Zytoon, 2013; Öhrström *et al*., 1979; Hart, 2006; Agarwal and Yadav, 2013; Borg, 1998 and Toftum *et al*., 2012)**.**

3.7 Statistical Analyses

The data collection for the experimental group was performed using both subjective (questionnaire) and objective (physical measurements of the environmental factors) methods. Collected data were statistically analyzed using Statistical Package for Social Sciences (SPSS for windows, v.20.0.0) to explore any significant change across months, seasons, time or location. Data collected (as described hereinabove) were subjected to appropriate statistical analysis and a significance level of $p \leq 0.05$ (Dianat *et al*., 2016) was considered significant for all statistical tests.

Data for ascertaining the influences of illumination and noise on the cognitive workload in term of workers satisfaction with respect to mental demand, physical demand, temporal demand, performance, effort and frustration was collected by using NASA-TLX **-** Rating Scale along with workload comparison charts.

All the data generated as above were treated with Kolmogorov-Smirnov (KS) test of normality to examine whether they could form a normal distribution (i.e. whether the data were distributed normally). None of the raw datasets passed the normality test (KS) for any month (significance of KS being $p < 0.01$ or $p < 0.001$). Hence the data underwent non-parametric analyses techniques only.

3.7.1 Reliability of questionnaires (Illumination and Noise)

All the questions of the questionnaires regarding impact of illumination and noise in this research were constructed using the standard procedure and their administration reliability was examined by subjecting them through Cronbach's Alpha ('α') for their reliability and internal consistency of the scales. The questionnaire was adopted only when Cronbach's α achieved ≥ 0.8 ($\alpha \geq 0.8$) and the inter-item covariance matched across the corresponding levels. After validation of the reliability of the questionnaire, they were scored in terms of the number of responses and the generated data then underwent Friedman Chi-Squared test (χ^2_F) for independence. For every case, statistical significance was set at $p \leq 0.05$.

3.7.2 Friedman's Chi-Squared (χ^2_F) tests for independence

The questions contained in questionnaire for (a) impact of illumination (light) and (b) impact of noise (sound) on weavers' psycho-physiological state (and discomfort) were subjected to Friedman's Chi-Squared (χ^2_F) test for association between illumination / noise level and psycho-physiological discomfort, to explore whether the questions were independent of illumination level/ noise levels; because a significant association between questions and noise or illumination would bias the respondent while registering their responses to the questions in the questionnaires.

3.7.3 Correlation between environmental factors and their subjective perception

To explore whether illumination and noise affect health and performance of the handloom sector workers, their subjective responses (Through the administered questionnaire) towards the exposure to illumination and noise were evaluated using Spearman's correlation coefficient (r). Effects of exposure to light, sound and both were evaluated using r for the set of questionnaires on impact of light and sound. To enumerate these observations a correlation matrix was analyzed using independent calculations of r (without considering other variables for that particular variable). Further, the coefficient of Determination (CoD, expressed as r^2) was also calculated to examine that to what extent the variables share their variance (i.e. what percentage of discomfort could be explained by the causing factors like illumination and noise.

4.0 RESULTS

4.1 Comparison of illumination level at loom workstations

4.1.1 Illumination levels compared pairwise across 12 months

Table 4.1 Illumination level (lux) measured at four locations during four times of the day on each handloom for every month of the year

Month ▶ Time ▼	Jan	Feb	Mar	Apr	May	Jun
0800 h	111.78 ± 24.91	122.27 ± 28.93	153.00 ± 45.07	185.09 ± 45.39	177.65 ± 40.83	160.58 ± 37.94
1200 h	126.20 ± 28.57	127.57 ± 29.22	194.44 ± 49.29	224.66 ± 60.23	211.31 ± 51.93	197.22 ± 68.21
1600 h	74.21 ± 16.55	78.93 ± 16.14	99.11 ± 20.23	122.42 ± 31.07	115.74 ± 28.75	107.69 ± 23.71
1900 h	56.48 ± 9.27	56.52 ± 9.29	75.81 ± 19.71	76.14 ± 20.67	76.09 ± 19.80	76.21 ± 20.65

Month ▶ Time ▼	Jul	Aug	Sep	Oct	Nov	Dec
0800 h	144.90 ± 42.54	146.11 ± 35.92	151.45 ± 38.72	134.13 ± 30.26	133.35 ± 39.92	110.20 ± 25.86
1200 h	176.82 ± 39.34	177.06 ± 43.65	186.40 ± 65.06	171.45 ± 59.80	159.21 ± 37.52	126.20 ± 28.57
1600 h	91.36 ± 39.93	94.97 ± 19.82	96.45 ± 41.62	89.85 ± 19.32	84.02 ± 36.35	74.08 ± 16.10
1900 h	66.23 ± 15.16	69.11 ± 15.86	73.13 ± 19.19	61.11 ± 13.41	58.20 ± 12.66	56.23 ± 9.12

Values are expressed as Mean ± SD. 0800 h, 1200 h, 1600 h and 1900 h – Time of measuring of the illumination values. Statistical interpretation is tabulated in Tables 4.2 – 4.5.

The values (Mean ± SD) of the illumination of the workplace were shown in Table 4.1. The data revealed that illumination value varied considerably during the daytime, and it was found to be maximum at 1200 h and minimum at 1900 h, maintaining an overall persistent trend of variation. The illumination level displayed the minimal reading during the month of Dec and Jan followed by an upward trend till the month of Apr; then the illumination level decreased gradually up to the month of Jul (Fig. 4.1). It again logged upwards after Jul; and after Sep, the value decreased considerably till Jan. The variation of illumination between 56.23 lux – 224.66 lux across the months registered significant difference ($p \leq 0.001$, on treatment of data with Friedman Chi-Square test for nonparametric analysis of significance of ranked variable) at a given time of the day (viz. 0800 h, 1200 h, 1600 h or 1900 h) while comparing one month to another month in most of the cases.

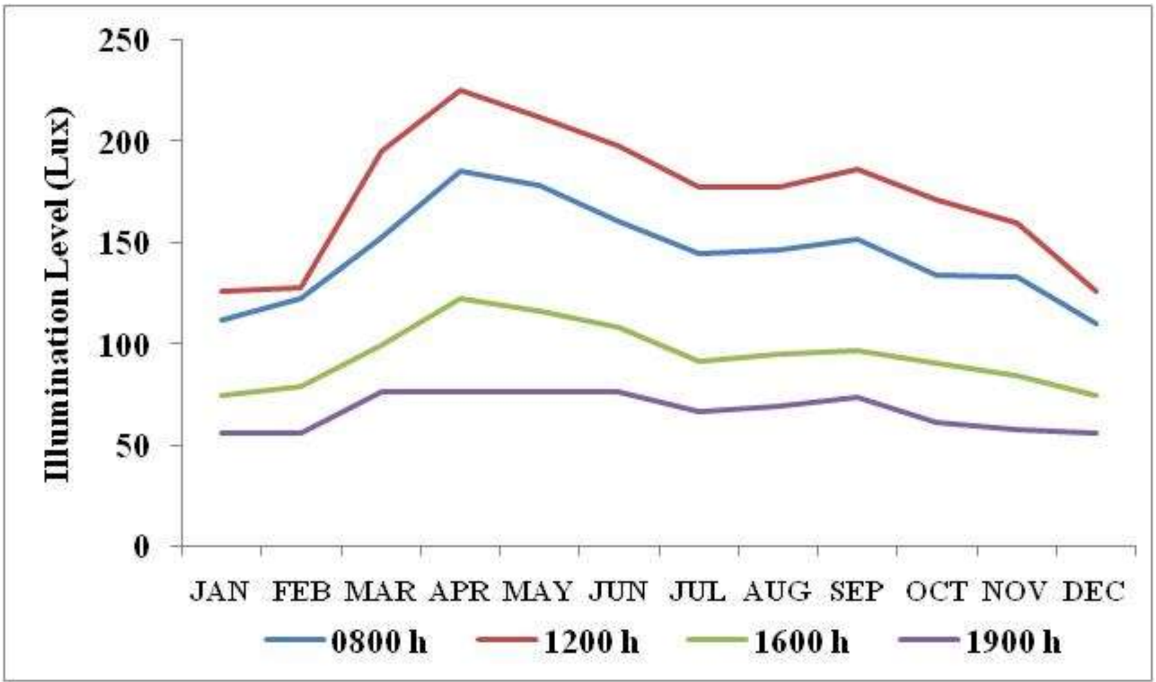

Fig. 4.1 Mean illumination level (lux) measured on each handloom workstation (month-wise)

Table 4.2 Variation of illumination level at 0800 h across the year (12 months) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	*	***	***	***	***	***	***	***	***	***	NS
Feb		—	***	***	***	***	***	***	***	***	NS	***
Mar			—	***	***	**	***	**	NS	***	***	***
Apr				—	NS	***	***	***	***	***	***	***
May					—	*	***	***	***	***	***	***
Jun						—	***	***	**	***	***	***
Jul							—	NS	***	*	***	***
Aug								—	**	***	***	***
Sep									—	***	***	***
Oct										—	NS	***
Nov											—	***
Dec												—

*Significances expressed by * against the pair of months, where *, ** and *** denotes significant difference at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively. NS - No significant difference ($p > 0.05$).*

Between-group analyses of illumination level across the months at 0800 h (Table 4.2) reflected significant (p ≤ 0.001) differences in most of the cases. It was observed that, between the months of Jan vs. Feb, May vs. Jun and Jul vs. Oct the difference in illumination level was significant at p ≤ 0.05; while the difference was significant at p ≤ 0.01 between the months of Mar vs. Jun, Mar vs. Aug, Jun vs. Sep and Aug vs. Sep however, no significant (p > 0.05) difference was observed for comparison of illumination between Jan vs. Dec, Feb vs. Nov, Mar vs. Sep, Apr vs. May, Jul vs. Aug and Oct vs. Nov.

Table 4.3 Variation of illumination level at 1200 h across the year (12 months) and significance of the difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	NS	***	***	***	***	***	***	***	***	***	NS
Feb		—	***	***	***	***	***	***	***	***	***	NS
Mar			—	***	***	NS	***	***	***	***	***	***
Apr				—	NS	***	***	***	***	***	***	***
May					—	***	***	***	***	***	***	***
Jun						—	**	***	***	***	***	***
Jul							—	NS	NS	*	***	***
Aug								—	NS	**	***	***
Sep									—	***	***	***
Oct										—	NS	***
Nov											—	***
Dec												—

*Significances expressed by * against the pair of months, where *, ** and *** denotes significant difference by p ≤ 0.05, p ≤ 0.01 and p ≤ 0.001 respectively. NS – No significant difference (p > 0.05).*

Table 4.3 reflected significant (p ≤ 0.001) differences in most of the cases for between-group analyses of illumination level across the months at 1200 h. Significant difference at p ≤ 0.05 was observed between Jul vs. Oct; whereas for the months of Jun vs. Jul and Aug vs. Oct, this difference was significant at p ≤ 0.01. No significant (p > 0.05) difference, however, was observed on comparison of illumination for Jan vs. Feb, Jan vs. Dec, Feb vs. Dec, Mar vs. Jun, Apr vs. May, Jul vs. Aug, Jul vs. Sep, Aug vs. Sep and Oct vs. Nov.

Table 4.4 (presenting comparison of between-group analyses of illumination level across the months for 1600 h the illumination values were) manifested no significant (p >

0.05) difference between illumination levels of Jan vs. Nov, Jan vs. Dec, Feb vs. Jul, Feb vs. Nov, Mar vs. Sep, Apr vs. May, May vs. Jun, Jul vs. Oct, Aug vs. Sep, Aug vs. Oct and Nov vs. Dec.

Table 4.4 Variation of illumination level at 1600 h across the year (12 months) and significance of the difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	NS	NS
Feb		—	***	***	***	***	NS	***	***	**	NS	***
Mar			—	***	***	***	***	*	NS	***	***	***
Apr				—	NS	***	***	***	***	***	***	***
May					—	NS	***	***	***	***	***	***
Jun						—	***	***	***	***	***	***
Jul							—	**	***	NS	***	***
Aug								—	NS	NS	***	***
Sep									—	**	***	***
Oct										—	***	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where *, ** and *** denotes significant difference by $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively. NS – No significant difference ($p > 0.05$).*

Difference in illumination level for Mar vs. Aug was significant at $p \leq 0.05$, whereas the difference was significant at $p \leq 0.01$ for Feb vs. Oct, Jul vs. Aug and Sep vs. Oct. Significant difference at $p \leq 0.001$ was seen for rest of the pairs of months.

Illumination values at 1900 h (Table 4.5) revealed no significant ($p > 0.05$) difference between illumination levels for Jan vs. Feb, Jan vs. Nov, Jan vs. Dec, Feb vs. Nov, Feb vs. Dec, Mar vs. Apr, Mar vs. May, Mar vs. Jun, Apr vs. May, Apr vs. Jun, May vs. Jun, Jul vs. Aug, Jul vs. Oct, Aug vs. Sep and Nov vs. Dec; whereas in all other cases, the difference was significant at ($p \leq 0.001$) levels.

Table 4.5 Variation of illumination level at 1900 h across the year (12 months) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	NS	***	***	***	***	***	***	***	***	NS	NS
Feb		—	***	***	***	***	***	***	***	***	NS	NS
Mar			—	NS	NS	NS	***	***	***	***	***	***
Apr				—	NS	NS	***	***	***	***	***	***
May					—	NS	***	***	***	***	***	***
Jun						—	***	***	***	***	***	***
Jul							—	NS	***	NS	***	***
Aug								—	NS	***	***	***
Sep									—	***	***	***
Oct										—	***	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where *** denotes significant difference by $p \leq 0.001$. NS – No significant difference ($p > 0.05$).*

4.1.2 Variations in illumination across seasons viz. summer (Mar-Jun), monsoon (Jul-Sep) and winter (Oct-Feb)

The values (Mean ± SD) of the illumination of workplace, measured at different locations of the handloom and categorized under different climatic seasons, were shown in Table 4.6. Significance of difference of illumination level at each handloom workstation across different seasons was also reflected in the same table.

Table 4.6 Mean illumination level at various handloom workstations with the significance of difference between observations among different climatic seasons

Season	0800 h	1200 h	1600 h	1900 h
Summer	169.04 ± 44.26	206.93 ± 52.49	111.24 ± 24.73	76.05 ± 18.04
Monsoon	147.49 ± 39.19	180.09 ± 39.28	94.23 ± 27.27	69.49 ± 13.19
Winter	122.34 ± 32.05	142.13 ± 43.16	80.22 ± 23.07	57.71 ± 11.05
Summer Vs monsoon	***	***	***	***
Summer Vs Winter	***	***	***	***
Monsoon Vs Winter	***	***	***	***

*Values are expressed as Mean ± SD. Significance at $p \leq 0.001$ was denoted by *** against the data.*

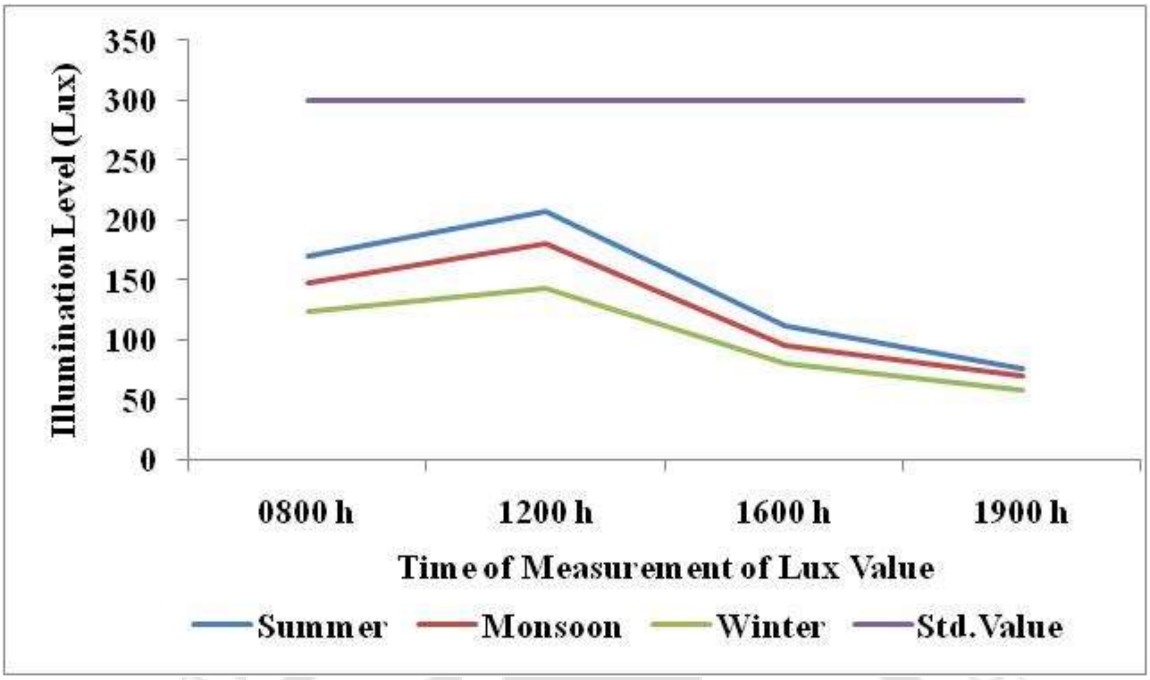

Fig. 4.2 Illumination across seasons with recommended standard value

Mean illumination levels of the seasons depicted very low illumination across all the seasons in comparison to the recommended Indian as well as International standards (Fig. 4.2). Minimal illumination was observed during the winter throughout the day, whereas the illumination value was on higher side during the whole day in the summer. The illumination at 1200 h during summer was the maximum among all other seasons. The highest value obtained across all the seasons was 206.93 lux at 1200 h during summer, and minimum was 57.71 lux at 1900 h during winter. A significant ($p \leq 0.001$) difference of the illumination was observed between all pairs of seasons during all the four times of the day, as reflected in Table 4.6.

4.1.3 Comparison of illumination (yearly average level) of the loom workstation with recommended standard values

The experimental study clearly elucidated that, the highest illumination level (yearly average, vide Table 4.7) was 173.21 ± 46.68 lux (Mean ± SD) at 1200 h, with extensive fluctuation, while the lowest value of 66.77 ± 15.35 lux (Mean ± SD) was observed at 1900 h, both which were considered to be far below the recommended standard value of illumination (Fig. 4.3) for medium and fine work.

Table 4.7 Illumination value (lux) of the whole year with recommended standard level of illumination

Time of Observation of Illumination Value	Illumination Value (Lux)	Recommended Standard level of Illumination (for medium & fine work)
0800 h	144.19 ± 36.22	BIS : 300 Lux – 700 Lux
1200 h	173.21 ± 46.68	ISO : 300 Lux
1600 h	94.06 ± 25.72	CIE : 300 Lux
1900 h	66.77 ± 15.35	IES : 400 Lux – 750 Lux

Values were expressed as Mean ± SD. BIS – Bureau of Indian Standards; ISO – International Organization for Standardization; CIE – Commission Internationale de I'Eclairage (International Commission on Illumination); IES – Illuminating Engineering Society.

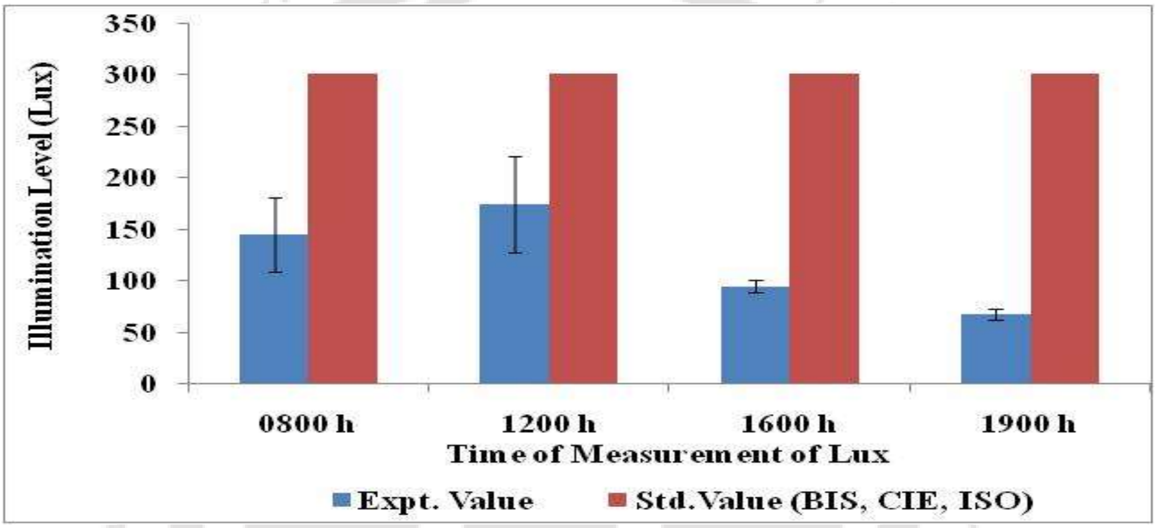

Fig. 4.3 Illumination (yearly average level in lux) of the whole year with recommended standard value. Values were expressed as Mean ± SD

4.2 Comparison of noise level at handloom workstations

4.2.1 Noise levels compared pair wise across 12 months

The values (Mean ± SD) of the noise level at 2 different locations of the loom (workstation), viz. maximal and minimal noise levels near the right ear of the weaver (E_{MAX} and E_{MIN} respectively) and at the centre of the workstation (C_{MAX} and C_{MIN} respectively) were shown in Table 4.8. The data reflected that there was a considerable variation in the noise level on the handloom as well as around the workstation. Noise level varied considerably and followed the increasing trend from Jan up to May (when it reached maximum), and thereafter decreased gradually till Aug. In Sep, it increased further and subsequently started decreasing up to Jan. The maximal noise was recorded near the weaver's right ear during May and minimal noise was noted at the centre of the work shed during Jan (Fig. 4.4).

Table 4.8 Noise level (dBA) measured on two locations in the handloom shed (Month Wise)

Month	Jan	Feb	Mar	Apr	May	Jun
E_{MAX}	82.16± 3.31	86± 2.59	86.63 ± 1.20	87.9± 2.83	88.87 ± 2.87	87.11 ± 2.71
E_{MIN}	44.01 ± 4.52	44.78 ± 4.67	46.63 ± 4.41	47.3± 4.98	48.94 ± 4.63	47.08 ± 4.72
C_{MAX}	69.98 ± 5.81	71.72 ± 7.36	74.04 ± 6.28	74.66 ± 5.94	74.72 ± 5.77	74.06 ± 7.79
C_{MIN}	39.19 ± 4.24	40.82 ± 4.21	42.24 ± 3.88	42.77 ± 4.94	42.94 ± 4.32	42.59 ± 4.51
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
E_{MAX}	86.6 ± 1.93	84.99 ± 2.62	86.46± 1.27	86.21 ± 2.87	83.73 ± 1.46	83.60 ± 1.50
E_{MIN}	45.91 ± 4.61	45.64 ± 4.76	45.28 ± 4.63	44.83 ± 4.51	44.58 ± 4.1	44.25 ± 4.39
C_{MAX}	73.78 ± 6.08	73.71 ± 5.47	73.61 ± 6.99	73.5 ± 6.01	71.68 ± 5.8	71.62 ± 6.69
C_{MIN}	42.17 ± 4.35	42.12 ± 4.73	42.01 ± 4.53	41.55 ± 3.80	40.68 ± 4.35	40.04 ± 4.25

Values are expressed as Mean ± SD. E_{MAX} – Maximum value of noise near the weaver's Right ear; E_{MIN} – Minimum value of noise near the weaver's Right ear C_{MAX} – Maximum value of noise in the center of the shed; C_{MIN} – Minimum value of noise in the center of the shed. Statistical interpretation is tabulated in Tables 4.9 – 4.12.

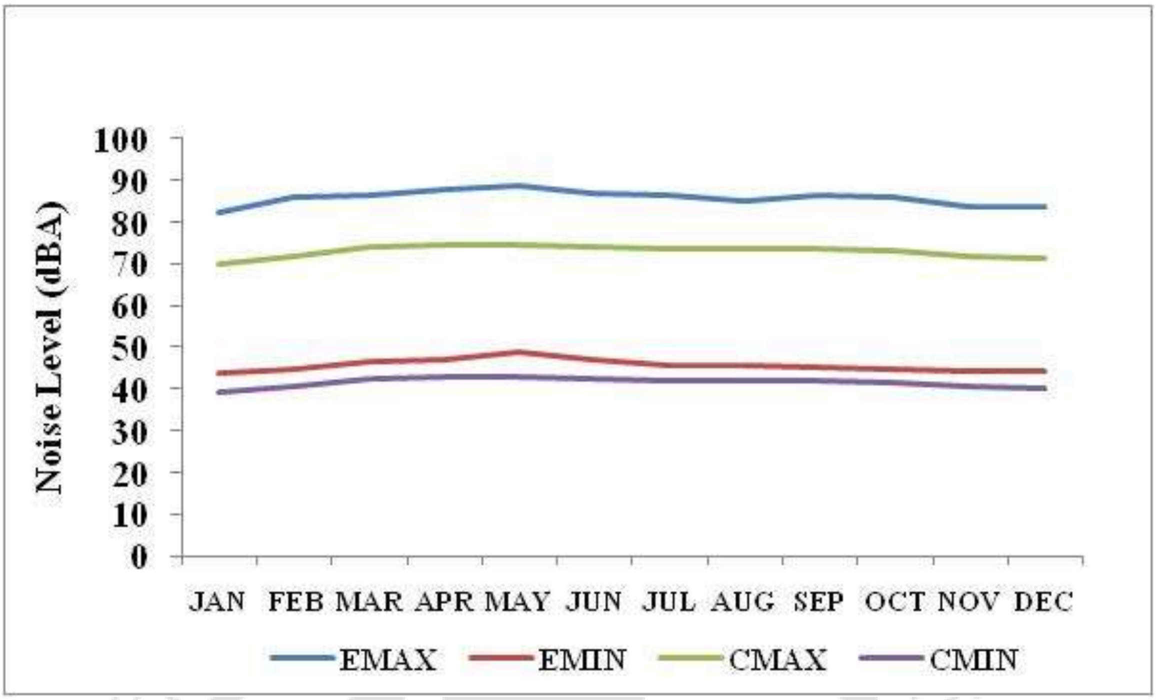

Fig. 4.4 Noise level (dBA) measured at different position of the handloom workstation (Month Wise). E_{MAX} – Maximum value of noise near the weaver's Right ear; E_{MIN} – Minimum value of noise near the weaver's Right ear C_{MAX} – Maximum value of noise in the centre of the shed; C_{MIN} – Minimum value of noise in the centre of the shed. Values were expressed as Mean ± SD

Table 4.9 Comparison across 12 months between maximal noise (dBA) value near the ear (E_{MAX}) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	NS	NS
Feb		—	***	***	***	***	***	***	***	NS	***	***
Mar			—	***	***	NS	NS	***	NS	***	***	***
Apr				—	**	***	***	***	***	***	***	***
May					—	**	***	***	***	***	***	***
Jun						—	NS	***	NS	***	***	***
Jul							—	***	NS	*	***	***
Aug								—	***	***	***	***
Sep									—	*	***	***
Oct										—	***	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where *, ** and *** denotes significant difference $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively. NS - No significant difference ($p > 0.05$).*

The analyses of maximal noise level near the ear of the weaver (E_{MAX}) across the months (vide Table 4.9) revealed significant ($p \leq 0.001$) differences in most of the cases. Moreover, it was also observed that for Jul vs. Oct and Sep vs. Oct, the difference in noise level was significant at $p \leq 0.05$ whereas the difference in noise level was significant at $p \leq 0.01$ level for Apr vs. May and May vs. Jun. However, no significant ($p > 0.05$) difference was observed while comparing the noise levels for Jan vs. Nov, Jan vs. Dec, Feb vs. Oct, Mar vs. Jun, Mar vs. Jul, Mar vs. Sep, Jun vs. Jul, Jun vs. Sep, Jul vs. Sep and Nov vs.Dec.

Table 4.10 Comparison across 12 months between minimal noise (dBA) value near the ear (E_{MIN}) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	**	NS
Feb		—	***	***	***	***	***	***	**	NS	NS	***
Mar			—	NS	***	NS	***	***	***	***	***	***
Apr				—	***	NS	***	***	***	***	***	***
May					—	***	***	***	***	***	***	***
Jun						—	**	***	***	**	***	***
Jul							—	NS	***	***	***	***
Aug								—	NS	***	***	***
Sep									—	**	***	**
Oct										—	NS	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where ** and *** denotes significant difference $p \leq 0.01$ and $p \leq 0.001$ respectively. NS – denotes No significant difference ($p > 0.05$).*

Analyses of the minimal noise level near the right ear (E_{MIN}) of the weaver (vide Table 4.10) revealed significant ($p \leq 0.001$) differences in most of the cases. However the difference was significant at $p \leq 0.01$ for Jan vs. Nov; Feb vs. Sep; Jun vs. Jul; Jun vs. Oct; Sep vs. Oct and Sep vs. Dec; while no significant ($p > 0.05$) difference was observed during comparison of Jan vs. Dec, Feb vs. Oct, Feb vs. Nov, Mar vs. Apr, Mar vs. Jun, Apr vs. Jun, Jul vs. Aug, Aug vs. Sep, Oct vs. Nov and Nov vs. Dec.

The maximum noise level at the center of the handloom shed (C_{MAX}) revealed significant ($p < 0.001$) difference between the noise level across different pairs of months (Table 4.11), except some cases with no significant ($p > 0.05$) difference for Feb vs. Nov, Feb vs. Dec, Mar vs. Jun, Mar vs. Jul, Mar vs. Sep, Apr vs. May, Apr vs. Jun, May vs. Jun, Jul vs. Aug, Jul vs. Sep, Jul vs. Oct, Aug vs. Sep, Aug vs. Oct, Sep vs. Oct, and Nov vs. Dec.

Table 4.11 Comparison across 12 months between maximal noise (dBA) value at the centre of the work shed (C_{MAX}) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	***	***
Feb		—	***	***	***	***	***	***	***	***	NS	NS
Mar			—	***	***	NS	NS	***	NS	***	***	***
Apr				—	NS	NS	***	***	***	***	***	***
May					—	NS	***	***	***	***	***	***
Jun						—	***	***	***	***	***	***
Jul							—	NS	NS	NS	***	***
Aug								—	NS	NS	***	***
Sep									—	NS	***	***
Oct										—	***	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where *** denotes significant difference $p \leq 0.001$ respectively. NS – No significant difference ($p > 0.05$).*

Table 4.12 showed significance of difference between the minimal noise levels at the centre (C_{MIN}) of the handloom work-shed across various pairs of months.

Table 4.12 Comparison across 12 months between minimal noise (dBA) value at the centre of the work shed (C_{MIN}) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	***	NS
Feb		—	***	***	***	***	***	***	***	***	NS	***
Mar			—	**	***	NS	NS	NS	NS	***	***	***
Apr				—	NS	NS	***	***	***	***	***	***
May					—	**	***	***	***	***	***	***
Jun						—	NS	NS	*	***	***	***
Jul							—	NS	NS	***	***	***
Aug								—	NS	***	***	***
Sep									—	**	***	***
Oct										—	***	***
Nov											—	NS
Dec												—

*Significances expressed by * against the pair of months, where *, ** and *** denotes significant difference $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively. NS – No significant difference ($p > 0.05$).*

The difference between the noise levels was significant ($p < 0.001$) across the pairs of the months except for Jun vs. Sep ($p \leq 0.05$); for Mar vs. Apr, May vs. Jun and Sep vs. Oct ($p \leq 0.01$) and for Jan vs. Dec, Feb vs. Nov, Mar vs. Jun, Mar vs. Jul, Mar vs.

Aug, Mar vs. Sep, Apr vs. May, Apr vs. Jun, Jun vs. Jul, Jun vs. Aug, Jul vs. Aug, Jul vs. Sep, Aug vs. Sep and Nov vs. Dec ($p > 0.05$, not significant).

4.2.2 Variations in noise across seasons viz. summer (Mar-Jun), monsoon (Jul-Sep) and winter (Oct-Feb)

Maximal and minimal noise levels measured at two locations inside the handloom workstations viz. near the weavers' right ear and at the center of the handloom shed across different climatic seasons and tabulated as Mean ± SD shown in Table 4.13. it could be understood that, maximal noise was perceived during the summer near the weaver's right ear (E_{MAX}, 87.62 ± 2.36 dBA), considered to be far above the recommended value of Indian Standards (75 dBA) for noise (Fig. 4.5), while the minimal recorded was during the winter at the centre of the shed (C_{MIN}, 40.45 ± 4.24 dBA), a significant ($p \leq 0.001$) difference of noise level was observed across all pairs of seasons at all positions during the year except in case of C_{MAX} for summer vs. monsoon ($p \leq 0.05$).

Table 4.13 Mean of the season wise noise value (dBA) at two locations of the handloom workstations with the significance level between observations among different climatic seasons

Season	E_{MAX}	E_{MIN}	C_{MAX}	C_{MIN}
Summer	87.62 ± 2.36	47.48 ± 4.26	74.37 ± 5.80	42.63 ± 3.96
Monsoon	86.02 ± 1.66	45.61 ± 3.61	73.70 ± 4.80	42.10 ± 3.51
Winter	84.34 ± 2.90	44.49 ± 4.44	71.70 ± 6.45	40.45 ± 4.24
Summer Vs Monsoon	***	***	*	***
Summer Vs Winter	***	***	***	***
Monsoon Vs Winter	***	***	***	***

*Values are expressed as Mean ± SD. Significance expressed by * and *** against the data, which indicated $p \leq 0.05$ and $p \leq 0.001$ respectively.*

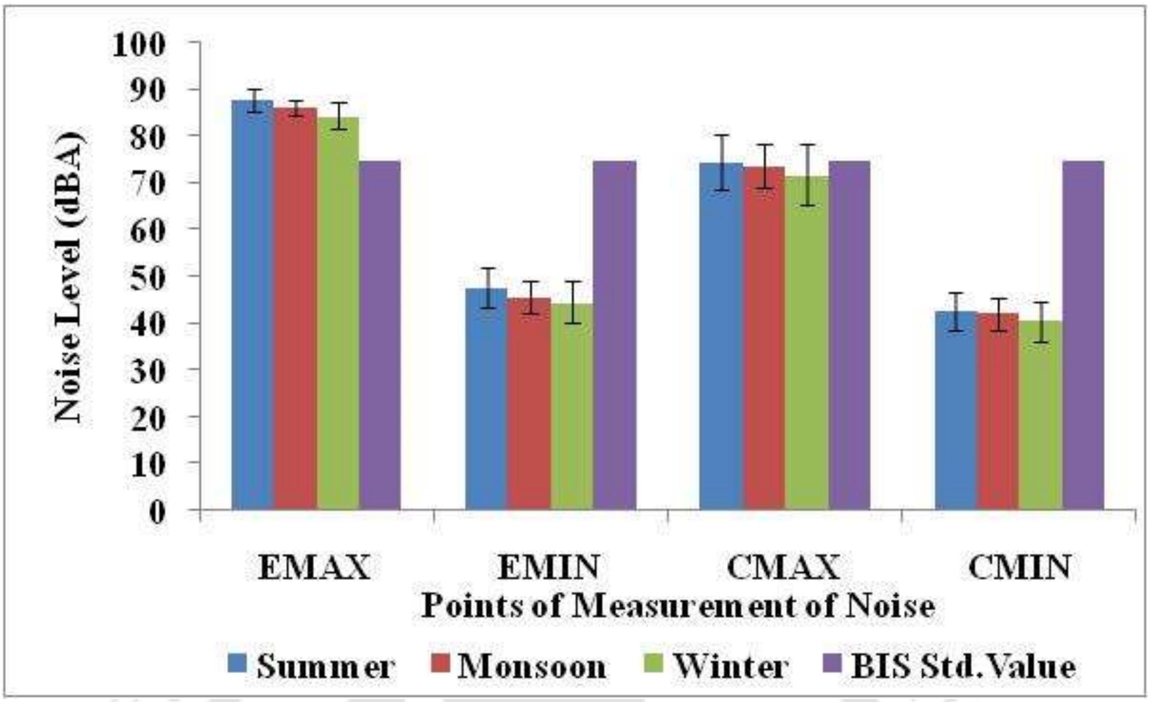

Fig. 4.5 Season wise noise value (dBA) at two locations in the handloom shed. Values are expressed as Mean ± SD

4.2.3 Comparison of Noise (yearly average level) of the loom workstation with recommended standard values

Table 4.14 Noise value (dBA) at two locations in the handloom shed for the whole year with recommended Standard level of Noise

Observation Point	Noise Level (dBA)	Recommended Standard level of Noise
EMAX	85.85 ± 2.21	Bureau of Indian Standards (**BIS**) – ***45*** to***75 dBA***
EMIN	45.77 ± 4.55	
CMAX	73.09 ± 6.26	
CMIN	41.59 ± 4.29	

Values are expressed as Mean ± SD.

The noise level revealed, on an average across the year, maximal noise level near the right ear of the weaver (85.85 ± 2.21 dBA, Mean ± SD) as shown in Table 4.14, which was higher in comparison to the recommended Indian Standards (45 dBA to 75 dBA). The noise level had wide and unstable deviation (Fig. 4.6) and the lowest value (41.59 ± 4.29 dBA) was observed at the center of the shed.

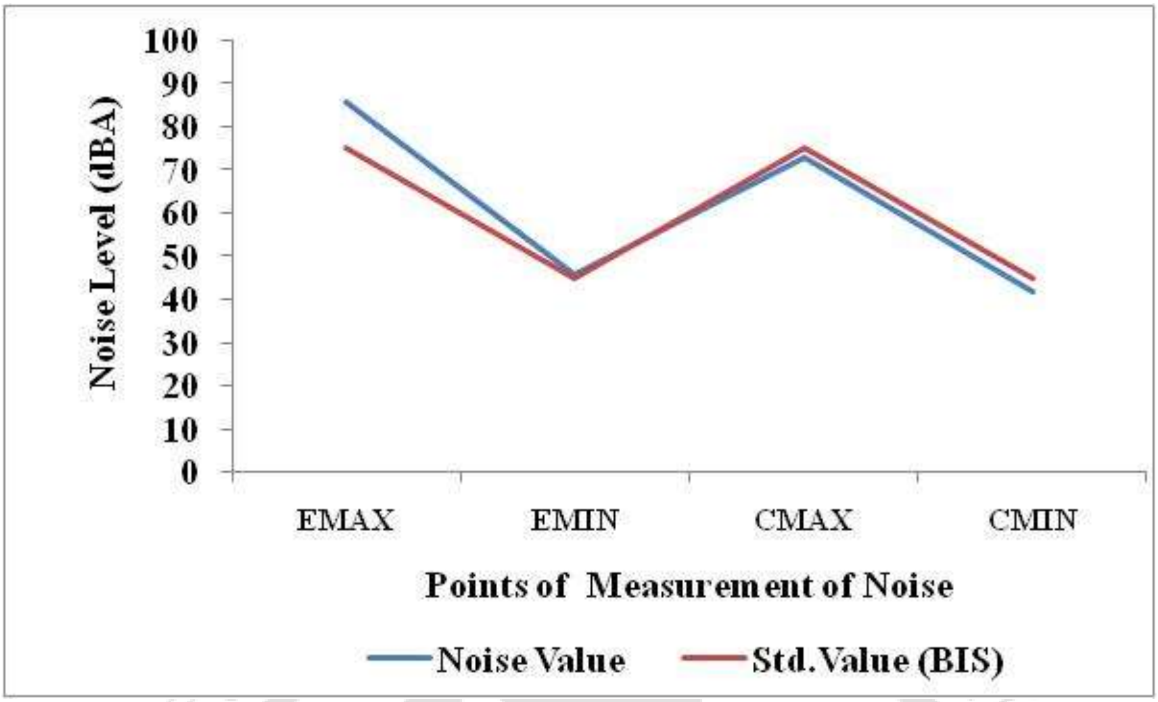

Fig. 4.6 Noise value (dBA) at two locations in the handloom shed for the whole year with recommended BIS Standard level of Noise. Values are expressed as Mean ± SD

4.3 Comparison of heart rate of the weavers at loom workstations

4.3.1 Heart rate compared pair wise across 12 months

The values (Mean ± SD) of the heart rate of the individual weaver were shown in Table 4.15. The data revealed somewhat inconsistent trend of variation. The heart rate was minimal during Jan, followed by a trend of gradual increase till May; with a further trend of slow decrease up to Dec (Fig. 4.7).

Table 4.15 Working Heart Rate (bpm) levels of the weavers on the handloom workstation for every month of the year

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
HR (bpm)	80.58 ± 10.33	81.49 ± 10.53	83.75 ± 10.32	84.10 ± 9.84	84.23 ± 10.22	83.87 ± 10.40
Month	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
HR (bpm)	83.41 ± 10.08	82.73 ± 9.99	82.58 ± 10.14	82.44 ± 10.36	81.41 ± 10.10	80.91 ± 10.15

Values are expressed as Mean ± SD. bpm – Beats per minute. Statistical interpretation is tabulated in Tables 4.16.

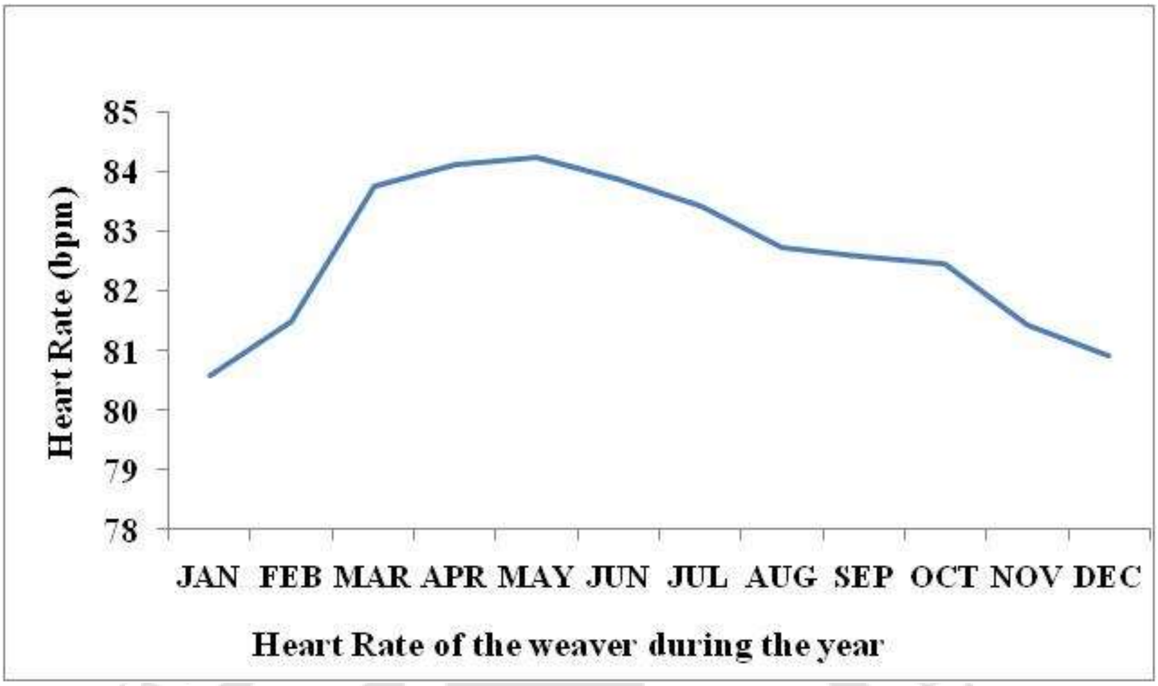

Fig. 4.7 Working Heart Rate (bpm) of the weavers on the handloom (Month Wise)

Table 4.16 presented pair-wise between-group analyses of working heart rate across the months. There was no significant ($p > 0.05$) difference between heart rate for Jan vs. Dec, Feb vs. Nov, Mar vs. Apr, Mar vs. May, Mar vs. Jun, Mar vs. Jul, Apr vs. May, Apr vs. Jun, May vs. Jun, Jun vs. Jul, Aug vs. Sep and Aug vs. Oct.

Table 4.16 Variation of heart rate levels across the year (12 months) and significance of difference between observations among different months of the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan	—	***	***	***	***	***	***	***	***	***	***	NS
Feb		—	***	***	***	***	***	***	***	***	NS	***
Mar			—	NS	NS	NS	NS	***	***	***	***	***
Apr				—	NS	NS	***	***	***	***	***	***
May					—	NS	***	***	***	***	***	***
Jun						—	NS	***	***	***	***	***
Jul							—	***	*	***	***	***
Aug								—	NS	NS	***	***
Sep									—	***	***	***
Oct										—	***	***
Nov											—	*
Dec												—

*Significances expressed by * against the pair of months, where * and *** denotes Significant difference $p \leq 0.05$ and $p \leq 0.001$ respectively. NS – No significant difference ($p > 0.05$).*

Difference in heart rate level for Jul vs. Sep and Nov vs. Dec was significant at $p \leq 0.05$; whereas for rest of the pairs of months, significant difference at $p \leq 0.001$ was seen.

4.3.2 Season wise variations viz. summer (Mar-Jun), monsoon (Jul-Sep) and winter (Oct-Feb) of heart rate

Table 4.17 Mean of the working heart rate value (bpm) of the weavers on the handloom workstation with the significance of difference between observations among different climatic seasons

Seasons	Mean ± SD
Summer	83.99 ± 10.19
Monsoon	82.9 ± 10.08
Winter	81.37 ± 10.31
Summer Vs Monsoon	***
Summer Vs Winter	***
Monsoon Vs Winter	***

Values are expressed as Mean ± SD. Significance is noted by against the data which is ***and denoted by $p \leq 0.001$.*

The values (Mean ± SD) of the heart rate of the weavers, grouped under different climatic seasons, were shown in Table 4.17. Significance of difference of heart rate at each handloom workstation across different seasons was also reflected in the same table.

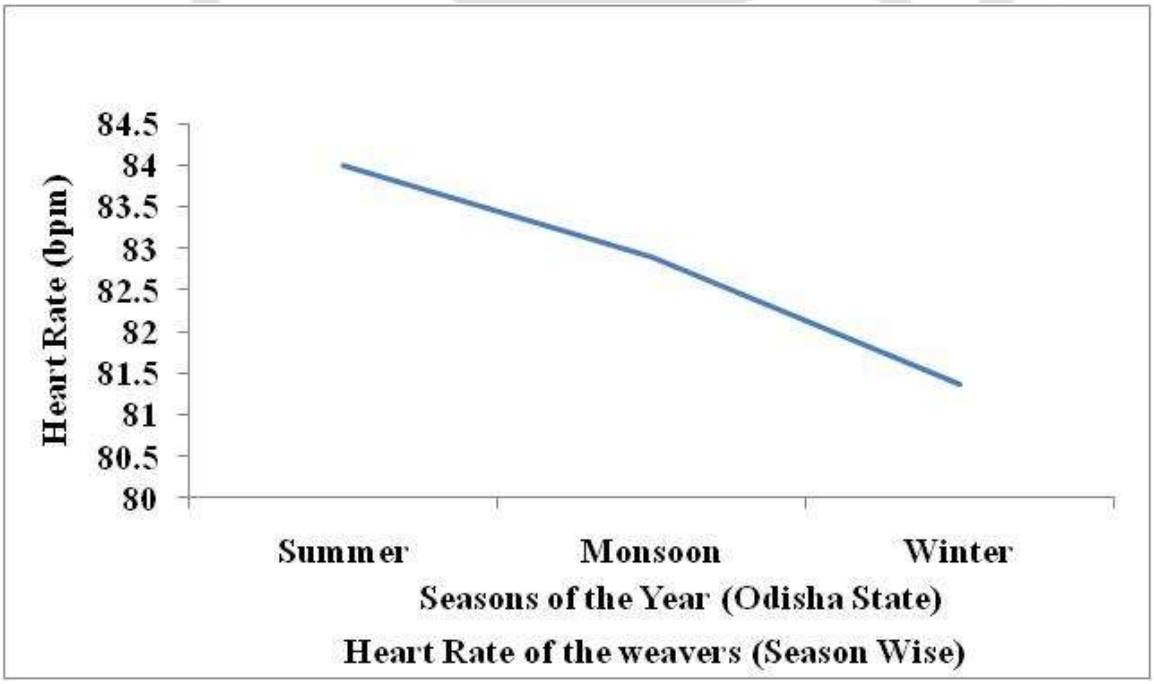

Fig. 4.8 Working heart rate (bpm) of the weavers on the handloom workstation (Season Wise)

A significant ($p \leq 0.001$) difference of the resting heart rate was observed across all pairs of seasons, as reflected above. The resting heart rate revealed a trend of gradual decrease from summer season through the monsoon to winter season (Fig. 4.8).

4.4 Cognitive workload analyses

The ratings for each of the six subscales along with the weightage of the demand of individual weaver were ascertained after the completion of a task of the cognitive workload by means of the NASA TLX tool. Data tabulated vide Table 4.18.

The ratings of the data reflected the maximal subjective workload for physical demand (Table 4.18), considered on advanced side. The overall mean weighted workload score (MWWL) was arrived at 73.87 ± 12.32 (Mean ± SD). Even though all the subscale demands were on higher side but amongst these the physical demand, effort and frustration were rated very high by the weavers while performing the main weaving as well as ancillary supporting works inside the work shed (Table 4.18).

Table 4.18 Cognitive demand levels as rated by the weavers while working on the handlooms using NASA TLX

Psychological Parameter	Raw Score (Mean ± SD)	Mean Weighted Ratio
Mental Demand (MD)	62.09 ± 20.1	67.5
Physical Demand (PD)	75.97 ± 17.09	79.59
Temporal Demand (TD)	64.36 ± 17.97	69.63
Performance (OP)	51.5 ± 12.22	55.36
Effort (EF)	75.62 ± 13.74	77.92
Frustration (FR)	71.46 ± 16.36	75.47
Average Mean Weighted Ratio	-	70.91
Overall Mean Weighted Workload Score (MWWL)	73.87 ± 12.32	-

*Values are expressed as Mean ± SD. R-Rating on NASA-TLX 20 point scale; W-Weightage of demand, n-number of samples. Raw Score = (∑R*5/n); Mean Weighted Ratio = (∑R*5*W/∑W); Overall Mean Weighted Workload Score = ∑[{MD(R*5*W) + PD(R*5*W) + TD(R*5*W) + OP(R*5*W) + EF(R*5*W) + FR(R*5*W)} / 15] / n*

Mean weighted ratio of the physical demand was rated very high (79.59) by the weavers. It reflected that in spite of putting in lots of physical, mental and temporal demand the performance of the weavers was on the dismal side. The weavers put in more efforts and were found to be successful in completing the tasks associated with their jobs even though they encountered very dispiriting working conditions which resulted in high frustration (Fig. 4.9). It is evident from the NASA TLX rating that it was the need of the hour to focus on reducing the perceived physical demand, effort and frustration amongst the weavers by providing the necessary remedial input in order to improve the working conditions of the weavers at their workstation.

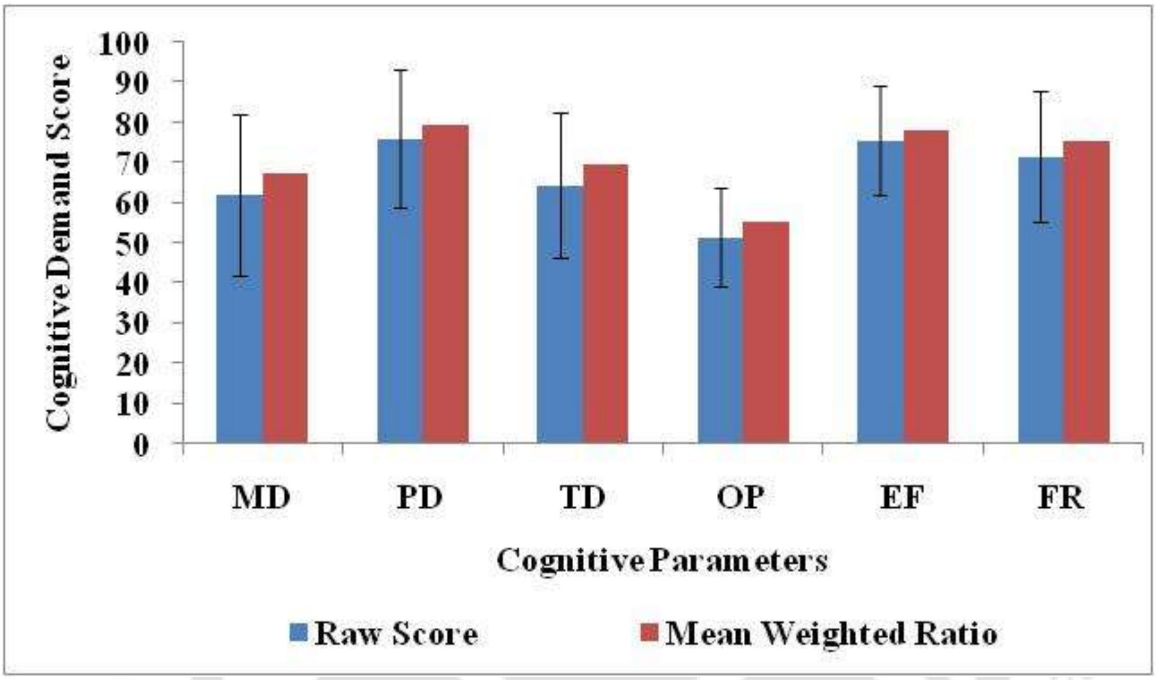

Fig. 4.9 Values were expressed as Mean ± SD. Cognitive demand values with mean weighted ratio as reported by the weavers while working on the handlooms using NASA TLX scale.MD, PD, TD, OP, EF and FR denote mental demand, physical demand, temporal demand, performance, effort and frustration respectively

4.5 Analyses of responses to questionnaire constructed for subjective evaluation of the impact of illumination and noise

Performance and efficiency of the weavers could be affected by various factors such as light, noise, air quality and thermal environment (Olesen, 1995). Table 4.19, 4.20 and 4.21 showcased the observations of the subjective responses to quantify the various discomfort parameters (like physical, physiological and psychological) using the questionnaires for effect of illumination and noise respectively (Appendix A) while carrying out the weaving operations.

4.5.1 Analysis of responses to the questionnaire for impact of illumination

Data demonstrated that in the prevailing illumination conditions the weavers underwent excruciating phases, which ultimately affected the quality and quantity of the product / output, besides impairment of their occupational health.

Table 4.19 Analysis of questionnaire on discomfort due to prevailing illumination level.

(Q.)	Aspects of Discomfort	Score (Mean ± SD)	Rating (Range)
(1)	Effect on work efficiency	4.07 ± 0.57	3 – 6
(2)	Headache	6.33 ± 0.47	6 – 7
(3)	Fatigue due to light	5.62 ± 0.68	5 – 7
(4)	Eye irritation	6.4 ± 0.49	6 – 7
(5)	Redness of eyes	5.39 ± 0.50	5 – 7
(6)	Water falling from eye	2.97 ± 0.86	2 – 5
(7)	Neck pain	6.23 ± 1.23	4 – 9
(8)	Lower back pain	7.03 ± 0.73	6 – 8
(9)	Thigh pain	5.58 ± 1.60	3 – 8
(10)	Waist pain	6.03 ± 0.78	5 – 8
(11)	Ankle/feet pain	3.86 ± 1.49	2 – 6
(12)	Shoulder pain	5.85 ± 1.11	4 – 8
(13)	Visual environment at work station	2.91 ± 0.38	1 – 3
(14)	Discomfort due to glare	4.41 ± 0.70	4 – 7
(15)	Sensation of light on handloom	3.25 ± 0.82	2 – 4
(16)	Sensation of light around the loom	3.70 ± 0.53	2 – 4
(17)	Illumination satisfaction level on loom	3.29 ± 0.77	1 – 4
(18)	Effect of light on job performance	2.22 ± 0.55	1 – 3
(19)	Mental demand	13.90 ± 2.15	10 – 20
(20)	Physical demand	15.98 ± 1.85	11 – 19
(21)	Temporal demand	13.22 ± 2.72	9 – 18
(22)	Performance	12.15 ± 2.23	10 – 20
(23)	Effort	15.68 ± 1.78	11 – 19
(24)	Frustration	15.94 ± 1.77	12 – 19
(25)	RPE due to illumination	3.62 ± 0.89	3 – 5

Ratings documented on 7-point Likert scale (Q1-Q6 and Q13-Q18), Borg's (Q7-Q12 and Q25) and NASA-TLX (Q19-Q24).

The weavers were most distraught with the drop in work efficiency. Nearly 91% of the weavers reported medium to moderately high bend in their work efficiency. While 77% of them complained of high headache, 33% informed of very high headache in course of working on the handloom. Some 51% described to have high to very high fatigue under such illumination. High and very high eye irritation was also borne by 60% and 40%

weavers respectively. Most of the weavers complained about the high redness of eyes while working in such work environment. Water falling from the eyes, however, was less frequently experienced with existing illumination in the loom workstation.

Most of the weavers (about 74.5%) enumerated very severe low back pain, whereas 25.5% had severe pain. Most of the weavers complained of very severe to severe pain in the waist, neck, shoulder and thigh. Some (20%) weavers reported ankle and foot pain. More than 80% weavers reported to suffer from pain most of the time of the day. 94% of the weavers reported slight discomfort (while others expressed severe discomfort) with the visual environment at the workstation. Discomfort due to glare was informed by 30% of the weavers. Perception of illumination on and around the handloom as reported was mostly below average. About 55% of the weavers were not satisfied with the level of illumination on their loom, which might pose detrimental effects on their job performance and leading to reduction in performance and efficiency by up to 20%, 10% and 5%, as testified by 6.5%, 65.5% and 27% of the weavers respectively.

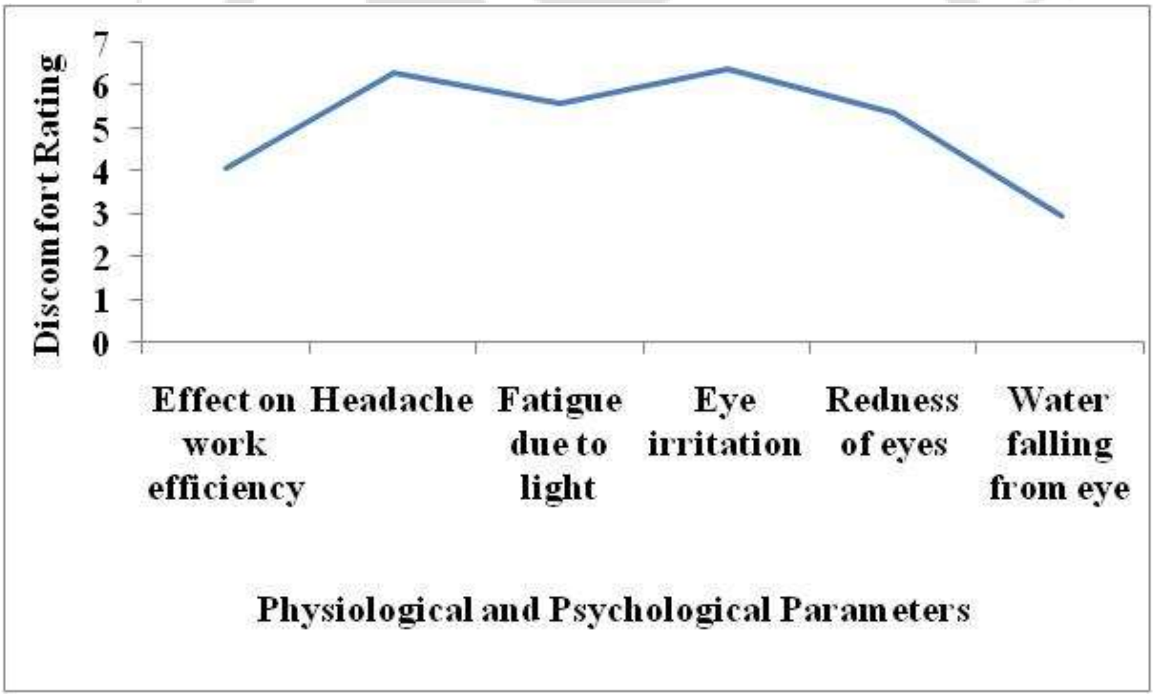

Fig. 4.10 (A) Physiological and Psychological discomfort due to prevailing illumination level as reported by the weavers. *Ratings documented on 7-point Likert scale.* Values are expressed as Mean.

As informed by the weavers, there was an overall reduction in job performance by 12%. Rate of perceived exertion was moderate strong (3) to strong (5) on Borg's scale. While marking the subjective mental workload using NASA-TLX, the weavers reported greater physical demand, efforts and frustration, whereas the other cognitive work load parameters like temporal demand, mental demand and performance were on a lower side. The data reflected that the weavers had to put more efforts in order to fulfil the physical demands, and might get frustrated for non-conformity to the temporal and mental demands

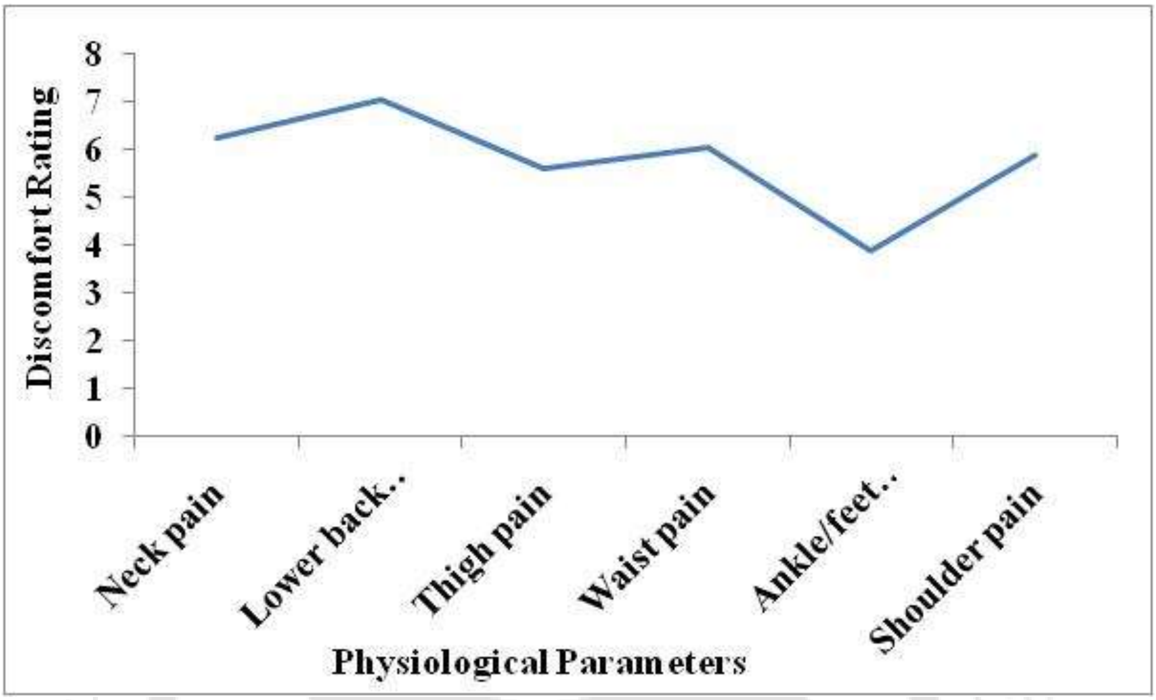

Fig. 4.10 (B) Physiological discomfort due to prevailing illumination level as reported by the weavers. *Ratings documented on Borg's 10 point.* Values are expressed as Mean.

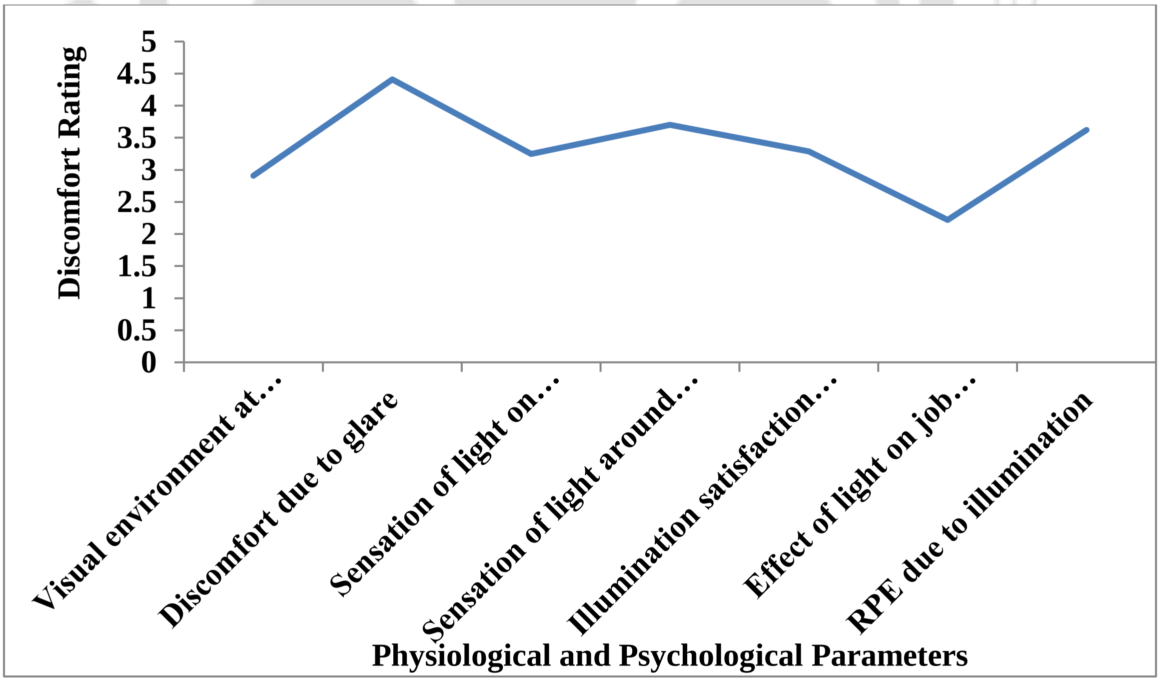

Fig. 4.10 (C) Physiological and Psychological discomfort due to prevailing illumination level as reported by the weavers. *Ratings documented on 7-point Likert scale.* Values are expressed as Mean.

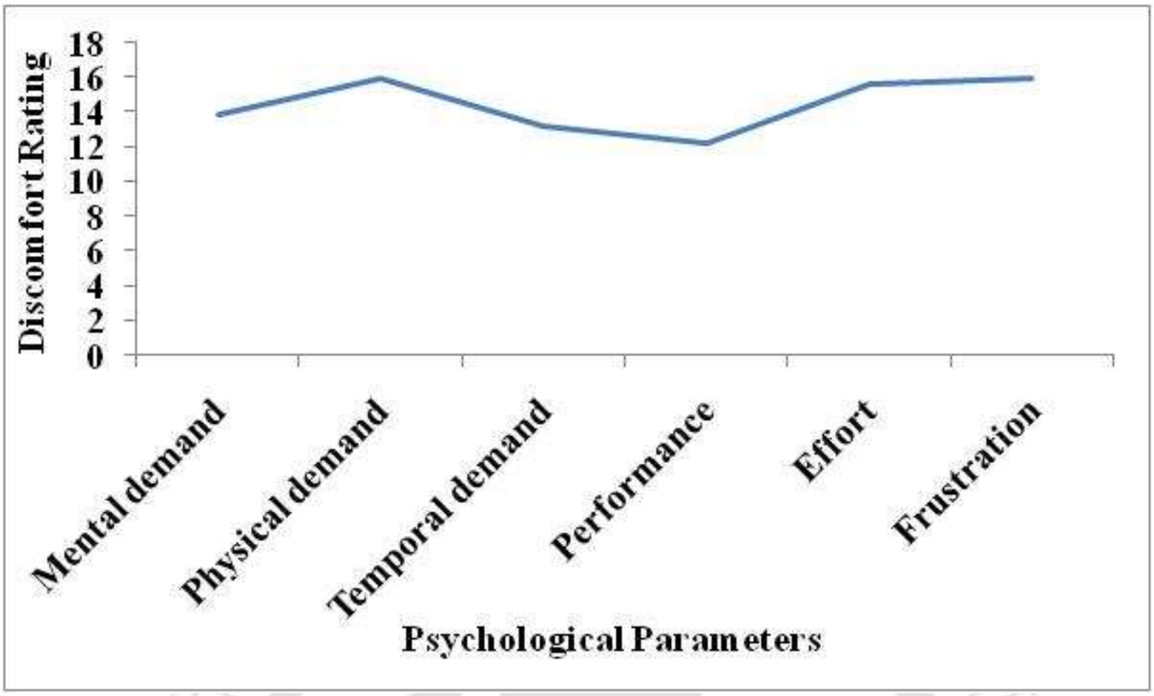

Fig. 4.10 (D) Psychological discomfort due to prevailing illumination level as reported by the weavers. *Ratings documented on NASA-TLX.* Values are expressed as Mean.

In response to the working on the loom various part of the body experiences discomfort/pain (Table 4.20); 48.5% of the weavers reported excruciating (10) to very severe (8) neck pain discomfort (while others expressed severe discomfort) in that prevailing illuminating environment. Very severe discomfort due to lower back pain was informed by 74.5% of the weavers. About 33.5% of the weavers had very severe thigh pain while other enunciated severe to moderate discomfort. Very severe waist pain was reported by 27.5% weavers and rest others were affected by severe (6) pain.

Table 4.20 Rating of perceived exertion of various discomfort factors as per Borg's CR10 Scale due to prevailing illumination levels

Discomfort Factor	Neck	Beck	Thigh	Waist	Feet	Shoulder
Rating of Perceived Exertion (Mean ± SD **)**	6.56 ± 1.01	6.44 ± 1.27	6.42 ± 0.95	5.60 ± 1.08	4.69 ± 1.03	5.74 ± 1.16

Values are expressed as Mean ± SD.

Due to the prevailing illumination level conditions 34.5% of the weaver uttered to have severe pain and rest had moderate to mild feet pain during weaving. As informed 34% of the weavers had very severe shoulder pain and the rest two third suffered severe to moderate. Neck pain was most excruciating discomfort parameter followed by lower back pain, thigh and shoulder pain and the perceived exertion due to feet pain was the least (Fig. 4.11) amongst them.

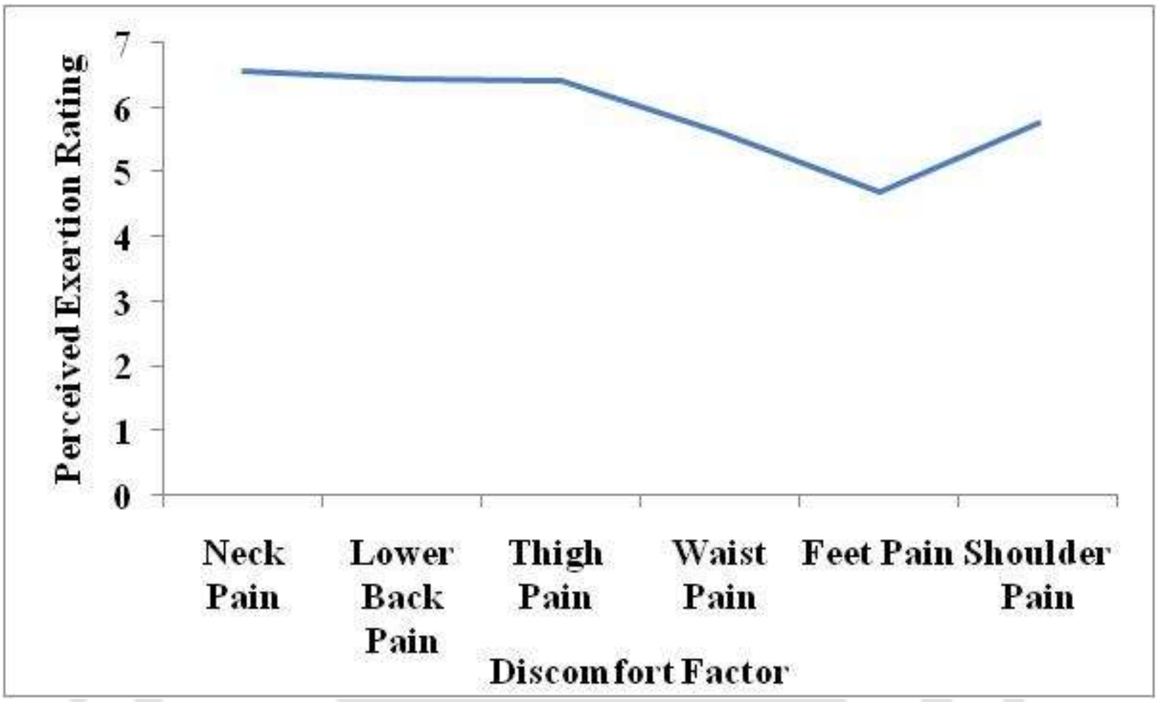

Fig. 4.11 Perceived Exertion Rating of various discomfort factors (Borg's CR 10 Scale)

Various tools and scales such as 7 point Likert scales, Borg's CR 100 Perceived Exertion Rating scale and NASA TLX tools were utilised to ascertain the precise subjective responses of physical, physiological and psychological distress of the weavers working in the handloom workstation under existing noisy environment.

In response to the impact of noise on weaving activities (Table 4.21), 83.5% of the weavers expressed and adjudged the medium noise level at the workplace while 16.5% scaled moderately high to high. Prevalent noise imposed negative consequences on the physiological parameters, which most of the weavers reported, like headache, fatigue, nausea, pain in ear and hearing problem in the scale of medium (4 on 7-point scale) to high (6 on 7-point scale).

Rate of perceived exertion due to noise was scored moderate strong (3) to strong (5) on Borg's scale, as expressed by 61% and 33% of the weavers respectively. Low level of satisfaction with the working conditions in the handloom shed was expressed by 72.5% of the weavers, whereas 27.5% reported that as moderate low to very low. Impact of noise on the working efficiency was rated in the scale of medium to moderately high by 90% and 10% weavers respectively.

4.5.2 Analysis of responses to the questionnaire for impact of noise

Table 4.21 Analysis of questionnaire on discomfort due to prevailing noise level.

(Q.)	**Aspects of Discomfort**	**Score(Mean ± SD)**	**Rating (Range)**
(1)	Perception of noise level	4.19 ± 0.44	4 – 6
(2)	Headache	4.33 ± 0.63	4 – 6
(3)	Fatigue due to noise	3.36 ± 0.61	3 – 5
(4)	Nausea due to noise	3.68 ± 0.70	3 – 6
(5)	Pain in ear due to noise	2.59 ± 0.91	2 – 6
(6)	Hearing problem (Threshold shift)	2.83 ± 0.96	2 – 5
(7)	RPE due to noise	3.62 ± 0.89	3 – 5
(8)	Satisfaction level with conditions on loom	2.71 ± 0.49	1 – 3
(9)	Degree of impact of noise on working efficiency	4.10 ± 0.30	4 – 5
(10)	Impact of noise on weaver	3.62 ± 0.50	2 – 4
(11)	Mental demand	13.89 ± 2.15	10 – 20
(12)	Physical demand	15.98 ± 1.85	11 – 19
(13)	Temporal demand	13.22 ± 2.72	9 – 18
(14)	Performance	12.15 ± 2.23	10 – 20
(15)	Effort	15.68 ± 1.78	11 – 19
(16)	Frustration	15.94 ± 1.77	12 – 19

Ratings documented on 7-point Likert scale (Q1-Q6 and Q8-Q10), Borg's (Q7) and NASA-TLX (Q11-Q16).

Even though the impact of noise level on the weaver during weaving process was not tolerable, they appeared to be somewhat accustomed to that – this was intrinsically hollowing and resulting in depleted occupational health conditions of the concerned, which might indirectly have dismal effect on their performance. During the cognitive workload measurement, the weavers described physical demand, efforts, and frustration to be on higher side, while temporal demand, mental demand, and performance were on lower side.

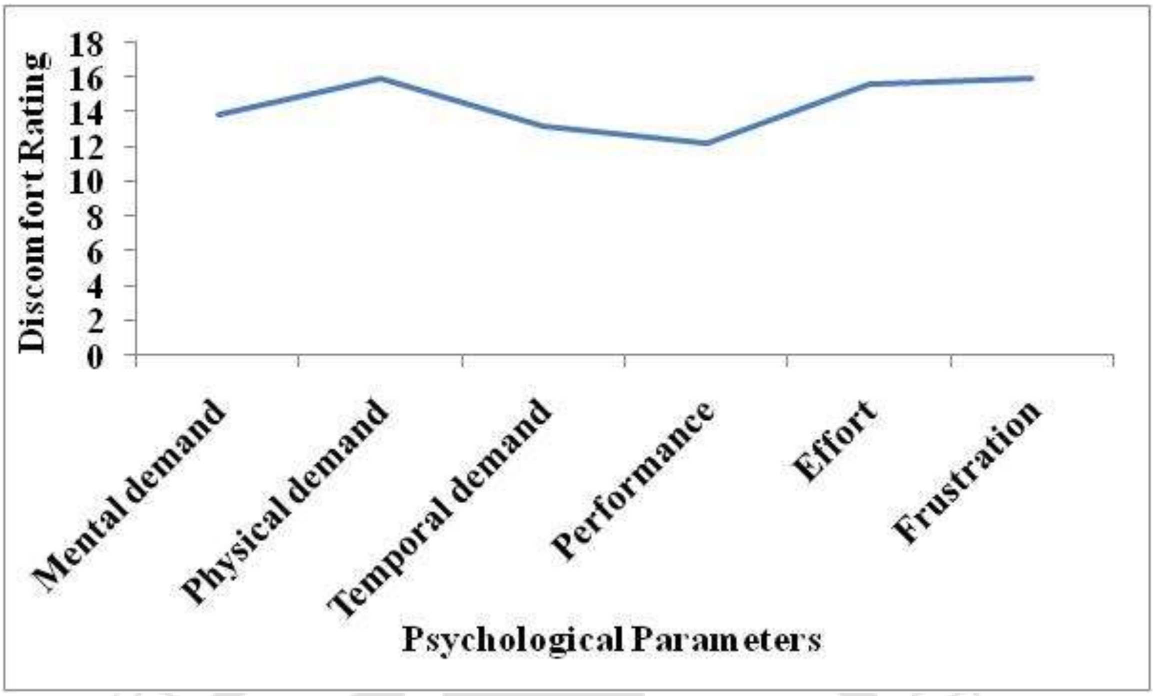

Fig. 4.12 (A) Psychological discomfort due to prevailing noise level as reported by the weavers. Ratings documented on NASA-TLX scale. Values are expressed as Mean.

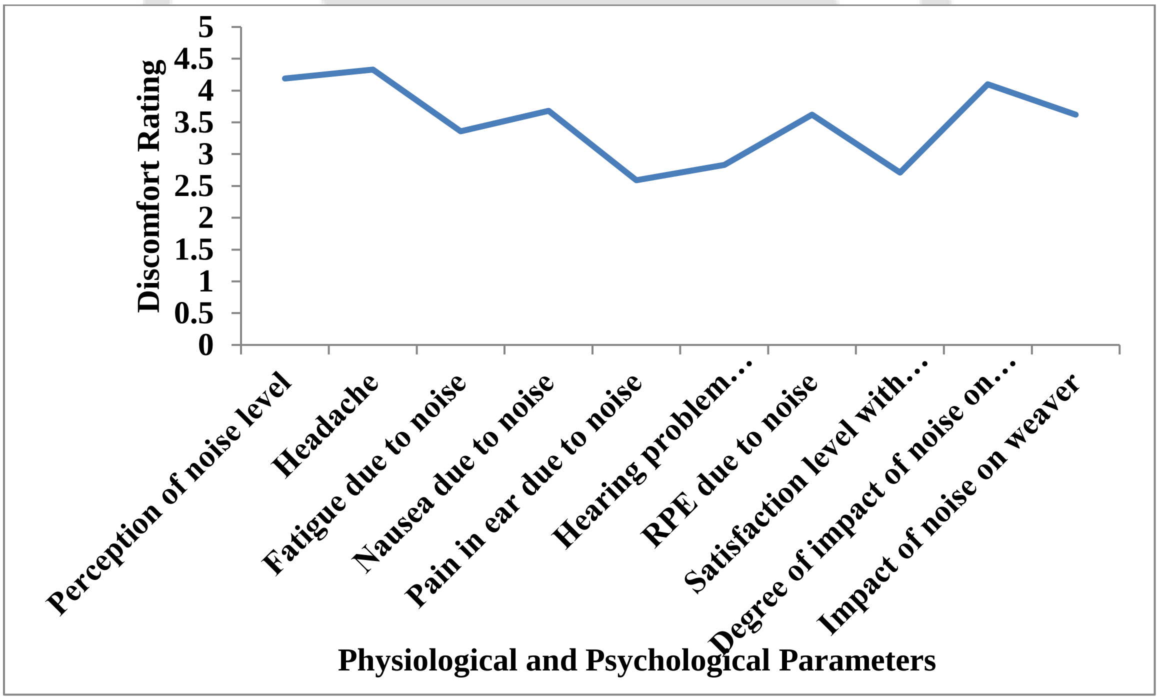

Fig. 4.12 (B) Physiological and Psychological discomfort due to prevailing noise level as reported by the weavers. *Ratings documented on 7-point Likert scale.* Values are expressed as Mean.

4.5.3 Reliability of questionnaire related to existing workplace illumination level

The questionnaire, before administering to the respondents was analysed for validity and test- retest reliability using Cronbach's Alpha (α) in statistical package for social science (SPSS v.20.0.0 for windows). Reliability evaluation of the questionnaire administered revealed excellent internal consistency thereby ensuring reliability of questions asked through the questionnaire (Cronbach's α = 0.979; α based on standardized items = 0.980). This was further confirmed by inter-item correlation and covariance matrices, which showed periodicity and regularity among rows and columns. The variances and covariances of the scores, were found to be within normal ranges with an excellent α. ANOVA with Friedman's Chi- Squared (χ^2_F) for between people (BP) and between items (BI) analysis showed no significant association [χ^2_F (BP-BI): 16.028, NS] and also no significant variation within people (WP) with residual component of non-additivity (RNI) [χ^2_F (WP-RNI): 0.951, NS]. However, Kendall's coefficient of concordance (W) represented little agreement between preference of ratings of the questions in the questionnaire rated by the respondents (W=0.011), thus indicating that the respondents fairly understood the rating / scoring of the questionnaire and marked their score after understanding the questions properly.

4.5.4 Reliability of questionnaire related to existing workplace noise level

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RNI) : 23.985, p < 0.001]. However, Kendall's coefficient of concordance represented little agreement between preference of ratings of the questions in the questionnaire rated by the respondents (W = 0.013), thus indicating that the respondents fairly understood the rating / scoring of the questionnaire and marked their score after understanding the questions properly.

4.5.5 Friedman's Chi-Squared (χ^2_F) test for independence of association for questionnaire on illumination

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 1,13,14 and 25 revealed no significant association between illumination and the psychological discomforts, such as, effect on work efficiency in the existing lighting, visual environment at workstation, discomfort due to glare, rating of perceived exertion (RPE) due to illumination [χ^2_F: 172.6 (NS) for Jan; 172.9 (NS) for Feb; 278.8 (NS) for Mar; 296.9 (NS) for Apr; 284.5 (NS) for May; 296.9 (NS) for Jun; 227.3 (NS) for Jul; 230.6 (NS) for Aug; 278.2 (NS) for Sep; 212.3 (NS) forOct;221.2 (NS) for Nov; 170.2 (NS) for Dec.], indicating that the questions were all independent of the illumination conditions.

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 2 – 6 revealed no significant association between illumination and the physical discomforts, such as, headache due to existing lighting conditions, fatigue due to light, eye irritation, redness of eyes, water falling from eye [χ^2_F: 272.6 (NS) for Jan; 272.9 (NS) for Feb; 494.1 (NS) for Mar; 527.9 (NS) for Apr; 503.0 (NS) for May; 527.9 (NS) for Jun; 389.2 (NS) for Jul; 398.4 (NS) for Aug; 490.2 (NS) for Sep; 356.2 (NS) for Oct; 369.6 (NS) for Nov; 267.9 (NS) for Dec.], indicating that the questions were all independent of the illumination conditions and subjective responses.

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 15 – 18 revealed no significant association between illumination and the psychological discomforts such as sensation of light on loom, sensation of light around loom, illumination satisfaction level on loom and effect of light on job performance [χ^2_F: 46.3 (NS) for Jan; 46.3 (NS) for Feb; 65.6 (NS) for Mar; 69.4 (NS) for Apr; 64.0 (NS) for May; 69.4 (NS) for Jun; 61.9 (NS) for Jul; 60.8 (NS) for Aug; 67.8 (NS) for Sep; 61.2 (NS) for Oct; 52.9 (NS) for Nov; 46.6 (NS) for Dec], indicating that the questions were all independent of the illumination conditions.

Table 4.22 Association / independence of questions in questionnaire with respect to illumination (Lux) value

Month	Jan			Feb			Mar			Apr		
Parameter	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P
Q.1,13,14,25	172.6	1916	NS	172.9	1916	NS	278.8	1916	NS	296.9	1916	NS
Q.2-6	272.6	2395	NS	272.9	2395	NS	494.1	2395	NS	527.9	2395	NS
Q.7-12	574.4	2874	NS	574.9	2874	NS	887.2	2874	NS	931.2	2874	NS
Q.15-18	46.3	1916	NS	46.3	1916	NS	65.6	1916	NS	69.4	1916	NS
Q.19-24	657.6	2874	NS	658.4	2874	NS	1244.3	2874	NS	1317.9	2874	NS
Month	May			Jun			Jul			Aug		
Parameter	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P
Q.1,13,14,25	284.5	1916	NS	296.9	1916	NS	227.3	1916	NS	230.6	1916	NS
Q.2-6	503.0	2395	NS	527.9	2395	NS	389.2	2395	NS	398.4	2395	NS
Q.7-12	897.3	2874	NS	931.2	2874	NS	744.0	2874	NS	757.3	2874	NS
Q.15-18	64.0	1916	NS	69.4	1916	NS	61.9	1916	NS	60.8	1916	NS
Q.19-24	1257.6	2874	NS	1317.9	2874	NS	983.4	2874	NS	1011.5	2874	NS
Month	Sep			Oct			Nov			Dec		
Parameter	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P	χ^2_F	df	P
Q.1,13,14,25	278.2	1916	NS	212.3	1916	NS	221.2	1916	NS	170.2	1916	NS
Q.2-6	490.2	2395	NS	356.2	2395	NS	369.6	2395	NS	267.9	2395	NS
Q.7-12	880.9	2874	NS	698.4	2874	NS	708.8	2874	NS	568.3	2874	NS
Q.15-18	67.8	1916	NS	61.2	1916	NS	52.9	1916	NS	46.6	1916	NS
Q.19-24	1229.2	2874	NS	892.8	2874	NS	888.8	2874	NS	641.	2874	NS

Q1 to Q25 represent the questions in the questionnaire for subjective rating of workplace illumination, where Q1 rates effect on work efficiency, Q2 headache, Q3 fatigue due to light, Q4 eye irritation, Q5 redness of eyes, Q6 water falling from eye, Q7 neck pain, Q8 lower back pain, Q9 thigh pain, Q10 waist pain, Q11 ankle / feet pain, Q12 shoulder pain, Q13 visual environment at work station, Q14 discomfort due to glare, Q15 sensation of light on loom, Q16 sensation of light around loom, Q17 illumination satisfaction level on loom, Q18 effect of light on job performance, Q19 mental demand, Q20 physical demand, Q21 temporal demand, Q22 performance Q23 effort, Q24 frustration and Q25 RPE due to illumination. Questions were grouped for better apprehension regarding aspect of perception and corresponding subjective responses. 'χ^2_F' represents Chi Squared Test value, df represents degree of freedom, 'P' represents probability and 'NS' represents no significant difference ($p > 0.05$).

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 19 – 24 revealed no significant association between illumination and the cognitive discomforts such as mental demand, physical demand, temporal demand, performance, effort and frustration [χ^2_F: 657.6 (NS) for Jan; 658.4 (NS) for Feb; 1244.3 (NS) for Mar; 1317 (NS) for Apr; 1257.6 (NS) for May; 1317.9 (NS) for Jun; 983.4 (NS) for Jul; 1011.5 (NS) for Aug; 1229.2 (NS) for Sep; 892.8 (NS) for Oct; 888.8 (NS) for Nov; 641.0 (NS) for Dec.], indicating that the questions were all independent of the illumination conditions.

4.5.6 Friedman's Chi-Squared (χ^2_F) test for independence of association for questionnaire on Noise

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 1 – 7, 10 revealed no significant association between noise and the questions on physical discomforts (Table 4.23) such as perception of noise level, headache due to noise, fatigue due to noise, nausea due to noise, pain in ear, hearing problem, rating of perceived exertion and impact of sound level on weaver [χ^2_F: 157.6 (NS) for Jan; 168.6 (NS) for Feb; 191.2 (NS) for Mar; 165.6 (NS) for Apr; 165.75 (NS) for May; 166.4 (NS) for Jun; 177.7 (NS) for Jul; 166.6 (NS) for Aug; 189.6 (NS) for Sep; 162.9 (NS) for Oct;183.6 (NS) for Nov; 182.7 (NS) for Dec], indicating that the questions were all independent of the noise conditions.

Friedman's Chi Squared (χ^2_F) test for independence of association for question numbers 8, 9, 11 – 16 revealed no significant association between noise and the questions on psychological discomforts such as satisfaction level with working condition in the loom shed, degree of impact of noise on working efficiency, mental demand, physical demand, temporal demand, performance, effort and frustration [χ^2_F: 159.9 (NS) for Jan; 175.9 (NS) for Feb; 200.1 (NS) for Mar; 168.9 (NS) for Apr; 171.7 (NS) for May; 169.6 (NS) for Jun; 184.3 (NS) for Jul; 169.9 (NS) for Aug; 198.7 (NS) for Sep; 164.3 (NS) for Oct; 191.1 (NS) for Nov; 190.0 (NS) for Dec], indicating that the questions were all independent of the noise conditions.

Table 4.23 Association / independence of questions in questionnaire with respect to noise value

Month	Jan			Feb			Mar			Apr		
Parameter	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p
Q.1-7,10	157.6	3832	NS	168.6	3832	NS	191.2	3832	NS	165.6	3832	NS
Q.8,9,11-16	159.9	3832	NS	175.9	3832	NS	200.1	3832	NS	168.9	3832	NS
Month	**May**			**Jun**			**Jul**			**Aug**		
Parameter	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p
Q.1-7,10	165.75	3832	NS	166.4	3832	NS	177.7	3832	NS	166.6	3832	NS
Q.8,9,11-16	171.7	3832	NS	169.6	3832	NS	184.3	3832	NS	169.9	3832	NS
Month	**Sep**			**Oct**			**Nov**			**Dec**		
Parameter	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p	χ^2_F	df	p
Q.1-7,10	189.6	3832	NS	162.9	3832	NS	183.6	3832	NS	182.7	3832	NS
Q.8,9,11-16	198.7	3832	NS	164.3	3832	NS	191.1	3832	NS	190.0	3832	NS

Q1 to Q16 represent the questions in the questionnaire for subjective rating of workplace noise, where Q1 rates perception of noise level,Q2 headache, Q3, fatigue due to noise, 4 nausea due to noise, 5 pain in ear due to noise; 6 hearing problem (Threshold shift), 7 RPE due to noise, 8 satisfaction level with conditions on loom, 9 degree of impact of noise on working efficiency, 10 impact of noise on weaver, 11 mental demand, 12 physical demand, 13 temporal demand, 14 performance, 15 effort and 16 frustration. Questions were grouped for better apprehension regarding aspect of perception and corresponding subjective responses. 'χ^2_F' represents Chi Squared Test value, df represents degree of freedom, 'P' represents probability and 'NS' represents no significant difference ($p > 0.05$).

4.5.7 Spearman's correlation coefficient (r) and Coefficient of Determination (CoD, r^2) for correlation of illumination level and corresponding subjective responses

Subjective responses to question numbers 1, 13, 14 and 25 in the questionnaire (Table 4.24) on the impact of illumination revealed that there was significant ($p < 0.001$) indirect correlation between illumination and the psychological discomfort factors such as effect on work efficiency in the existing lighting, visual environment at workstation, discomfort due to glare, rating of perceived exertion(RPE) due to illumination (r = - 0.09, p < 0.001 for Jan; r = - 0.09, p < 0.001 for Feb; r = -0.07, p < 0.001 for Mar; r = - 0.07, p < 0.001 for Apr; r = - 0.07, p < 0.001 for May; r = - 0.07, p < 0.001 for Jun; r = - 0.06, p < 0.001 for Jul; r = - 0.06, p < 0.001 for Aug; r = - 0.07, p < 0.001 for Sep; r = - 0.06, p < 0.001 for Oct; r = - 0.08, p < 0.001 for Nov; r = - 0.09, p < 0.001 for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of effect on work efficiency in the existing lighting, visual environment at workstation, discomfort due to glare, rating of perceived exertion(RPE) due to illumination (r^2=0.008 for Jan; r^2=0.008 for Feb; r^2=0.005 for Mar; r^2=0.005 for Apr; r^2=0.005 for May; r^2=0.005 for Jun; r^2=0.004 for Jul; r^2=0.005 for Aug; r^2=0.005 for Sep; r^2=0.004 for Oct; r^2=0.006 for Nov; r^2=0.008 for Dec).

Table 4.24 Month wise representation of correlation properties (r and r^2) showing the significance of difference between illumination and questions in the questionnaire

Month	Jan		Feb		Mar		Apr		May		Jun	
Parameter	r	r^2	r	r^2	r	r^2	r	r^2	r	r^2	r	r^2
Q.1,13,14,25	-0.92 ***	0.008	-0.09 ***	0.009	-0.07 ***	0.005	-0.07 ***	0.005	-0.07 ***	0.005	-0.07 ***	0.005
Q.2,3,4,5,6,	-0.35 ***	0.119	-0.34 ***	0.119	-0.32 ***	0.104	-0.33 ***	0.106	-0.33 ***	0.108	-0.33 ***	0.106
Q.7,8,9,10,11,12	-0.49 ***	0.242	-0.49 ***	0.242	-0.49 ***	0.236	-0.49 ***	0.237	-0.49 ***	0.238	-0.49 ***	0.237
Q.15,16,17,18	0.61 ***	0.376	0.61 ***	0.376	0.58 ***	0.340	0.59 ***	0.343	0.59 ***	0.350	0.59 ***	0.343
Q.19,20,21,22,23,24	-0.75 ***	0.565	-0.75 ***	0.566	-0.73 ***	0.539	-0.73 ***	0.539	-0.74 ***	0.545	-0.73 ***	0.539
Month	Jul		Aug		Sep		Oct		Nov		Dec	
Parameter	r	r^2	r	r^2	r	r^2	r	r^2	r	r^2	r	r^2
Q.1,13,14,25	-0.06 ***	0.004	-0.06 ***	0.004	0.068 ***	0.005	-0.06 ***	0.004	-0.06 ***	0.004	0.068 ***	0.005
Q.2,3,4,5,6,	-0.31 ***	0.096	-0.31 ***	0.099	-0.32 ***	0.102	-0.31 ***	0.093	-0.31 ***	0.109	-0.32 ***	0.118
Q.7,8,9,10,11,12	-0.47 ***	0.223	-0.48 ***	0.227	-0.48 ***	0.232	-0.47 ***	0.219	-0.48 ***	0.236	-0.48 ***	0.242
Q.15,16,17,18	0.56 ***	0.310	0.57 ***	0.320	0.58 ***	0.331	0.56 ***	0.302	0.57 ***	0.351	0.58 ***	0.375
Q.19,20,21,22,23,24	-0.72 ***	0.520	-0.73 ***	0.528	-0.73 ***	0.534	-0.72 ***	0.511	-0.73 ***	0.550	-0.73 ***	0.564

*Q1 to Q25 represent the questions in the questionnaire for subjective rating of workplace illumination, where Q1 rates effect on work efficiency, Q2 headache, Q3 fatigue due to light, Q4 eye irritation, Q5 redness of eyes, Q6 water falling from eye, Q7 neck pain, Q8 lower back pain, Q9 thigh pain, Q10 waist pain, Q11 ankle / feet pain, Q12 shoulder pain, Q13 visual environment at work station, Q14 discomfort due to glare, Q15 sensation of light on loom, Q16 sensation of light around loom, Q17 illumination satisfaction level on loom, Q18 effect of light on job performance, Q19 mental demand, Q20 physical demand, Q21 temporal demand, Q22 performance, Q23 effort, Q24 frustration and Q25 RPE due to illumination. Questions were grouped for better apprehension regarding aspect of perception and corresponding subjective responses. 'r' represents spearman's correlation coefficient and 'r^2' represents coefficient of determination (CoD), *** against an 'r' value indicates significant correlation at $P < 0.001$ between existing workplace illumination and mentioned questions of the questionnaire against the corresponding 'r'*

Subjective responses to Question numbers 2 – 6 in the questionnaire on the impact of illumination revealed significant ($p < 0.001$) inverse correlation between illumination and the physiological discomfort factors such as headache due to existing lighting conditions, fatigue due to light, eye irritation, redness of eyes, water falling from eye ($r = -0.35$, $p < 0.001$ for Jan; $r = -0.34$, $p < 0.001$ for Feb; $r = -0.32$, $p < 0.001$ for Mar; $r = -0.33$, $p < 0.001$ for Apr; $r = -0.33$, $p < 0.001$ for May; $r = -0.33$, $p < 0.001$ for Jun; $r = -0.31$, $p < 0.001$ for Jul; $r = -0.31$, $p < 0.001$ for Aug; $r = -0.32$, $p < 0.001$ for Sep; $r = -0.30$, $p < 0.001$ for Oct; $r = -0.33$, $p < 0.001$ for Nov; $r = -0.34$, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of effect on headache due to existing lighting conditions, fatigue due to light, eye irritation, redness of eyes, water falling from eye ($r^2 = 0.119$ for Jan; $r^2 = 0.119$ for Feb; $r^2 = 0.104$ for Mar; $r^2 = 0.106$ for Apr; $r^2 = 0.108$ for May; $r^2 = 0.106$ for Jun; $r^2 = 0.096$ for Jul; $r^2 = 0.099$ for Aug; $r^2 = 0.102$ for Sep; $r^2 = 0.093$ for Oct; $r^2 = 0.109$ for Nov; $r^2 = 0.118$ for Dec).

Subjective responses to Question numbers 7 – 12 in the questionnaire on the impact on illumination revealed significant ($p < 0.001$) inverse correlation between illumination and the physiological discomfort factors such as neck pain due to existing lighting conditions, lower back pain, thigh pain, waist pain, ankle/ feet pain and shoulder pain ($r = - 0.49$, $p < 0.001$ for Jan; $r = - 0.49$, $p < 0.001$ for Feb; $r = - 0.49$, $p < 0.001$ for Mar; $r = - 0.49$, $p < 0.001$ for Apr; $r = - 0.49$, $p < 0.001$ for May; $r = - 0.49$, $p < 0.001$ for Jun; $r = - 0.47$, $p < 0.001$ for Jul; $r = - 0.48$, $p < 0.001$ for Aug; $r = - 0.48$, $p < 0.001$ for Sep; $r = - 0.47$, $p < 0.001$ for Oct; $r = - 0.49$, $p < 0.001$ for Nov; $r = - 0.49$, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of neck pain due to existing lighting conditions, lower back pain, thigh pain, waist pain, ankle/ feet pain and shoulder pain ($r^2 = 0.242$ for Jan; $r^2 = 0.242$ for Feb; $r^2 = 0.236$ for Mar; $r^2 = 0.237$ for Apr; $r^2 = 0.238$ for May; $r^2 = 0.237$ for Jun; $r^2 = 0.223$ for Jul; $r^2 = 0.227$ for Aug; $r^2 = 0.232$ for Sep; $r^2 = 0.219$ for Oct; $r^2 = 0.236$ for Nov; $r^2 = 0.242$ for Dec).

Subjective responses to question numbers 15 – 18 in the questionnaire on the impact of illumination revealed highly significant ($p < 0.001$) direct correlation between illumination and the physiological discomfort factors such as sensation of light on loom, sensation of light around loom, illumination satisfaction level on loom and effect of light on job performance ($r = + 0.61$, $p < 0.001$ for Jan; $r = + 0.61$, $p < 0.001$ for Feb;

$r = +0.58$, $p < 0.001$ for Mar; $r = +0.59$, $p < 0.001$ for Apr; $r = +0.59$, $p < 0.001$ for May; $r = +0.59$, $p < 0.001$ for Jun; $r = +0.56$, $p < 0.001$ for Jul; $r = +0.57$, $p < 0.001$ for Aug; $r = +0.58$, $p < 0.001$ for Sep; $r = +0.55$, $p < 0.001$ for Oct; $r = +0.59$, $p < 0.001$ for Nov; $r = +0.61$, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of sensation of light on loom, sensation of light around loom, illumination satisfaction level on loom and effect of light on job performance ($r^2 = 0.376$ for Jan; $r^2 = 0.376$ for Feb; $r^2 = 0.340$ for Mar; $r^2 = 0.343$ for Apr; $r^2 = 0.350$ for May; $r^2 = 0.343$ for Jun; $r^2 = 0.311$ for Jul; $r^2 = 0.320$ for Aug; $r^2 = 0.331$ for Sep; $r^2 = 0.302$ for Oct; $r^2 = 0.351$ for Nov; $r^2 = 0.375$ for Dec).

Subjective responses to question numbers 19 – 24 in the questionnaire on the impact of illumination revealed highly significant ($p < 0.001$) inverse correlation between illumination and the psychological discomfort factors such as mental demand, physical demand, temporal demand, performance, effort and frustration ($r = -0.75$, $p < 0.001$ for Jan; $r = -0.75$, $p < 0.001$ for Feb; $r = -0.73$, $p < 0.001$ for Mar; $r = -0.73$, $p < 0.001$ for Apr; $r = -0.74$, $p < 0.001$ for May; $r = -0.73$, $p < 0.001$ for Jun; $r = -0.72$, $p < 0.001$ for Jul; $r = -0.73$, $p < 0.001$ for Aug; $r = -0.73$, $p < 0.001$ for Sep; $r = -0.71$, $p < 0.001$ for Oct; $r = -0.74$, $p < 0.001$ for Nov; $r = -0.75$, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of effect on work efficiency in the existing lighting, visual environment at workstation, discomfort due to glare, rating of perceived exertion(RPE) due to illumination ($r^2 = 0.565$ for Jan; $r^2 = 0.566$ for Feb; $r^2 = 0.539$ for Mar; $r^2 = 0.539$ for Apr; $r^2 = 0.545$ for May; $r^2 = 0.539$ for Jun; $r^2 = 0.520$ for Jul; $r^2 = 0.528$for Aug; $r^2 = 0.534$ for Sep; $r^2 = 0.511$ for Oct; $r^2 = 0.550$ for Nov; $r^2 = 0.564$ for Dec).

4.5.8 Spearman's correlation coefficient (r) and Coefficient of Determination (CoD, r^2) for correlation of Noise level and corresponding subjective responses

Subjective responses to Questions 1 – 7, 10 in the questionnaire on the impact of noise revealed highly significant ($p < 0.001$) direct correlation between noise and the physical discomfort factors such as perception of noise level, headache due to noise, fatigue due to noise, nausea due to noise, pain in ear, hearing problem, rating of perceived exertion and impact of sound level on weaver (r = + 0.63, $p < 0.001$ for Jan; r = + 0.64, $p < 0.001$ for Feb; r = + 0.59, $p < 0.001$ for Mar; r = + 0.66, $p < 0.001$ for Apr; r = + 0.66, $p < 0.001$ for May; r = + 0.66, $p < 0.001$ for Jun; r = + 0.66, $p < 0.001$ for Jul; r = + 0.65, $p < 0.001$ for Aug; r = + 0.60, $p < 0.001$ for Sep; r = + 0.67, $p < 0.001$ for Oct; r = + 0.64, $p < 0.001$ for Nov; r = + 0.65, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD ; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of perception of noise level, headache due to noise, fatigue due to noise, nausea due to noise, pain in ear, hearing problem, rating of perceived exertion and impact of sound level on weaver (r^2 = 0.392 for Jan; r^2 = 0.414 for Feb; r^2 = 0.343 for Mar; r^2 = 0.432 for Apr; r^2 = 0.433 for May; r^2 = 0.437 for Jun; r^2 = 0.430 for Jul; r^2 = 0.428 for Aug; r^2 = 0.360 for Sep; r^2 = 0.447 for Oct; r^2 = 0.409 for Nov; r^2 = 0.417 for Dec).

Table 4.25 Month wise representation of correlation and coefficient of determination (r and r^2, respectively) are showing the significance of difference between noise (dB) and questions in the questionnaire

Month	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
Parameter	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**
Q 1-7,10	0.63 ***	0.392	0.64 ***	0.414	0.59 ***	0.343	0.66 ***	0.432	0.66 ***	0.433	0.66 ***	0.437
Q 8,9,11-16	00.25 ***	0.064	0.26 ***	0.065	0.28 ***	0.077	0.27 ***	0.74	0.27 ***	0.070	0.28 ***	0.076

Month	**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Parameter	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**	**r**	**r^2**
Q 1-7,10	0.66 ***	0.430	0.65 ***	0.428	0.60 ***	0.360	0.67 ***	0.447	0.64 ***	0.409	0.65 ***	0.417
Q 8,9,11-16	0.28 ***	0.077	0.27 ***	0.073	0.27 ***	0.075	0.28 ***	0.078	0.28 ***	0.077	0.28 ***	0.077

Q1 to Q16 represent the questions in the questionnaire for subjective rating of workplace noise, where Q1 rates perception of noise level,Q2 headache, Q3, fatigue due to noise, 4 nausea due to noise, 5 pain in ear due to noise; 6 hearing problem (Threshold shift), 7 RPE due to noise, 8 satisfaction level with conditions on loom, 9 degree of impact of noise on working efficiency, 10 impact of noise on weaver, 11 mental demand, 12 physical demand, 13 temporal demand, 14 performance, 15 effort and 16 frustration. 'r' represents spearman's correlation coefficient; ***r^2*** *represents coefficient of Determination(CoD) and *** against an 'r' value indicates significant correlation at $p < 0.001$ between existing workplace noise and mentioned questions of the questionnaire against the corresponding 'r'.*

Subjective responses to Questions 8, 9, 11 – 16 in the questionnaire on the impact of noise revealed significant ($p < 0.001$) direct correlation between noise and the psychological discomfort factors such as satisfaction level with working condition in the loom shed, degree of impact of noise on working efficiency, mental demand, physical demand, temporal demand, performance, effort and frustration. ($r = + 0.25$, $p < 0.001$ for Jan; $r = + 0.26$, $p < 0.001$ for Feb; $r = + 0.28$, $p < 0.001$ for Mar; $r = + 0.27$, $p < 0.001$ for Apr; $r = + 0.27$, $p < 0.001$ for May; $r = + 0.28$, $p < 0.001$ for Jun; $r = + 0.28$, $p < 0.001$ for Jul; $r = + 0.27$, $p < 0.001$ for Aug; $r = + 0.27$, $p < 0.001$ for Sep; $r = + 0.28$, $p < 0.001$ for Oct; $r = + 0.28$, $p < 0.001$ for Nov; $r = + 0.28$, $p < 0.001$ for Dec).

Calculation of coefficient of determination (CoD; r^2) showed variable trend of shared variance, thereby indicating differential level of dependence of satisfaction level with working condition in the loom shed, degree of impact of noise on working efficiency, mental demand, physical demand, temporal demand, performance, effort and frustration. ($r^2 = 0.064$ for Jan; $r^2 = 0.065$ for Feb; $r^2 = 0.077$ for Mar; $r^2 = 0.074$ for Apr; $r^2 = 0.070$ for May; $r^2 = 0.0760$ for Jun; $r^2 = 0.077$ for Jul; $r^2 = 0.073$ for Aug; $r^2 = 0.075$ for Sep; $r^2 = 0.078$ for Oct; $r^2 = 0.077$ for Nov; $r^2 = 0.077$ for Dec).

4.5.9 Correlation matrix to analyse month wise vs. question wise inter-item correlation

Correlation matrix of questions in the questionnaires on impact of illumination and noise revealed considerable dependence of illumination and noise on the health and performance of the weavers, as tabulated in the table 4.26 and 4.27 respectively. It could be seen from the table that subjective rating showed marked influence of illumination and noise.

Table 4.26 depicted correlation of subjective perception with illumination level, compared individually month-wise (from Jan to Dec). It was clearly evinced from the table above that *correlation of effect on work efficiency (Q1) with illumination level* showed greater extent of compromise of work efficiency with lesser level of illumination revealing though a variable trend. It elucidated that there is a strong indirect association of work efficiency with illumination as a factor ($-0.64 \geq r \geq -0.68$). The *correlation of headache (Q2) with illumination level* expressed a fluctuating trend of greater chances of headache with lesser level of illumination. There was a remarkable indirect association/relation of headache with illumination as a factor ($-0.63 \geq r \geq -0.73$).The testament of the statistical inference reflected that the *correlation of fatigue (Q3) with the existing lighting conditions* have significant dent and having varying trend which caused greater extent of suffering on the fatigue with lesser level of illumination There was also a remarkable indirect association of illumination with fatigue as an important component ($-0.73 \geq r \geq -0.83$).

Table 4.26 Month wise representation of correlation coefficient (r) between illumination (Lux) and response against the questions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q1	-0.67	-0.67	-0.65	-0.64	-0.65	-0.64	-0.68	-0.67	-0.66	-0.68	-0.67	-0.67
Q2	-0.73	-0.73	-0.66	-0.67	-0.68	-0.67	-0.64	-0.65	-0.66	-0.63	-0.69	-0.73
Q3	-0.83	-0.83	-0.78	-0.79	-0.80	-0.79	-0.74	-0.75	-0.77	-0.73	-0.80	-0.83
Q4	-0.78	-0.78	-0.72	-0.73	-0.74	-0.73	-0.69	-0.70	-0.71	-0.68	-0.74	-0.78
Q5	-0.77	-0.77	-0.71	-0.71	-0.72	-0.71	-0.68	-0.69	-0.70	-0.66	-0.73	-0.76
Q6	-0.86	-0.86	-0.82	-0.82	-0.82	-0.82	-0.79	-0.80	-0.81	-0.78	-0.83	-0.85
Q7	-0.97	-0.97	-0.96	-0.96	-0.96	-0.96	-0.94	-0.95	-0.95	-0.93	-0.96	-0.97
Q8	-0.92	-0.92	-0.90	-0.90	-0.90	-0.90	-0.87	-0.88	-0.89	-0.87	-0.90	-0.92
Q9	-0.98	-0.98	-0.97	-0.97	-0.97	-0.97	-0.94	-0.95	-0.96	-0.93	-0.97	-0.98
Q10	-0.91	-0.91	-0.88	-0.88	-0.89	-0.88	-0.86	-0.86	-0.87	-0.85	-0.88	-0.91
Q11	-0.95	-0.95	-0.91	-0.92	-0.92	-0.92	-0.88	-0.89	-0.90	-0.86	-0.92	-0.94
Q12	0.90	0.90	0.85	0.85	0.86	0.85	0.82	0.83	0.84	0.81	0.86	0.89
Q13	0.33	0.33	0.29	0.28	0.29	0.28	0.28	0.28	0.28	0.28	0.30	0.32
Q14	0.87	0.87	0.90	0.89	0.89	0.89	0.92	0.92	0.90	0.92	0.89	0.87
Q15	0.85	0.85	0.78	0.80	0.81	0.80	0.76	0.77	0.79	0.74	0.81	0.84
Q16	0.66	0.66	0.59	0.59	0.60	0.59	0.57	0.57	0.58	0.56	0.61	0.65
Q17	0.81	0.81	0.78	0.78	0.79	0.78	0.74	0.75	0.76	0.72	0.79	0.81
Q18	0.86	0.86	0.86	0.86	0.86	0.86	0.83	0.84	0.85	0.83	0.85	0.86
Q19	-0.93	-0.93	-0.90	-0.90	-0.91	-0.90	-0.89	-0.90	-0.90	-0.88	-0.91	-0.93
Q20	-0.97	-0.97	-0.97	-0.97	-0.97	-0.97	-0.98	-0.98	-0.97	-0.97	-0.97	-0.97
Q21	-0.95	-0.95	-0.92	-0.92	-0.93	-0.92	-0.88	-0.89	-0.91	-0.86	-0.93	-0.95
Q22	-0.80	-0.80	-0.76	-0.76	-0.77	-0.76	-0.73	-0.74	-0.75	-0.72	-0.77	-0.80
Q23	-0.98	-0.98	-0.97	-0.97	-0.97	-0.97	-0.97	-0.98	-0.98	-0.97	-0.98	-0.98
Q24	-0.80	-0.98	-0.97	-0.97	-0.97	-0.97	-0.95	-0.96	-0.96	-0.95	-0.97	-0.98
Q25	-0.74	-0.74	-0.67	-0.67	-0.69	-0.67	-0.65	-0.65	-0.66	-0.63	-0.70	-0.73

Q1 to Q25 represent the questions in the questionnaire for subjective rating of workplace illumination, where Q1 rates effect on work efficiency, Q2 headache, Q3 fatigue due to light, Q4 eye irritation, Q5 redness of eyes, Q6 water falling from eye, Q7 neck pain, Q8 lower back pain, Q9 thigh pain, Q10 waist pain, Q11 ankle / feet pain, Q12 shoulder pain, Q13 visual environment at work station, Q14 discomfort due to glare, Q15 sensation of light on loom, Q16 sensation of light around loom, Q17 illumination satisfaction level on loom, Q18 effect of light on job performance, Q19 mental demand, Q20 physical demand, Q21 temporal demand, Q22 performance, Q23 effort, Q24 frustration and Q25 RPE due to illumination. 'r' represents spearman's correlation coefficient.

The result articulates that the correlation of *eye irritation (Q4) with lighting conditions* showed a greater extent of suffering on the eye irritation with lesser level of illumination having a variable trend. There was a significant indirect correlation of illumination with eye irritation as a factor (-0.68 ≥ r ≥ -0.78). The results clearly enunciated that the correlation of the *redness of eyes (Q5) with the prevailing illumination level conditions* having fickle trend exhibited greater extent of failure on redness of eyes with lesser level of illumination. There was a significant indirect association of illumination with redness of eyes as one of the factor (-0.66 ≥ r ≥ -0.77).

Similarly the *correlation of water falling from the eyes (Q6) with illumination level* evinced greater extent of compromise of eye watering with lesser level of illumination revealed a variable trend. It clearly indicate a strong relation of water falling from the eyes with the existing illumination level conditions as a factor (-0.78 ≥ r ≥ -0.86). The *correlation of* neck pain *(Q7) with illumination level* showed an inconstant trend of having greater chances of neck pain with lesser level of illumination. The neck pain with illumination as a factor has exhibited a significant indirect association (-0.93 ≥ r ≥ -0.97).

The *correlation of lower back pain (Q8) with illumination level* showed a fluctuating inverse trend of having greater chances of back pain with lesser level of illumination. Results also reflected that there was considerable association of illumination with lower back pain as a factor (-0.87 ≥ r ≥ -0.92). Moreover, the data elucidated that *correlation of thigh pain (Q9) during handloom operation with the illumination level* was highly excruciating and based on data evidence exhibited a high level of sufferings of thigh pain with respect to the existing level of illumination having a fluctuating tendency. A remarkable relation of illumination with thigh pain as a factor has been noticed (-0.93 ≥ r ≥ -0.98). The *correlation of waist pain (Q10) with the existing illumination level* has very crucial interaction which reflected a variable tendency with greater extent of consistency on the waist pain with lesser level of illumination. Based on evidence it was concluded that the existing illumination level with waist pain as a factor has remarkable association (-0.85 ≥ r ≥ -0.91). The outcome of the statistical analysis also enunciates that *correlation of ankle / feet pain (Q11) during handloom operation with illumination level* have shown a greater extent of sufferings on the ankle/feet pain with the existing illumination level conditions with a varying trend. Considerable association of illumination with ankle / feet pain as a factor have been exhibited (-0.86 ≥ r ≥ -0.95). The *correlation of shoulder pain (Q12) with* *illumination level* has depicted a direct influence with variable tendency to a greater extent of failure on the shoulder pain with higher level of illumination. Notable relation of illumination with shoulder pain as a factor has been marked (+0.81 ≥ r ≥ +0.90). Based on the results as shown the *correlation of visual environment (Q13) with illumination conditions* have reflected a positive tendency with inferior extent of effectiveness on the visual environment with lesser level of illumination propound a variable trend. No remarkable association have been observed between the illumination with the visual environment in the shed (+0.28 ≥ r ≥ +0.33). *Correlation of the degree of discomfort (Q14) due to glare* established a positive preference with a greater extent of suffering on the degree of discomfort portrayed a fluctuating tendency. Glare with degree of discomfort as a factor has remarkable positive association (+0.87 ≥ r ≥ +0.92). The correlation of the *sensation for lighting on the handloom (Q15) with illumination level* evinced positive well-built relation with fluctuating trend and suffering on the sensation for illumination on the workplace (+0.74 ≥ r ≥ +0.85). It was clearly understood that the *correlation of the sensation for lighting (Q16) around the handloom also expressed* a variable tendency of having chance of positive sensation with the prevailing illumination level and have association of illumination with sensation of lighting around the handloom up to certain extent (+0.56 ≥ r ≥ +0.66). The outcome of the statistical analysis enunciate that correlation of the *satisfaction level (Q17) for illumination with illumination level* have shown a positive strong compromise on the satisfaction level with prevailing level of illumination exhibited a varying trend. The relation of illumination with satisfaction level for illumination was seen healthy (+0.72 ≥ r ≥ +0.81). Regarding the impact of illumination conditions the correlation of *job performance (Q18) with the illumination level* conditions have expressed direct pernicious effect on the job performance due to prevailing illumination conditions at the workplace with a variable trend. Strong relation of illumination with job performance at the workplace has been established (+0.83 ≥ r ≥ +0.86). The testament of the results showed the correlation of the mental workload with illumination level which has elucidated a negative correlation of all the cognitive load factors with illumination conditions. In total there were six subscales out of which three focused on the demand (mental Q19, physical Q20 and temporal Q21 demand) while the other three focused on the interaction of the weaver with the task (performance Q22, effort Q23 and frustration Q24 level). The correlation of *the demand factors (Q19, Q20 and Q21) as well as of the task interaction factors (Q22; Q23 and Q24) with the illumination level* conditions have expressed indirect effect of illumination level on the cognitive and task demand factors with a variable tendency. Strong relation of illumination has been established with the cognitive as well as with the task demand factors. Based on statistical evidence it can be inferenced that poor illumination conditions have detrimental effect on the physical ($-0.97 \geq r \geq -0.98$) demand and effort ($-0.97 \geq r \geq -0.98$) followed by mental ($-0.88 \geq r \geq -0.93$) and temporal ($-0.86 \geq r \geq -0.95$) demands whereas the frustration ($-0.80 \geq r \geq -0.98$) and performance ($-0.72 \geq r \geq -0.80$) were also considerably influenced by the prevailing illumination conditions.

The correlation of the *rating of perceived exertion (Q25) with illumination level* evinced indirect relation with variable tendency and suffering on the perceived exertion with poor level of illumination. Prominent association has been ascertained regarding rating of perceived exertion ($-0.63 \geq r \geq -0.74$) with illumination as a factor.

Table 4.27 Month wise representation of correlation coefficient (r) between noise (dB) and response against the questions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Q1	0.84	0.89	0.72	0.85	0.88	0.82	0.80	0.87	0.68	0.81	0.77	0.69
Q2	0.85	0.89	0.74	0.89	0.90	0.91	0.88	0.89	0.76	0.91	0.86	0.88
Q3	0.85	0.90	0.73	0.90	0.91	0.89	0.88	0.90	0.73	0.89	0.86	0.84
Q4	0.88	0.86	0.88	0.90	0.88	0.90	0.89	0.89	0.91	0.90	0.91	0.91
Q5	0.91	0.95	0.80	0.93	0.95	0.93	0.92	0.94	0.80	0.93	0.88	0.87
Q6	0.87	0.88	0.82	0.92	0.90	0.92	0.93	0.91	0.85	0.94	0.92	0.94
Q7	0.77	0.80	0.69	0.83	0.84	0.84	0.83	0.82	0.72	0.86	0.79	0.83
Q8	0.47	0.47	0.72	0.55	0.49	0.56	0.58	0.55	0.69	0.59	0.62	0.64
Q9	0.71	0.83	0.59	0.78	0.78	0.77	0.68	0.78	0.56	0.71	0.71	0.62
Q10	0.57	0.56	0.78	0.65	0.60	0.66	0.70	0.63	0.85	0.70	0.68	0.76
Q11	0.89	0.90	0.93	0.95	0.93	0.95	0.95	0.95	0.92	0.96	0.95	0.94
Q12	0.75	0.74	0.87	0.82	0.79	0.83	0.85	0.82	0.84	0.85	0.86	0.85
Q13	0.81	0.83	0.90	0.89	0.86	0.90	0.91	0.88	0.94	0.93	0.90	0.94
Q14	0.94	0.95	0.91	0.95	0.95	0.95	0.95	0.96	0.89	0.94	0.95	0.92
Q15	0.76	0.76	0.90	0.84	0.81	0.85	0.85	0.83	0.86	0.87	0.86	0.85
Q16	0.78	0.76	0.89	0.84	0.81	0.86	0.88	0.83	0.88	0.89	0.87	0.89

Q1 to Q16 represent the questions in the questionnaire for subjective rating of workplace noise, where Q1 rates perception of noise level,Q2 headache, Q3, fatigue due to noise, 4 nausea due to noise, 5 pain in ear due to noise; 6 hearing problem (Threshold shift), 7 RPE due to noise, 8 satisfaction level with conditions on loom, 9 degree of impact of noise on working efficiency, 10 impact of noise on weaver, 11 mental demand, 12 physical demand, 13 temporal demand, 14 performance, 15 effort and 16 frustration. 'r' represents spearman's correlation coefficient.

Table 4.27 depicted correlation of subjective perception with noise level, compared individually month-wise (from Jan to Dec).Above table clearly elucidated that *correlation of perception of noise (Q1) with respect to ambient noise level* showed greater extent of settlement of the perception of noise level with higher noise environment reflecting however a variable trend. It clarified that there was a strong association of the perception of noise with high level of noise as a factor (+0.72 ≥ r ≥ +0.89). The *correlation of headache (Q2) with noise level* expressed a fluctuating tendency of greater chances of headache with high level of noise. Association of headache with noise as a factor was found to be significant (+0.74 ≥ r ≥ +0.91).

The testament of the statistical inference reflected that the *correlation of fatigue (Q3) with the prevailing noise conditions* having varying trend, caused greater extent of suffering on the fatigue with high level of noise. Association of noise with fatigue as an important component, was notable (+0.73 ≥ r ≥ +0.91). The correlation of *nausea (Q4) with noise level conditions* showed a greater extent of suffering on the queasiness with high level of noise having a variable trend. Significant relation of noise with nausea as a factor was observed (+0.86 ≥ r ≥ +0.91).

Similarly the *correlation of pain in ear (Q5) with high noise level* evinced greater extent of compromise of ear pain with higher level of noise revealed a variable trend. It clearly indicated a strong relation of ear pain with the existing noise level conditions as a factor (+0.80 ≥ r ≥ +0.95). The *correlation of* hearing problem *(Q6) with noise level* showed an inconstant trend of having greater chances of threshold shift with higher level of noise. The significant association between hearing problem with noise as a factor has been exhibited (+0.82 ≥ r ≥ +0.94).

The data regarding *correlation of the rating of perceived exertion (Q7) with noise level* showed direct relation with variable tendency and compromised on the perceived exertion with high level of noise. Prominent association has been ascertained regarding rating of perceived exertion with noise as a factor (+0.72 ≥ r ≥ +0.86). Results also reflected that *correlation of the level of satisfaction (Q8) with the working condition in the handloom shed with the existing noise level* have displayed suffering on the satisfaction level with higher level of noise which evinced a variable tendency. There was considerable association of noise with the level of satisfaction with the working condition in the handloom shed as a factor (+0.47 ≥ r ≥ +0.72). A direct *correlation of the impact of noise on working efficiency (Q9) with the noise level* was noticed and based on data evidence exhibited a high level of sufferings on working efficiency with respect to the prevailing noise level which was having a fluctuating tendency. A remarkable relation of noise has been observed with working efficiency as a factor (+0.56 $\geq$ r $\geq$ +0.83). Moreover the data elucidated that the *correlation of the impact of sound on weaver (Q10) with the noise level* has very crucial interaction which reflected a variable tendency with greater extent of consistency of the impact on the weaver with high level of noise. Based on evidence it was concluded that the existing noise level and the impact of it on the weaver as a factor have remarkable association (+0.56 $\geq$ r $\geq$ +0.85).

The statistical results showed the correlation of the mental workload with noise level which has shown a positive correlation of all the cognitive load factors with noise conditions. In total there were six subscales out of which three focused on the demand (mental Q11, physical Q12 and temporal Q13 demand) while the other three factors focused on the interaction of the weaver with the task (performance Q14, effort Q15 and frustration level Q16). The correlation of *the mental* (+0.89 $\geq$ r $\geq$ +0.96)*, physical (*+0.74 $\geq$ r $\geq$ +0.87) *and temporal (*+0.81 $\geq$ r $\geq$ +0.94) *demand factors (Q11, Q12 and Q13) as well as of the task interaction factors viz. Q14 performance* (+0.89 $\geq$ r $\geq$ +0.96), *Q15 effort* (+0.76 $\geq$ r $\geq$ +0.90) *and Q16 frustration* (+0.76 $\geq$ r $\geq$ +0.89) *level with the noise level* conditions have expressed direct effect of noise level on the cognitive and task demand factors with a variable tendency. Strong relation of noise with cognitive as well as with the task demand factors have been established. The data reflected that high level of noise has decisive impact on the mental and temporal demand as compared to physical demand whereas amongst the task interaction factors performance evinced higher cognitive workload as compared to efforts and frustration.

5. General discussion and conclusion of the overall thesis

5.1 Introduction

Textiles have multifaceted importance endowed with an economic boost to many countries of the world. Currently, the world business in textiles and clothing amounts to the US $ 836 billion and is growing constantly (World Trade Statistical Review, 2016). More than two-thirds of world exports in textiles and clothing is from the developing countries and India's textile exports accounted 4.72% of global textile and clothing exports (Dixit, 2015).

The textile industry has a significant existence in many national economies of the world and primarily consist of two sectors i.e. organized sector and unorganized sector. The organized sector consists of spinning, apparel and garments segment which is highly mechanized whereas unorganized sector consists of handloom, handicrafts and sericulture, work on the small-scale using traditional tool and methods. Even in the contemporary era the Indian cultural heritage is at advantage of having the asset of richest and vibrant hand weaving technology which has rarely flourished anywhere in the world, over and above this sector is eco-friendly, less capital intensive, trivial use of power, compliance to market requirements and persistent for passing on the skills from one generation to another.

Handloom industry of India, being one of the vital ancient industries, is distinctive and has remarkable survival regardless of its extinction in other countries. India is advantageous of having the highest loomage (including handlooms) in the world and contributes to about 61 percent of the total loomage globally. Directly or indirectly every sixth household depends on the textile sector for their livelihood in India. Handloom sector shared nearly 15% of the total cloth production in the country (Kar, 2015; FICCI, 2016) and more than 125 countries are now buying handloom products from India (Jain and Gera, 2017; Bansal, 2012).

Occupational well-being of the weavers played an important role for their all-round advancement and is currently the growing concern which has multifarious advantages. Environmental factors, especially the Indoor environmental factors (IEF), being one of the crucial parameters, substantiate the effect on the well-being and comforts of the occupants which necessitate immediate attention.

Handlooms, being a household indoor activity have significant interface with the indoor physical environmental factors such as temperature, relative humidity, lighting, noise level, Airflow which directly or indirectly have diverse influential role on the occupational health of the weavers resulting in distraction of performance, productivity and speed of work of these weavers and allied workers (Serghides *et al*., 2015; Leech *et al*., 2002 and Landström *et al*., 1995). It is the prime issue need to be addressed properly and immediately. Therefore, it is the need of today to focus on these environmental issues and to study artificial lighting, daylight, glare and visual comfort together in order get a more holistic view (VanDenWymelenberg and Inanici, 2014; Huang *et al*., 2012).

Despite substantial research pertaining to different aspects of environmental and occupational health have been reported from various industries (Dianat *et al*., 2016; Dianat *et al*., 2013; Hossain *et al*., 2012; Huang *et al*., 2012; Frontezak *et al*., 2011; Vural & Balanlı, 2011), there is still little or scanty information is available with respect to handloom sector, as far as environmental and occupational health is concerned. It is inevitably required to address the impact of various environmental factors on the occupational health and performance of the weavers in Indian handloom scenario.

It was perceived that two crucial environmental parameters i. e. illumination and noise were having dominance affect throughout the year on the performance, productivity and psycho-physiological well-being of the weavers involved in the handloom sector. Therefore, in the present research, these two (illumination and noise) prominent environmental factors have been considered amongst the various other environmental variables. Even though all the indoor physical environmental factors have influence on the occupational health of the inhabitants but the variables other than illumination and noise fluctuate in their severity and have effect according to the seasonal variation. Hence other factors than illumination and noise have not been included for the study.

To initiate the research concerning the impact of prevailing level of noise and illumination on occupational health of the weavers involved in Indian handloom sector, Bargarh district of Odisha state was selected purposively and purposefully to execute the research objectives. Being the maximum handloom owning household state, the handloom production of Odisha state for the year 2015 – 16 was approximately US$ 78 billion (Rs.500 crores) in which the contribution of Bargarh district was 19.7%. Out of the total handloom Ikat sarees production in Odisha state, more than 70% are from Bargarh district. This district has been awarded the highest number (8 out of the total 18 number) of 'A' category handloom clusters (Handloom Clusters, 2017). The district is honoured to have the highest number of national awardees (51%) and the state awardees (36%) out of the total awardees in the state (National Awardees, 2017). Therefore, as a case study for the current research, Bargarh district in Odisha has been selected.

To carry out the case study based on the handlooms of Bargarh district, a total of 480 handloom workstations from 10 clusters were selected for assessing the impact of illumination and noise. Experimental data collected by using subjective (questionnaire) and objective (physical measurements of illumination and noise) methods by means of Lux meter of M/s- Sigma make, Model No. 1010A, year – 2011 and sound level meter of M/s Kusam Meco make, Model No.KM 929, Year – 2014. Collected data was subjected to appropriate statistical analysis using Statistical Package for Social Sciences (SPSS for windows, v.20.0.0) to explore any significant change across months, seasons, time or location and a significance level of $p \leq 0.05$ was considered for all statistical tests. The data interpreted and inferences of these observations have been described in the subsequent sections.

5.1.1 Lack of research and studies on the impact of prevailing illumination and noise levels on the occupational health of the weavers in the Indian handloom sector

The importance of the basic indoor environmental parameter conditions in different workplace settings have been well identified and reflected that lot of work have been done all over the world on indoor physical environment including the field of noise and illumination in various industries, offices, residential buildings, aircraft [Abbasi *et al*., 2011; Abdul and Ahmed, 2011; Agarwal and Yadav, 2013; Bauman *et al*., 1995; Bureau of Indian Standards, 2002; 1992 c; 1992; Frontczak and Wargocki, 2011; Hoppe, 1988]. Moreover, documentations in the garment sector (Colovic, 2014), power loom weaving sector (Bhattacharya *et al*., 1989; Uttam, 2015) and in textile Industry related to internal air quality and pollution (Choudhury, 2014; Schwela, 2000; McDowall, 2007; Jones, 1999; Cheremisinoff, 2002; Tulchinsky and Varavikova, 2000) have been well acknowledged.

Available literature highlighted that in Indian scenario a plenty of work has been done in the field of occupational health and environmental factors in various industries including the handicraft, garment, power loom, agriculture, cashew and quartz stone etc. (Nag *et al*., 2016; Nag, 2010; Meena *et al*., 2012; Pandit *et al*., 2013; Banerjee and Gangopadhyay, 2003; Singh *et al*., 2010 b; Ahmad, 2003), which is well documented. Quantum of research work on the various handloom topics related to the issues on the problems of weavers cooperative societies, the role and working of handloom industry, livelihood through handloom weaving, employment in handloom, working of entrepreneurs in a competitive low technology industry, regarding the schemes floated especially for the handloom sectors, intellectual property rights, strategy and for development of handloom industry, have been precisely documented (Mohapatra, 2013; Dash, 1996; Patil, 2012; Jain and Goswami, 2010; Mathew, 2011; Bhagavatula, 2010; Nehra and Suman, 2015; Vinayan, 2012; Goswami and Jain, 2014). However, so far little and inadequate research findings have been reported on the environmental factors and occupational health of the weavers in the handloom sector and especially in the area of illumination and noise. Negligible information is available about the approaches and measures for improvement of the psycho-physiological condition of the weavers, which needed to be explored in vivid details.

Efforts on the investigations in the area of occupational health in the handloom sector have not been focused from the environmental perspective. On hand studies in the Indian handloom sector substantiate the dominance of occupational health risk factors. Even indoor physical environmental issues have largely been ignored during the installation and commissioning of handloom workstation in the handloom clusters. An extensive review of literature ascertained that, till date, little or no work has been reported pertaining to the studies on the impact of prevailing illumination and noise levels on the occupational health of the weavers in the Indian handloom sector.

5.1.2 Textile Industry: Global and Indian Scenario

The Textile industry of India is the second largest manufacturer and exporter in the world next to China. India has a share of 5% of the global trade in textile and apparel and the export of textile and clothing including handicraft was US$ 40 billion during the year 2014 – 15 (Comtrade, 2015). Textile industry as a whole contributes to 10% of the total manufacturing production, 2% of India's GDP and 13% to the export earnings of the country and it is one of the largest sources of employment (Annual Report, 2016 – 17)

By adopting the precautionary approach in maintaining the indoor environmental conditions, most of the successful economies of the world have overcome the problem of occupational health and safety which has resulted in the improvement in quality and productivity of their output whereas in poor working conditions, productivity for the long-terms as well as quality of products and services are difficult to achieve.

In the developing world, most of the workers are ignorant of occupational health and safety issues and pay less attention to their wellbeing in order to earn their livelihood at the cost of health. In the Indian context, preference of work is more oriented to social and economic and least importance is given to the individual's health. In small-scale cottage industries, the situation is even worst where they are deprived of workers' right and other occupational safety and health issues and their contribution to economy is highly ignored. Lack of strict adherence to work environment standards and legislation, this massive labour force in small-scale and cottage industries including the handloom sector, is being subjected to various severe work hazards. It has been evinced that occupational health programs are being the only centre of attention in major industries, neglecting health issues of the vast majority of the workforce which depends on small-scale and cottage industries for their livelihood (Kromhout, 1999; Christiani *et al.*, 1990).

5.1.3 Scenario of handlooms in India

Handloom, being one of the largest economic activities after agriculture, bestows with low capital costs and is the support of rural masses of India. Being, extensive skill based rural cottage industry engaged 43.31 lakh weavers and allied workers, contributes to about 15% of the total cloth production in the country (Kar, 2015; FICCI, 2016) and makes available 95% of the world's hand-woven fabric (Handloom Census of India, 2009 – 2010). Various schemes have been floated by the government for promotion and up gradation of this sector resulting in the improvement of the income levels of the weavers. Handloom industry is not energy demanding and is a sustainable model of rural economic background even in this contemporary era of most modern technical know-how. Weavers of the handloom sector have always been unobserved inhabitants. Indoor physical environmental conditions as well as occupational health problems among these strata have always been ignored and not being given due attention. Being the drudgery nature of work, the traditional approach of working for commercial production has not been disregarded even though advancement and developments of innovative technology in the handlooms is very well in place (Garg *et al*., 2012), leading to the development of physical, physiological and psychological problems among the weavers' fraternity. Frijns and Vliet (1999), as well as Chen *et al.* (1999) stated that having the immense importance in diverse socio-economic aspects and sustainable development, the small scale and cottage industries should deviate from the traditional approach to advance technology.

5.1.4 Need for research initiatives in Indian Handloom sector from occupational health perspectives

In anticipation of the enhanced growth of handloom sector in India and particularly in the Eastern part of India, there is a strong thought that it is the decisive time to conduct exploration from environmental and occupation health point of view in the existing handloom industries. This idea will facilitate to pinpoint the difficulties encountered and uncover the issues and problems through appropriate research methodologies. The result of which in future shall compound the benefit of the weavers in long run for improving the occupational work environment and will upshot the morale of weavers in terms of enhanced work satisfaction, quality and better yield.

5.2 Research findings

In this research detailed measurement of the illumination and noise levels as well as their effect on the physical, physiological and psychological parameters, have been studied in a specified manner and nowhere in the world has this type of work being done in such vivid details. Assessment of occupational well-being have been considered in various fields including the weaving sheds of the power loom sectors but in the present research, the intention was to analyze and assess the findings of the effect of illumination and noise conditions on the occupational well-being in the handloom sector through rigorous scientific approach.

This study intended to investigate the effect of existing contributors like illumination and noise on the occupational well-being of Indian handloom weavers and to explore the scope of improvement thereto. During the field visits to various handloom workstations in the clusters, it was observed that most of the weavers and allied workers were reluctant to perform the weaving or even allied operations during the evening and night hours due to the supply of low voltage current as well as due to frequent power failure. It was also observed that due to wrong placement of the lighting source on and around the handloom workstations compounded the poor visibility conditions. As observed most of the weavers were using the traditional source of illumination i.e. the incandescent lamps such as bulb and that too without canopy or shed caused the glaring effect on the eyesight of the weavers resulted in psycho-physiological discomforts.

Odisha, amongst the Indian states and union territories, have the benefit of maximum handloom owning household outside the north-east region which is also over and above the national average (Handloom Census of India, 2009 – 2010). Bargarh district being ‘A’ category handloom cluster (Handloom Clusters, 2017), located in the western part of Odisha, produced maximum tie and dye cotton sarees in terms of quality and quantity, having the infinite number of motif and designs labelled under special titles. Being commercial production hub for the tie and dye cotton sarees, this place was preferred for conducting the present research. 480 weavers were selected using purposive stratified sampling from 10 clusters. Data was collected for subjective and objective assessments using questionnaire, scales and tools (Appendix A). Measurement of illumination and noise was carried out in the daytime, while the handlooms were in operation at the workstations.

The outcome from this study signified the adverse effects of environmental factors on workers' satisfaction, job performance, health and safety which clearly indicate that the workers might have been exposed to various environmental conditions. It had also been documented that the perceived responses to the environmental factors depend on individual acuity as well as on a number of factors including physical, physiological and psychological (Parsons, 2000). Thus, it is necessary to conduct studies in each working environment that is under the prevailing illumination and noise level conditions in order to find out how these factors would affect the weavers while working at the handloom workstation.

The average levels of illumination (See Chapter-4, Sub Section-4.1.1, and Table-4.1) on the handloom workstations were observed to be on the lower side as compared to the Bureau of Indian Standards (1966) IS 3646-2 as well as of IES (Illuminating Engineering Society, 1973) and ISO 8995-1:2002 standards. The ratio of minimum to the average illumination (the diversity factor) was found to be 0.56 against the recommended value of $\geq$ 0.80 which revealed that a number of locations of the handloom workstations were having poor illumination level. The process of weaving was carried out indoors on all handloom workstations and during the daytime most of the weavers were using artificial light beside the natural daylight. The variation of illumination value on the handloom was mainly attributed by various factors prevailing on and around the handloom workstation such as a) type of roof and ceiling; b) location and number of doors and window in the workshed; c) location of the handloom with respect to the doors and window of the workshed; d) location and positioning of illuminating source on the handloom; e) direction of sunlight during the day time with respect to the location of handloom; f) frequency of power failure and low voltage supply of electricity; g) usage of the type of illuminant and h) use of canopy / shed or cover during weaving.

The data revealed that, across the entire year (See Chapter-4, Section-4.1, Sub Section-4.1.1, and Table-4.1), the illumination value on all the positions at different time period in a month varied considerably and it was lowest at 1900 h in the month of December and highest at 1200 h in the month of April, which was found to be far below the recommended Indian Standard (IS: 6665-1972) and IES (1973) standards.

Group analyses (See Chapter-4, Section-4.1, Sub Section-4.1.1, Table 4.2, 4.3, 4.4 and 4.5) revealed that, there was significant ($p \leq 0.001$) difference in the values of illumination level across the months at different timings of the day except in few months where no significant difference between the values was observed at $p > 0.05$. The significant difference might be attributed by the variation of natural daylight in different months and consequent with the change in day to day indoor ambient environment across the whole year, as well as due to the voltage fluctuation of the illuminating source. Drummond (1956) measured the natural illumination level month wise and concluded that during the month of December the solar elevation was reported maximum between 39º to 85º and endorsed that solar elevation is one of the factors which affect the variation of daylight on the earth. During the winter season, the intensity of the natural daylight was poor, which could be due to higher solar elevation as well as the distance of the sun from the earth. Moreover, the rays of the sun impinged with a tangential direction during morning and evening hours. The intensity of the natural light was observed maximum during the summer season (around the noon of the day) which caused the highest level of illumination, perhaps because of direct sunlight with the gradually decreasing trend towards the minimum level during the winter. Rotation of earth on its axis as well as around the sun and the ambience environmental conditions affect the intensity of natural illumination on the handloom workstation, apart from the artificial illumination.

Under various climatic seasons, the values of indoor illumination environment at different locations of the handloom workstations (See Chapter-4, Section-4.1, Sub Section-4.1.2 and Table 4.6) revealed very low illumination in comparison to the recommended standards. The value of illumination level was lowest during the winter season and highest during the summer season which was very low when compared to Indian and International standards; and was in consonance to the findings of Dianat et al (2013) and Kozaki et al (2012). Illumination values across the different seasons registered highly significant difference ($p \leq 0.001$) for all pair of seasons viz. Summer vs. Monsoon, Summer vs. Winter and Monsoon vs. Winter; which might have occurred due to the variation of intensity of the natural daylight across the seasons and fluctuation of voltage (artificial electric illumination) confirmed that there was the considerable difference amongst the seasons of summer, monsoon and winter.

The average value across the whole year (See Chapter-4, Section-4.1, Sub Section-4.1.3 and Table 4.7) varied and was the lowest at 1900 h and highest at 1200 h throughout the year, which reflected that the existing illumination was evidently poor with significant deviation from the recommended illumination values. The findings were in agreement with the study conducted by Uttam (2015) and Bhattacharya et al. (1989). Bhattacharya et al. (1989) substantiated that illumination level in the textile sector (i.e. in the power loom sector) was found to be on lower sides while comparing with the Indian as well as with the International standard illumination values. As most of the weavers had no visual comfort at their loom workstations and they expressed difficulties to impart optimal productivity.

The mean sound pressure levels (SPLs) / noise levels (dBA) at the different measurement locations on the handloom workstations observed every month across the year are presented in (See Chapter-4, Section-4.2, Sub Section-4.2.1) Table 4.8. The measurements were carried out in accordance with ISO 10534-2 using the sound level meter (IS-3932-1966). Assessment of noise exposure was done according to ISO 9612: 2009. Noise at the workstation is generally influenced by the factors like a) time of exposure; b) noise intensity; c) frequency and d) individual subject's sensitivity. The SPLs were high near the weaver's right ear (E_{MAX}) on all the handloom workstations in every month throughout the year.

Although the maximal noise level near the right ear of the weaver (E_{MAX}) was in the range of 82 dBA - 89 dBA which appears to be on the higher side when compared to the Bureau of Indian Standards, IS 9876 (45 dBA to 75 dBA for exposure of 8 h / day and for 5 working days in a week). Even though the noise levels on the handloom workstations were not very high but the impact of the aforesaid noise level was significant as the weavers in the Indian scenario and especially of Bargarh district work at least for 11 h in a day for 6-7 days of the week. This extended duration of exposure to noise led to the detrimental impact on the occupational health of the weavers. Daily exposure of the weavers to SPL > 85 dBA for several hours in a day might lead to permanent hearing impairment (Ahmed *et al.*, 2011). The Maximum value (E_{MAX}) of noise near the weaver's right ear on all the workstations had the highest SPLs due to the presence of main noise producing source in the vicinity of the handloom weavers. The findings were in agreement with the study conducted by Dianat *et al.*, 2016; Ahmed *et al.*, 2011; Gitau *et al.*, 2004; Reinhold *et al.*, 2007; Chavalitsakulchai *et al.*, 1989; Osibogun *et al.*, 2000.

The variation in noise level around as well as at the centre of the handloom shed was due to variation in distance from the source of origin of the sound. The main source of noise emission as identified earlier was shuttle, jacquard or dobby movement, beating mechanism and leather buffer besides the street noise. Another reason for higher SPLs might be due to the use of old handlooms having poor maintenance with substandard accessories. The degree to which the SPL affects the weaver depends on its nature, intensity, duration, time of occurrence and also on the activity of the individual at the time of exposure. The direct application of other standards such as OSHA, IES, ISO, NIOSH regulations in the Indian handloom industries were not applicable (Habali, 1989; Shaikh, 1999) as most of the handloom machines are being operated more than 5 working days per week for more than 8 h; which means the weavers were exposed to high SPLs for more than 40 h / week i.e. 12 h to 24 h on over time per week, over and above the normal working hours and estimating probably 25% - 80% per week higher than the recommended exposure time / week in USA or any other European country (Singh *et al.*, 2009 a). Lundh *et al.* (2011) reported that the impact of exposure to high level of noise was aggravated by the other factors such as heat, vibrations, humidity and awkward work postures and was found to be in consonance with those of Raman, 2006.

Group analyses revealed that (See Chapter-4, Section-4.2, Sub Section-4.2.1, Table 4.9, 4.10, 4.11 and 4.12) there was significant ($p \leq 0.001$) difference in the noise levels across the months at different measurement positions except in few months where no significant difference between the values was observed at ($p > 0.05$). The significant difference happened due to deviation in the ambient environment monthwise as well as with the variation of the impact of force propelled upon and the noise originated from various accessories and mechanisms during operation of handloom.

Noise levels across the different seasons (See Chapter-4, Section-4.2, Sub Section-4.2.2 and Table 4.13) registered highly significant difference ($p \leq 0.001$) for all pair of seasons viz. Summer vs. Winter, Monsoon vs. Winter and Summer vs. Monsoon for maximum value of noise near the weaver's right ear (E_{MAX}); minimum value of noise near the weaver's right ear (E_{MIN}); maximum value of noise in the centre of the shed (C_{MAX}) and minimum value of noise in the centre of the shed (C_{MIN}) except for C_{MAX} during Summer vs. Monsoon ($p \leq 0.05$). Maximum annual average exposure value (See Chapter-4, Section-4.2, Sub Section-4.2.3 and Table 4.14) was observed near the weaver's right ear (E_{MAX}) for > 40 h in a week (> 8 h for > 5 days) which was rationally higher than recommended levels [ISO (W) – 85 to 90 dBA, 5 days/ week for 8 h; ISO (Dev) – 88 dBA for 6 days / week; OSHA – 85 dBA; NIOSH – 85 dBA and BIS (IS) – 45 to 75 dBA]

Data revealed (See Chapter-4, Section-4.3, Sub Section-4.3.1 and Table 4.15) that the heart rate values were observed to be minimum in the month of January and maximum during May. The study substantiated that about 32% of the weavers were having heart rate more than 86 bpm and about 46% weavers' heart rate between 76 bpm to 85 bpm. Over and above, more than half of the weavers implicit that due to inapt environmental conditions in their working area have upshot the health-related issues which were further exaggerated by the prevailing environmental conditions including illumination and noise which were not being met as per the recommended standards. The heart rate fluctuation depends on various physical, physiological and psychological parameters as well as of individuals' food habit, life-style and working habits at the workstation. Regarding the health and safety consequences of the environmental factors, most of the weavers responded that the illumination and noise at their respective workstations have caused considerable physiological and psychological problems, which were in agreement with the previous researches (Parsons, 2000; Dianat *et al.*, 2016). Group analyses (See Chapter-4, Section-4.3, Sub Section-4.3.1 and Table 4.16) revealed that there was significant ($p \leq 0.001$) difference in the values of heartbeat across the months, except in few cases where no significant difference between the values was observed. The significant difference might be due to the variation of indoor ambient environment conditions during the whole year viz. illumination and noise across the different months.

The heart rate revealed a declining trend from summer season via monsoon to the winter season. The values across the different seasons (See Chapter-4, Section-4.3, Sub Section-4.3.2 and Table 4.17) registered highly significant difference ($p \leq 0.001$) for all pair of seasons viz. Summer vs. Monsoon, Summer vs. Winter and Monsoon vs. Winter which occurred possibly due to the variation of environmental factors including illumination and noise according to the seasons and due to working life-style.

The weavers' workload was also assessed using subjective measures in order to ascertain the psychological pressure they perceived while interacting with handloom machine and the material (Rubio *et al*., 2004). The subjective workload assessment for work activities was performed (See Chapter-4, Section-4.4 and Table 4.18) for handloom and allied activities inside the workstation. The ratings for various scale titles for the subjective workload assessments were significantly on the higher side. The mean weighted ratio (MWR) of the physical demand was rated very high by the weavers. It was observed that even though putting lots of mental, physical, temporal demands and efforts, the performance of the weavers was on dismal state, possibly because of high frustration which might be due to poor illumination and high noise conditions that prevailed inside the handloom workstations, which in turn alarmed various physical, physiological and cognitive complications. These findings were in agreement with the weavers' perception and dissatisfaction with the illumination and noise conditions that existed at the handloom workstation and were also in accordance with the other researchers (Dianat *et al*., 2016; Vahedi and Dianat, 2013; Parsons, 2000).

The Mean Weighted Workload Score (See Chapter-4, Section-4.4 and Table 4.18) was arrived at (73.87 ± 12.32, Mean ± SD). The weavers put forth more efforts and were found to be successful in completing the tasks associated with their jobs, even though they encountered very daunting working conditions. Hence, it was evident that environmental conditions improved and the interventions should primarily be focused on reducing the perceived physical demand and efforts besides minimizing the frustration levels amongst the weavers. The overall mean weighted workload scores (MWWL) of the weavers working on the handlooms inside the work shed in the study were on the higher side as compared to the results of other studies (Sepehr, 1988; Haga *et al*., 2002).

For satisfaction, increasing productivity and overall well-being of the people, indoor environmental factors played the very vital role. In order to ascertain the illumination conditions at the handloom workstations, the weavers expressed their perceptions through the questionnaire.

Questionnaire on illumination (See Chapter-4, Section-4.5, Sub Section-4.5.1 and Table 4.19) was analysed for various discomfort parameters like the effect of illumination on weavers' satisfaction level, perceived job performance, the perception of illumination, physiological and psychological parameters and evaluated to find the most appropriate methods of improvement to the working environment. It was also intended to compare the weavers' perceptions of the illumination levels with the actual physical measurements to determine how they were related to one another. The recommended illuminance levels were not met in 89.33% of the handloom workstations and the illumination levels were lower than required national and international standards. These findings were in agreement with the weaver's perception of illumination level, and with low satisfaction level in respect of illumination conditions on the handlooms in the indoor work environment. Adverse effects of lighting conditions on the work efficiency, perception of illumination (on and around the handloom), discomfort due to glare, eye irritation, were reported by 91%, 51% and 26.5%, 29.5%, 100% of the weavers respectively. Moreover, the weavers reported that the visual environment at the workstation, discomfort due to glare and perceived poor level of illumination were adjudged between slightly to moderately uncomfortable.

The weavers' satisfaction with lighting (See Chapter-4, Section-4.5, Sub Section-4.5.7 and Table 4.24) was also significantly inversely correlated as the Spearman's correlation coefficient (r) was in the range of ($-0.06 < r < -0.75$; $p < 0.001$) in respect of physiological and psychological parameters except in the case of some physiological discomfort factors such as sensation of light on and around the handloom, illumination satisfaction level on loom and effect of light on the job performance where the impact on illumination revealed highly significant ($+0.55 < r < +0.61$; $p < 0.001$) direct correlation between illumination and these factors. The coefficient of determination (CD, r^2) varied between 0.0037 to 0.5656 which indicate the differential level of dependence of various physiological and psychological discomfort factors on illumination.

Borg's CR10 Scale evinced (See Chapter-4, Section-4.5, Sub Section-4.5.1 and Table 4.20) the discomfort/pain experienced by various parts of the body of the weavers due to the prevailing environmental conditions while working on the handloom. Weavers rated severe to excruciating discomfort levels on the Borg's scale which revealed the rarity of illumination level on and around the handlooms.

Various discomfort parameters as mentioned in the questionnaire on noise (See Chapter-4, Section-4.5, Sub Section-4.5.2 and Table 4.21) were tabulated and analysed for the effect of sound pressure levels (SPLs) on weavers' perception of noise level at the work place as well as on headache, fatigue, nausea, pain in ear, hearing problem (threshold shift), rating of perceived exertion (RPE) due to noise, satisfaction level with conditions on loom, degree of impact of noise on working efficiency in addition to the impact of noise on weaver's mental demands such as physical demand; temporal demand; performance; effort and frustration. The noise was measured as per guidelines of IS: 4758-1968 (Reaffirmed 2002) followed by ISO (495) recommendations made for dealing with the general requirements for preparation of test codes which were required for measuring noise emitted by machines (Bureau of Indian Standards, 1968). Research findings revealed that as per the ISO the maximum permissible noise exposure limit is of 85 dBA – 90 dBA for 40 h / week, whereas United Kingdom, Denmark and Canada predetermined the sound pressure levels up to 90 dBA for 40 h / week while OSHA proposed a limit of 90 dBA for 8 h / day (Olayinka and Abdullahi, 2009). The maximum exposure to noise of 85 dBA – 90 dBA with an exposure time of 8 h / day for 5 days / week (40 h / week) was indicated by ISO (Habali *et al*., 1989; Shaikh, 1999). Recommendation to limit steady noise at 88 dBA in developing countries was put forth as most of the industrial plants in developing countries work 8 h / day for 6 days / week amounting to 48 h / week (Shaikh, 1999). Indian Factories Act (1948) specifies a limit of 90 dBA for an 8 h exposure (Rathod *et al*., 1987; Singh *et al*., 2009 a). People exposed to sound level of > 85 dBA for several hours a day may be prone to temporary or even permanent hearing impairment (Ahmed *et al*., 2011).

Mean noise levels at the handloom workstations were above the recommended limits, while the average sound levels at the centre of the work shed were below the recommended limits (See Chapter-4, Section-4.2, Sub Section-4.2.3 and Table 4.14). Noise level in excess of 90 dBA was observed at 9% of all the handloom workstations. Bridger (2002) and Helander (1995) suggested that machines which produce high levels of noise should either be replaced or isolated and noise levels can be controlled by reducing structure (machine/object) and air borne transmission. Airborne transmission of noise may be reduced by increasing the distance between source and worker, rotating noise source, using barriers and baffles, enclosing the noise source and workers, applying damping material and use of ear protection (Helander, 1995). Control at the noise source and reducing the structure-borne transmissions may not be possible in the small-scale and cottage sector which require substantial additional investment and engineering expertise. Therefore, airborne transmission of noise could be reduced using appropriate measures. According to the International recommended standards the SPLs were not met in 69.17% of the handloom workstations and as per Bureau of Indian Standards (BIS), all the weavers were exposed to the SPLs more than the recommended standards which might attract dismal performance of the weavers. About two-thirds of the weavers reported that the noise at their working environment could cause physiological and psychological discomforts, which was in consonance with the views of previous researchers (Parsons, 2000) as well as with the weaver's perception of moderate to high noise levels on the handloom in the indoor work environment. Adverse effects of noise level conditions on the perception of noise on the handloom, work efficiency, perceived exertion due to high noise, hearing problem, and level of satisfaction was reported by 100%, 100%, 33% and 27.5% and 27% of the weavers respectively. About 62.5% of the weavers reported that the noise environment was not tolerable, but accustomed to that ambient environment; whereas 37.5 % of the weavers expressed their annoyance with the noise level they encountered while performing the weaving operations at the handloom workstations. As per the subjective responses (See Chapter-4, Section-4.5, Sub Section-4.5.8 and Table 4.25) it was observed that there was highly significant ($+0.25 < r < +0.67$; $p < 0.001$); direct correlation persisted between noise and the physical, physiological and psychological discomfort factors. Moreover, the coefficient of determination (CD, r^2) varied in the range of 0.0641 to 0.4467, which indicated the high differential level of dependence of various physiological and psychological discomfort factors on the Noise.

Reliability and validity of questionnaire for Illumination as well as for noise (See Chapter-4, Section-4.5, Sub Section-4.5.3 and Sub Section-4.5.4) were tested by using the Cronbach's Alpha (α) in Statistical Package for Social Science (SPSS v.20.0.0 for windows) which revealed excellent internal consistency for both the questionnaires (Questionnaires of illumination and noise having Cronbach's $\alpha = 0.979$ and 0.990 respectively; with α based on standardized items = 0.980 and 0.991 respectively).

Independence of association of Questions were also adjudged by performing the Friedman's Chi-Squared (χ^2_F) test (See Chapter-4, Section-4.5, Sub Section-4.5.5 and Table 4.22 and See Chapter-4, Section-4.5, Sub Section-4.5.6 and Table 4.23) which revealed no significant association between the questions of questionnaires on illumination and noise with various questions related to physical, physiological and psychological parameters. The value of χ^2_F varied between 46.3 (NS) to 1317.9 (NS) for questionnaire on illumination and from 157.6 (NS) to 198.7 (NS) for questionnaire on noise which indicated that the questions were all independent of the illumination and noise conditions.

The data (See Chapter-4, Section-4.5, Sub Section-4.5.9 and Table 4.26) depicted that the correlation of the effect of prevailing illumination on work efficiency, headache, fatigue due to illumination, eye irritation, redness of eyes, water falling from eyes, neck pain, lower back pain, thigh pain, waist pain, ankle/feet pain, cognitive demands and rate of perceived exertion (RPE) due to illumination with month wise illumination levels have reflected greater extent of compromise of aforesaid parameters with lesser level of illumination revealing a variable trend and inverse correlation with respect to the illumination conditions. The subjective ratings showed the marked influence of illumination on the health and performance of the weavers. It was also revealed that, as the illumination on and around the workstations diminished, the impact of low level of illumination intensified the various aforesaid factors suffering whereas shoulder pain, visual environment at workstation, discomfort due to glare, sensation of illumination on and around the handloom, illumination satisfaction level on handloom, effect of light on job performance have direct correlation with the prevailing illumination conditions on the workstations. The remarkable association has been justified due to the low illumination conditions on most of the aforesaid factors except the factor of the visual environment at the workstation which articulated a very dismal relation and no remarkable association ($+0.28 \geq r \geq +0.33$).

Impact on the cognitive factors evinced that low illumination conditions on the workstation enhance the physical demand and efforts level of the weavers in comparison to other cognitive parameters. The correlation coefficients provided additional evidence that illumination factors had diverse effect on weavers' physiological and psychological parameters. Studies on the environmental conditions at various other indoor workstations also showed the similar effect at the International as well as in the Indian scenario (Dianat *et al*., 2013; Dianat *et al*., 2016). Vahedi and Dianat (2013) reported that the age of the workers was negatively correlated ($r = -0.229$; $p < 0.01$) with the illumination satisfaction.

The table (See Chapter-4, Section-4.5, Sub Section-4.5.9 and Table 4.27) figures showed that the correlation of the effect of noise on perception of noise level, headache, fatigue, nausea, pain in ear, hearing problem (Threshold shift), rate of perceived exertion (RPE), satisfaction level with conditions on loom, degree of impact on working efficiency, impact on weavers' mental demand, physical demand, temporal demand, performance, effort and frustration with month-wise noise levels have reflected greater extent of compromise of aforesaid parameters with higher level of noise revealing a variable trend and direct correlation with respect to the noise conditions. The subjective ratings showed marked influence of workplace noise on the health and performance of the weavers. It was also revealed that the effect of noise level intensity on the suffering such as nausea, pain in ear, hearing problem (Threshold shift) was on higher side ($r > 0.8$) and the impact of high level of noise intensified the miseries of the aforesaid factors whereas perception of noise level, headache, fatigue was also affected to a greater extent ($r > 0.7$). The remarkable association has been justified due to the high level of noise conditions on most of the aforesaid factors except the factor of satisfaction level with conditions on the loom which expressed inadequate association ($+0.47 \geq r \geq +0.72$). Impact on the cognitive factors reflected that high level of noise conditions on the workstation has the detrimental effect on the mental demand, temporal demand and performance ($r > 0.8$), whereas physical demand, effort and frustration supported the greater extent of compromise with the higher level of noise revealed a variable trend. The data reflected that high level of noise has the decisive impact on the mental and temporal demand as compared to physical demand whereas amongst the task interaction factors; performance evinced higher cognitive workload as compared to efforts and frustration. The correlation coefficients provided additional evidence that noise levels had the diverse effect on weavers' physiological and psychological parameters. Studies on the environmental conditions at various other indoor workstations also showed the similar effect at the International as well as in the Indian scenario (Dianat *et al*., 2013; Dianat *et al*., 2016).

The present research indicated that more than two thirds of the weavers agreed upon the fact that, environmental conditions of illumination and noise in their handloom workstations were not apt. According to the contingency coefficient analysis, there was a relatively good agreement between the measured illumination and sound pressure levels and the weavers' perception of these factors. The findings suggested that in most cases the weavers' assessment reflected the actual situation in such a way that the subjective rating was likely to be more appropriate if that work area met the standard and vice versa. It was observed that subjective and objective assessments which were carried out reflected the actual situation of the weavers' assessment. As in the results of a recent study in a hospital setting also signified a relatively good agreement between the measured illuminance levels and the employees' perception of the light level (Dianat *et* *al*., 2013). These findings highlighted that there was a potential that the workers' assessment may reflect the actual circumstances of the working environment. The majority of weavers in this study indicated that they were not satisfied with the indoor environmental conditions, particularly with the noise and illumination levels, at their handloom workstations.

It was interesting to note that the results of Spearman correlation analysis indicated that the recorded noise and illumination levels were highly correlated with weavers' satisfaction levels with these environmental factors in the work environment. Again, these findings might suggest that the satisfaction of the weavers with the environmental factors had a propensity to reflect the actual circumstances of the working environment. This was in agreement with the findings of several previous studies conducted in industrial and healthcare settings (Rasanen *et al*., 2000; Dawal and Taha, 2006; Dianat *et al*., 2013) who found similar results among industrial workers. These findings could help to find out how the weavers would feel about their working environment; and consequently to improve the understanding about the environmental conditions of the workstation. The results of Spearman correlation analysis indicated significant correlations between the recorded noise and illumination levels with perceived job performance. This supported the findings of previous studies which have reported significant relationships between different environmental factors including noise, lighting and thermal conditions and workers' productivity in industrial settings (Kahya, 2007). These findings highlighted the importance of appropriate environmental conditions in the workplace to improve weavers' job performance. Regarding the health consequences of the indoor environmental factors, about two third of the weavers indicated that the prevailing illumination and noise conditions at their handloom workstations might cause physiological and psychological responses, which was in agreement with the view of previous researchers (Parsons, 2000 and Vahedi and Dianat, 2014).

Besides providing job to the largest workforce, handloom industry of India has the significant contribution to the socio-economic development of the country and recognition at the global level. To meet out the demand and supply gap production is required to be enhanced in terms of quantity and quality. But due to poor environmental conditions, the weavers were unable to meet the targeted requirements. In view of this, it was the need of the day to improve the environmental conditions at the workstation in order to bring out the tacit intrinsic talent of the weavers for developing miracles on the fabrics. The weavers should be barrier-free in respect of environmental deformities. Hence environmental factor, especially illumination and noise, play a pivotal role for enhancement of quality and quantity, which entail immediate considerations.

Besides the collection of physical data, the questionnaire is an important tool to bring out the unstated information in order to ascertain whether the weavers are perceiving these problems in their day to day weaving work or not. The questionnaire is a contrivance used to encompass the subjective assessment and contains various scaled questions which are highly reliable, easy to read and can be easily completed by the participants.

For this research work detailed statistical analysis was inevitably required in order to understand and establish the in-depth and intrinsic correlation between the environmental factors such as illumination and noise and the occupational health of the weavers in order to understand the effect of these environmental factors on the physical, physiological and psychological parameters of the weavers working on the handloom workstations.

The result reported out of the data which has been collected in this research field through the questionnaire has not been detailed anywhere and not available in India and abroad as no work has been done and no published literature is available on this area in the field of handlooms. Reliability of the questionnaire and Friedman’s Chi-Squared (χ^2_F) test for independence of association has been performed in order to ascertain the subjective biasness in the questionnaire. In this research ANOVA Friedman’s Chi-Squared (χ^2_F) test for independence of association**,** Spearman’s correlation coefficient (r) and Coefficient of Determination (CoD, r^2) for correlation have been utilized and so far for the similar studies in the field of handloom sector nowhere such detailed statistics have been reported. A statistical analysis of this research study is the special novelty of this research work.

Since there was practically no report available on environmental factors and their impact on the performance, physiological and cognitive load of handloom weavers in Indian subcontinental context, this study intended to be the first of its kind to report such factors with detailed analysis along with thorough and rigorous statistical interpretation, which in turn beholds the real-time environment scenario of handloom weaving workstations and the pros and cons of their productivity along with the occupational health of the weavers.

5.3 Key Findings

The following salient findings were observed from indoor physical environmental and occupational health perspective with respect to the handlooms workstation of the Indian handloom cottage and small-scale sectors.

1. Symptoms of physical and physiological ailments were observed among the weavers at handloom workstations.
2. Symptoms of psychological ailments were observed among the weavers at handloom workstations.
3. Comparisons of prevailing indoor environmental conditions with guidelines specified by scientific organizations and researchers indicate the need for context- specific corrective actions.

5.4 Fulfilment of objectives

Objective 1: Assessment of the Illumination level in the handloom throughout the year.

Objective 2: Assessment of the noise level in the handloom throughout the year.

Illumination and noise level of the existing handloom workstation were assessed for one complete year with the aim of identifying location specific and season-specific risks. (refer Chapter - 4, Section - 4.1, Sub Section- 4.1.1, Table - 4.1 and Chapter - 4, Section - 4.2, Sub Section- 4.2.1, Table - 4.8). **Thus, the objective – 1 and 2 of the research work is accomplished**.

Objective 3: Explore the effect of prevailing illumination on the physiological and psychological aspects of the weavers

Symptoms of physiological and psychological ailments were observed among the weavers at the handloom workstations. The occurrence of the symptoms of musculoskeletal ailments (discomfort, pain and ache) and psychological ailments during the weaving and pre or post handloom activity was significantly higher for the weavers. Awkward working postures, prolonged work duration and awful workstation environmental conditions especially poor illumination conditions were established as risk factors for the high prevalence of symptoms of physical, physiological and psychological ailments among the weavers at the handloom workstations. The influence of working postures and environmental conditions on symptoms of physical, physiological and psychological ailments were found to be significantly ($p < 0.05$) mediated during working on the handloom workstation. It was also inferenced that there was a strong direct as well as indirect association of the symptoms of physical, physiological and psychological ailments with illumination as a factor ($0.28 \leq r \leq 0.92$) and ($-0.98 \geq r \geq -0.63$) respectively. Based on statistical evidence it can be concluded that there was a strong association of the effect of prevailing low level of illumination conditions on the physiological and psychological-aspects of the weavers (refer Chapter - 4, Section - 4.4, and Table - 4.18 and Chapter - 4, Section - 4.5, Sub Section- 4.5.1, and Table - 4.19 and 4.20). **Thus the objective - 3 of the research work is accomplished.**

Objective 4: Explore the effect of prevailing noise level on the physiological and psychological aspects of the weavers through subjective evaluation.

Physiological and psychological ailments indications were also evinced amongst the weavers at the handloom workstations. The physiological and psychological ailments were experienced during the weaving, pre and post handloom activities which were significantly higher for the weavers due to high level of noise. Prolonged working hours, as well as the high noise level conditions, were established as risk factors for the high prevalence of symptoms of physiological and psychological ailments among the weavers at the handloom workstations. The influence of the high noise level conditions on symptoms of physiological and psychological ailments was found to be significantly ($p < 0.05$) adjudicated during working on the handloom workstation. It was also inferenced that there was a strong association of the symptoms of physiological and psychological ailments with noise as a factor ($0.47 \geq r \geq 0.96$). Mean weighted ratio of the physical demand was rated very high (79.59) by the weavers due to the prevalence of noise level conditions. It has also been observed that inspite of putting in lots of mental and temporal demand, impeding effect was observed on the performance of the weavers. Prevalent noise imposed the detrimental consequence on the physiological parameters due to which most of the weavers reported a headache, fatigue, nausea, pain in ear and hearing problem in the scale of medium to high. Subjective responses to questions in the questionnaire on the impact on noise revealed highly significant ($p < 0.001$) direct correlation between noise and the physical discomfort factors (such as headache, fatigue, nausea, pain). The strong association of the perception of noise with high level of noise as a factor ($+0.72 \geq r \geq +0.89$) was observed. Through subjective evaluation and based on statistical indications it is concluded that there was a strong association of the effect of prevailing high level of noise conditions on the physiological and psychological aspects of the weavers. (refer Chapter - 4, Section - 4.4, and Table - 4.18 and Chapter - 4, Section - 4.5, Sub Section- 4.5.2, and Table - 4.21). **Thus, the objective - 4 of the research work is accomplished.**

Objective 5: Analyze if there were any correlation between the subjective rating with corresponding environmental factors, in order to understand the impact of illumination and noise.

The subjective ratings of the physiological and psychological parameters were strongly associated and high correlation was evinced with the corresponding environmental factors. (refer Chapter - 4, Section - 4.5, Sub Section - 4.5.7 – 4.5.9, and Table - 4.24 – 4.27) **Thus, the objective - 5 of the research work is accomplished.**

5.5 Testing of hypothesis

The experimental hypothesis as assumed at the commencement of the research work has been thus fulfilled with the research findings.

It was hypothesized that prolonged exposure to high level of noise and low level of illumination (either solitary or a combined impact) would significantly affect the physiological and psychological health of the weavers engaged in handloom workstations in unorganized / semi-organized handloom sectors.

From the result, (refer Chapter-4, Section-4.1, Sub Section-4.1.1, 4.1.2, 4.1.3 and Table-4.1, 4.6, and 4.7) data depicted the variation of illumination across the months, seasons and yearly average level and it has been confirmed that illumination level was low on all the handloom workstations as compared to the International standards. There was the significant difference ($p \leq 0.001$) in the value of illumination on one handloom to another at a particular time of the day while comparing one month to another month in most of the cases.

Table 5.1 Comparison of average observed value data (month wise, season wise and whole year) with standard illumination value (lux) measured at four locations during four times of the day on each handloom

Time	**Average Observed Value Data (Lux)**		**Standard Value (Lux)**	**Inference**
	Min	**Max**		
Month wise	56.23 ± 9.12	224.66 ± 60.23	**BIS : 300 -700** **ISO : 300** **CIE : 300** **IES : 400 -750**	The existing illumination values were below the recommended standard values. The findings were in agreement with the study conducted by Uttam, 2015 and Bhattacharya *et al*., 1989
Season wise	69.49 ± 13.19	206.93 ± 52.49		
Whole year (yearly average value)	66.77 ± 15.35	173.21 ± 46.68		

Values are expressed as Mean ± SD.

The result (refer Chapter-4, Section-4.2, Sub Section-4.2.1, 4.2.2, 4.2.3 and Table-4.8, 4.13, 4.14) data depicted the variation of noise levels across the months, seasons and yearly average level.

Table 5.2 Comparison of E_{MAX} (average observed value data) month wise, season-wise and of whole year with standard noise value (dBA) measured at two locations in the handloom workshed

Time	**E_{MAX} (Average Observed Value Data)**		**Standard Value (dBA)**	**Inference**
	Min (dBA)	**Max** (dBA)		
Month wise	82.16 ± 3.31	88.87 ± 2.87	**BIS – 45 to75** (Mean ± SD), for > 40 h in a week (> 8 h for > 5 days)	During the whole year, on all the workstations, the maximum value of noise near the weaver's right ear (E_{MAX}) had the highest noise level and rationally higher than recommended levels [BIS (IS) – 45 dBA to 75 dBA]. The findings were in agreement with the study conducted by Dianat *et al*., 2016; Ahmed *et al*., 2011; Gitau *et al*., 2004; Reinhold *et al*., 2007; Chavalitsakulchai *et al*., 1989 and Osibogun *et al*., 2000.
Season wise	84.34 ± 2.90	87.62 ± 2.36		
Whole year (yearly average value)	85.85 ± 2.21			

Values are expressed as Mean ± SD; E_{MAX} – Maximum value of noise near the weaver's Right ear

It has been confirmed that noise levels were on higher side near the right-hand ear of the weaver on most of the handloom workstations as compared to International standards. There was significant difference ($p \leq 0.001$) in the value of noise on one handloom to another and one month to another month in most of the cases. The data reflected that there was considerable variation in the noise level on as well as around the handloom workstation.

The table ((refer Chapter-4, Section-4.3, Sub Section-4.3.1, 4.3.2 and Table-4.15, 4.17) data represented the heart rate values (Mean ± SD) across the months, seasons and yearly average level and it was observed that the heart rate value for most of the weavers was on higher side than the standard value.

Table 5.3 Comparison of average observed value data (month wise, season-wise and whole year) with standard working heart rate (bpm) levels of the weavers on the handloom workstation

Heart Rate	Average Observed Value Data (bpm)		Standard Value (bpm)	Inference
	Min	Max		
Month wise	80.58 ± 10.33	84.23 ± 10.22	72	The existing heart rate values were very high than the recommended standard values.
Season wise	81.37 ± 10.31	83.99 ± 10.19		
Whole year (yearly average value)	82.99 ± 9.19			

There was significant difference ($p \leq 0.001$) in the heart rate value of one weaver to another and also varies from one month to another month in most of the cases.

A significant ($p \leq 0.001$) difference of the heart rate was observed across all pairs of months, seasons as well as during the whole year.

Between groups analyses (See Chapter-4, section- 4.1, Sub Section-4.1.1, Table 4.2 - 4.5) of illumination level and (See Chapter-4, Section-4.2, Sub Section-4.2.1 and Table-4.9 - 4.12) of noise levels across the months reflected that in most of the cases there were significant ($p \leq 0.001$) differences in the illumination and noise level values. Moreover, it has been confirmed through the statistical analysis while comparing with the International standards that there existed low level of illumination and the high level of noise in the handloom sectors.

Now the question surfaced whether the sufferings of the weavers were due to low illumination and high noise level conditions or any other environmental factor prevailing at the workstation. In order to confirm the effects of these factors on the physiological and psychological sufferings, the correlation tests were conducted.

Spearman's correlation coefficient (r) matrix of the questions in the questionnaires has the impact of illumination and noise which revealed the considerable dependence of health and performance of the weavers on the illumination and noise conditions.

Table 5.4 Correlation coefficient (r) between illumination value and the corresponding subjective responses as mentioned in the questionnaire.

Parameter	Variable	Correlation coefficient (r)	Inference
Physiological	Headache	$-0.63 \geq r \geq -0.73$	The result reflected that most of the physiological parameters have inverse correlation with the prevailing illumination levels on the handloom which inferred that due to poor illumination conditions the value of discomfort factors such as headache, fatigue due to light, eye irritation, redness of eyes, water falling from eye, neck pain, lower back pain, thigh pain, waist pain, ankle/ feet pain was on higher side and there was severity of neck pain, thigh pain, and ankle/ feet pain. Positive correlation of illumination was observed with the factors such as shoulder pain, sensation of light on loom, sensation of light around loom, illumination satisfaction level on loom, effect of light on job performance which may be due decrease in weaving speed or efficiency of the weavers which resulted in
	Fatigue due to light	$-0.73 \geq r \geq -0.83$	
	Eye irritation	$-0.68 \geq r \geq -0.78$	
	Redness of Eyes	$-0.66 \geq r \geq -0.77$	
	Water falling from eye	$-0.78 \geq r \geq -0.86$	
	Neck Pain	$-0.93 \geq r \geq -0.97$	
	Lower Back Pain	$-0.87 \geq r \geq -0.92$	
	Thigh Pain	$-0.93 \geq r \geq -0.98$	
	Waist Pain	$-0.85 \geq r \geq -0.91$	
	Ankle/ Feet Pain	$-0.86 \geq r \geq -0.95$	
	Shoulder Pain	$+0.81 \geq r \geq +0.90$	
	Sensation of light on loom	$+0.74 \geq r \geq +0.85$	
	Sensation of light around loom	$+0.56 \geq r \geq +0.66$	
	Illumination satisfaction level on loom	$+0.72 \geq r \geq +0.81$	

	Effect of light on job performance	+0.83 ≥ r ≥ +0.86	high effect on the job performance.
Psychological	Effect on Work Efficiency	-0.64 ≥ r ≥ -0.68	Inverse correlation was noticed on higher side between illumination and effect on work efficiency, rate of perceived exertion (RPE) due to illumination as well as with all the cognitive work load demands because of poor visibility at the workstation and there was severity of all the workload factors due to poor visibility. There was direct correlation of visual environment at work station and discomfort due to glare with low level of illumination which confirms that visual environment at work station was in conformity with the poor illumination conditions and there was severity of discomfort due to glare.
	Visual Environment at work station	+0.28 ≥ r ≥ +0.33	
	Discomfort due to glare	+0.87 ≥ r ≥ +0.92	
	RPE due to illumination	-0.63 ≥ r ≥ -0.74	
	Mental Demand	-0.88 ≥ r ≥ -0.93	
	Physical Demand	-0.97 ≥ r ≥ -0.98	
	Temporal Demand	-0.86 ≥ r ≥ -0.95	
	Performance	-0.72 ≥ r ≥ -0.80	
	Effort	-0.97 ≥ r ≥ -0.98	
	Frustration	-0.80 ≥ r ≥ -0.98	

'r' represents spearman's correlation coefficient.

Table 5.5 Correlation coefficient (r) between noise value and the corresponding subjective responses as mentioned in the questionnaire.

Parameter	Variable	Correlation coefficient (r)	Inference
physiological	Perception of Noise level	+0.72 ≥ r ≥ +0.89	Due to high noise level conditions on the handloom workstations, all the physiological as well psychological discomfort factors reflected the direct correlation. The severity of the impact was on higher side on nausea, pain in ear, hearing
	Headache	+0.74 ≥ r ≥ +0.91	
	Fatigue due to noise	+0.73 ≥ r ≥ +0.91	
	Nausea due to noise	+0.86 ≥ r ≥ +0.91	
	Pain in ear due to noise	+0.80 ≥ r ≥ +0.95	
	Hearing problem (Threshold shift)	+0.82 ≥ r ≥ +0.94	
	RPE due to noise	+0.72 ≥ r ≥ +0.86	
	Impact of noise on weaver	+0.56 ≥ r ≥ +0.85	
Psychological	Satisfaction level with conditions on loom	+0.47 ≥ r ≥ +0.72	

	Degree of impact of noise on working efficiency	$+0.56 \geq r \geq +0.83$	problem and cognitive demand.
	Mental Demand	$+0.89 \geq r \geq +0.96$	
	Physical Demand	$+0.74 \geq r \geq +0.87$	
	Temporal Demand	$+0.81 \geq r \geq +0.94$	
	Performance	$+0.89 \geq r \geq +0.96$	
	Effort	$+0.76 \geq r \geq +0.90$	
	Frustration	$+0.76 \geq r \geq +0.89$	

'r' represents spearman's correlation coefficient.

Symptoms of physical, physiological and psychological ailments due to terrible illumination and noise conditions which led to awkward working posture on the workstation were exacerbated in prolonged working hours. Recommendation of optimal illumination and noise level conditions that would not affect weavers' health in long run is crucial for humanizing working conditions at the handloom workstation.

Present research work established that unfavourable high noise level and poor illumination conditions were prevalent at the handloom workstations. **Thus, the hypothesis of the research work is accepted**.

5.6 Suggestions towards rectifying prevailing level of illumination and noise to reduce their impact on occupational health of the weavers.

The monotonous and drudgery nature of handloom weaving leads the weavers to excruciating problems during the weaving process under poor illumination and high noise conditions, which attract various physical, physiological and psychological disparities. During the research work, the illumination and noise levels were thoroughly recorded and statistically analysed. These analyses revealed that the occupational parameters significantly propounded the impact of low illumination and high noise for the occurrence of the symptoms of physical, physiological and psychological ailments. It was therefore, felt that recommendations/interventions to manage the illumination and noise level could be the solution towards reducing the occurrence of the symptoms mentioned above. Some intervention strategies mainly focusing on ergonomic design modifications in the workshed, in order to facilitate the access of more illumination on the sley (face of the fabric) of the handloom and reducing the noise generation and noise transmission to the weavers' ears, were proposed.

5.6.1 Specific recommendations towards design interventions for enhancing illumination level

- ***Use of LED lamps, canopy and inbuilt illuminating source in the frame of the handloom.***

  The observed data reflected that the average annual level of illumination was in the range of 66.77 lux – 173.21 lux. This level of illumination was relatively low for the weaving of pattern cloth using fine count yarn, as compared to the BIS standards (300 lux – 700 lux). In the handloom workshed the illuminating sources were randomly positioned which disseminated the diffused light on the handloom workstation resulted in poor visibility in the work area. It is recommended to install the illuminating source just above the handloom workstation or should be focused on the work area zone in order to have clear visibility. Based on the trials conducted in the present research, it was found that a 5W LED bulb fitted with the canopy placed at a distance of 1.5 feet above the face of the fabric surface on the handloom workstation gives an approximate illumination of 653 lux, which also conforms to IS: 6665-1972. Conical shape canopy/shade can be used for covering the illuminating source in order to preclude the glaring effect of direct light on the eyes of the weavers. The use of conical shape canopy also helps in compounding the illumination level for obtaining better light intensity over the face of the fabric surface. The positioning of an in-built illuminating source in the frame of the handloom can be one of the vital design interventions to have proper illuminating environment at the functional area of the handloom.

- ***Design modification of the roof / architectural structure of the working shed.***

  The intensity of illumination outside the handloom workstation was very high which varied in the range of [12400 lux (1600 h) to 72900 lux (1200 h)] can be utilized by design modification of windows and doors. To have better access of day light inside the workshed, it is recommended to enlarge the size of doors and windows of the shed during construction of the handloom workshed. Moreover, the opaque asbestos sheets of the roof of handloom workstation could be replaced with the transparent and translucent sheets in order to allow the daylight to pass through for better visibility on and around the workstation.

- ***Design intervention for prevention of glare.***

  For the prevention of glare, the reflected light should not coincide with the angle of view. As per the IS: 6665-1972 norms, the limiting glare index (LGI) should not exceed 19 for any type of fabric. Moreover, various corrective actions may also be mediated to reduce the luminance of the lighting source such as decrease the glare causing area of high luminance, angle between the line of vision and the glare source should be high and surrounding area of the glare source should have high luminance.

- ***System design approach for providing better supply of electricity.***

  Owing to the fluctuation of the voltage of the electricity on the handloom workstation, it was difficult for the weavers to continue weaving of intricate fabric using fine yarn during night hours. The concerned government and the cooperative societies/agencies must intervene in the matter in order to ensure a constant voltage of electric supply of 220 ± 5 % volts on the handloom workstation. Solar panels may be installed with the assistance of government agencies at the subsidized rate, at the block levels of handloom clusters in order to have the uninterrupted power supply to the individual handloom workstation in the clusters.

5.6.2 Specific recommendations for controlling the impact of noise

It has been established that high noise conditions attract various physical, physiological and psychological imbalances. Hence some recommendations as interventions were formulated to facilitate minimizing the impact of noise pollution.

Personal protective equipment

- ***Hearing Protective devices*** are recommended to be used when the noise level exceeds the action level and should adhere to the anthropometry dimensions of the weaver. These could be (1) *Earplugs*, which fit inside the ear (Leheto and Landry, 2012) or (2) *Ear muffs*, which fit over the top of the ear. Since commercially available devices are costly, weavers could use cotton plugs to protect the ears from exposure to high level of noise. Moreover, the weaver could also use the indigenous protective clothing like muffler / gamocha etc. in order to reduce the exposure to noise. However, further studies are required to be conducted to ascertain whether there is any reverse effect due to use of these protective devices vis a vis reduction in vigilance capability and wakefulness during weaving owing to the absence of noise during use of ear-plugs / ear-muffs.

Ergonomic / design interventions towards protection from noise

- ***Design interventions and use of sound absorbing material for attenuation.*** For damping the unnecessary noise originated out of the various moving parts of the machine, acoustic quieting, noise mitigation, and noise control measures can be taken. Noise generating sources can be enfolded by using the acoustic plates for minimizing the noise level. For the handloom sector some indigenous and natural leaf damping materials such as fern and baby tears plants in combination with soil substrate having 70% coconut fibers and 30% expanded perlite may be used which facilitate in absorbing the significant amount of acoustic energy (D'Alessandro *et al.*, 2015).
- ***Redesigning of sound producing accessories by using reinforced material.*** Source of noise can be modified by substitution and development of accessories such as shuttle, Jacquard and sley, using reinforced materials having low noise producing property and could be a possibility for future scope which can be studied.

5.6.3 General recommendations for overall wellbeing

- ***Incorporation of rest pauses.*** For uninterrupted work of an hour, a rest-pause of five minutes is suggested in order to up bring the performance to its initial level for the next hour (Colqtjhoun, 1959). Rest pauses have been suggested in various industries such as power loom, garment manufacturing, steel and iron industries sector for rejuvenation of the worker to be ready physically and mentally for the further assigned target.
- ***Reduction of visual / hearing strain.*** In order to avoid physical and physiological stress due to low level of illumination and high level of noise, weavers should be encouraged to take frequent rest pauses. During this rest pauses, the weavers may engage themselves in the other ancillary type of activities, such as making arrangement for raw material, winding, warping of beam, packaging of product and carrying out of some other household work.

- ***Workstation and work accessories.*** These should be so designed as to ensure proper working posture, in order to facilitate easy visibility for proper setting of the yarn in the body of the fabric.

5.7 Novelties (key contributions) of the present research

The research work extensively promoted the existing knowledge of the indoor physical environmental factors and occupational health investigations in the context of handlooms of the industrially developing countries, like in India. The key novelties of this research are pinpointed hereunder:

5.7.1 Contribution to Knowledge Base

The physical data of the Indoor environmental parameters (illumination and noise) were measured at each workstation for one complete year for investigations, evaluations and proposing guidelines. The data reflected that how month-wise and season-wise the illumination and noise values varied with the variation of time, location, change of month and season throughout the year and in near future these values could be utilized as a ready reckoner for references by the researchers, engineers, entrepreneurs, master weavers and the weavers for further developments and end use.

Thorough month-wise database for illumination and noise with respect to handloom workstations in India made available for the first time to serve as a prominent guideline for the enthusiastic research fraternity to exploit database with scientific rigour.

Intensive compilation of subjective perception of the handloom workstations regarding existing environmental factors presented to serve as the first-of-its-kind research database in India, perhaps across the globe. Present research work has established that unfavourable high noise level and low illumination level which were prevalent at the handloom workstations may be mitigated successfully with appropriate ergonomic interventions.

5.7.2 Methodological perspective

Scientific methodology backed by strong statistical techniques was adopted to draw inferences from the findings. Before administering the questionnaire (both for the impact of noise and of illumination level), reliability and validity of the questionnaire were tested.

Friedman Chi-Squared test for nonparametric analysis of the significance of ranked variable was undertaken to explore any significant difference between the variable means at $p \leq 0.05$. Upon χ^2_F being significant, Dunn's Multiple Correction *post hoc* test was applied to explore between group significances.

Friedman's Chi-Squared (χ^2_F) test for the independence of question association between illumination and the physical, physiological and psychological discomforts was performed. First-of-its-kind study to come up with rigorous statistical analysis to explore correlation between environmental factors and subjective responses for the handloom workstations.

Methodology adopted for framing the questionnaire, measurement of data using various assessing instruments involved in qualitative (questionnaires) and quantitative (measurement of illumination and noise values) evaluating techniques respectively in the present research would be helpful for future researchers to conduct investigations in similar direction. This innovative modus operandi shall be of significant importance after the current research. The upshot data produced would be useful to the stakeholder in the respective field to formulate strategies for further exploration.

An innovative combination of research methodologies incorporating physical, physiological and psychological parameters, mapping of subjective and quantitative indoor work environment (Illumination and noise) parameters, subjective workload assessments and statistical modelling were used to achieve the aim of the research work.

The methodology followed in the present research could be adopted by the budding researchers for conducting their research in the similar direction. Thus, the standardized methodology as described and adopted in the present research could serve as the research manual for future researchers.

This is perhaps the first study to establish the impact of environmental factors viz. illumination and noise on subjective physical, physiological and cognitive well-being, gross occupational wellbeing in a nutshell

5.7.3 Perspective of Intervention strategies

Following the observations from present research, various intervention strategies have been suggested to save the weavers from detrimental effect of high level of noise and low level of illumination (See section 5.6 for details). Many of these interventions are very much feasible and affordable to the stakeholders (master weavers, cooperative societies, NGOs etc.). Implementation of these strategies would definitely bring change to overcome the identified problems associated with the poor environmental conditions in terms of noise and illumination. These initiatives in long run would ensure the better occupational health of the weavers and thereby their performance, efficiency and productivity.

5.8 Limitations of the Present Research

Despite mammoth pain and scrupulous experimental protocols standardized and implemented in the present piece of research, the work experienced few virtually inescapable limitations deeming further research, by and large, due to stipulations like time limit and scope of realization/execution, as below:

- Male weavers were included in the present study as in the western part of Odisha i.e. Bargarh district, the weaving work on the handloom was mainly dominated by the male weavers and the females were engaged only in ancillary works besides their household occupation. For the future study, the research work can be focused in the similar direction by including the female weavers dominated handloom workstations.
- Only noise and illumination level parameters were considered – other environmental variables such as relative humidity, temperature, and thermal constraints were not included in the present study and in future these aforesaid factors could be included in the study.
- In handloom sector no such studies on the handloom workstation have been reported, moreover scarcely reported data was available with reference to the effect of various environmental factors including noise and illumination on the physical, physiological and psychological parameters of the handloom weavers working on the handloom workstations. Furthermore, research findings were to be initiated from someplace hence the experiments in the related fields were conducted in the eastern region (Bargarh district) of India only and in future other locations which are highly dominated by the handloom weaving activities can be included for the study purpose together with the north-eastern part of India.
- Analyses mainly based on subjective responses – objective measurements such as vision test, assessment of muscle fatigue, determination of noise-induced hearing problems such as threshold shift were afar the practicable limits.

These related issues require further investigations in the future research

6. Conclusion

Present research work has established that unfavourable environmental factors (high level of noise and low level of illumination) were prevalent at the handloom workstation of this cottage handloom sector under study. Such adverse environmental conditions may be mitigated successfully with some recommendations towards interventions which may tone down the ill-impact of poor illumination as well as high noise conditions. The combination of research methods featuring questionnaire study, empirical assessments of indoor work environment (illumination and noise levels) of the existing handloom workstation followed by subjective assessment using the field study questionnaire (Appendix A), statistical analysis, direct observation and NASA TLX technique were successful in identifying the symptoms of physical, physiological and psychological ailments in small-scale and cottage handloom manufacturing industries.

The research methodology followed in the present research work is perhaps first of its kind towards investigations from an occupational health perspective in small cottage enterprises in India. Research methodology utilized in present research work may be easily adopted by researchers, production supervisors/managers/engineers towards implementing context specific environmental related solutions in the manufacturing handloom sector of industrially developing countries.

Handloom weavers having a vision or admiration in expanding or establishing new handloom workstations in this small cottage sectors, shall find the results of the current research endeavour highly beneficial. The research methodology used in the current research may be replicated by initiating similar investigations in other sectors in order to identify industry-specific problems and propose appropriate solutions.

The research work significantly contributes to the existing knowledge base of the indoor physical environmental factors and occupational health investigations in the context of the industrially developing countries like India in the field of handlooms. Research outcome of the present thesis can be utilized by various stakeholders of the handloom sectors to facilitate the improvement in quality and efficiency of the system as well as of life of the weavers.

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8. Appendices

8.1 Appendix A

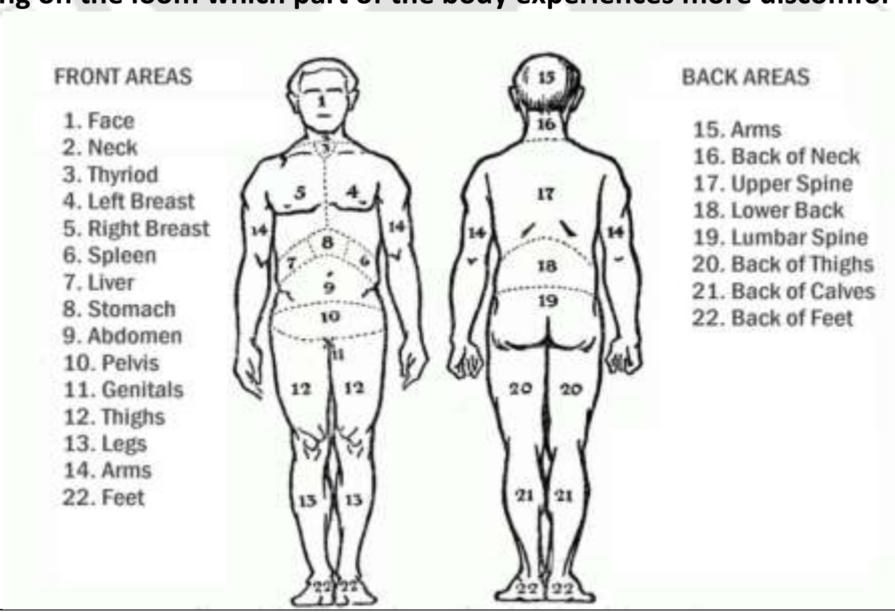
(adopted and modified from Recoup Ergonomic Workplace Analysis Manual, 2012; Bhattacharyya, 2011)

QUESTIONNAIRE FOR STUDY OF IMPACT OF LIGHT/ILLUMINATION ON HANDLOOM

Weaver's Code No. --------------------- Date of Data Collection. -------------------

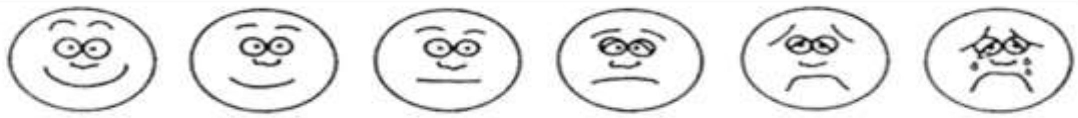
Name and address of the cluster………………………………………………………………………………

	Name of participant : Contact Number:
1.	**Effect on work efficiency in the existing lighting**. Nil/Very low Low Moderately low Medium Moderately high High Very high 1 2 3 4 5 6 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)
2.	**Headache due to existing lighting conditions.** Nil/Very low Low Moderately low Medium Moderately high High Very high 1 2 3 4 5 6 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)
3.	**Fatigue due to existing lighting conditions.** Nil/Very low Low Moderately low Medium Moderately high High Very high 1 2 3 4 5 6 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)

4.	**Eye Irritation while working in the existing illuminance** Nil/Very low — Low — Moderately low — Medium — Moderately high — High — Very high 1 — 2 — 3 — 4 — 5 — 6 — 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)
5.	**Redness of eyes while working in the existing illuminance** Nil/Very low — Low — Moderately low — Medium — Moderately high — High — Very high 1 — 2 — 3 — 4 — 5 — 6 — 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)
6.	**Water falling from eyes while working in the existing illuminance:** Nil/Very low — Low — Moderately low — Medium — Moderately high — High — Very high 1 — 2 — 3 — 4 — 5 — 6 — 7 Duration - Not at all - Daily(Whole day/Sometime) - Weekly(Once/Twice/Thrice/Many Times) - Monthly(Once/Twice/Thrice/Many Times)
7-12	**While working on the loom which part of the body experiences more discomfort/pain:** 

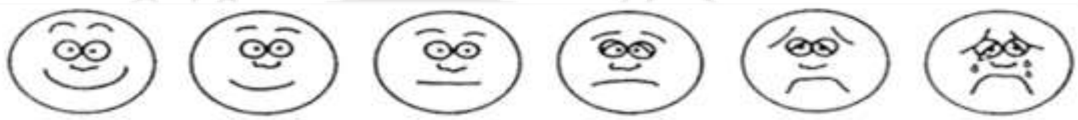
7. **Neck pain with respect to existing lighting conditions.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong



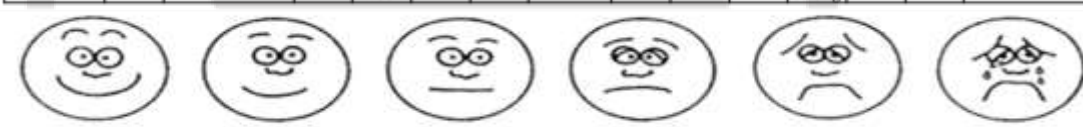
8. **Lower back pain while working on the handloom in the existing illuminance.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong



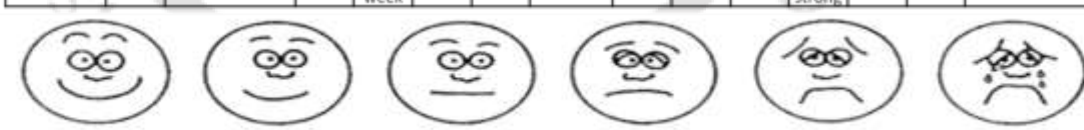
9. **Thigh pain while working on the handloom in the existing illuminance.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong



10. **Waist pain while working on the handloom in the existing illuminance.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong



11. **Ankle/Feet pain while working on the handloom in the existing illuminance.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong

12. **Shoulder pain while working on the handloom in the existing illuminance.**

0	0.3	0.5	0.7	1	1.5	2	3	4	5	6	7	8	9	10
Noting at all		Extremely week		Very week		week	moderate		Strong		Very strong			Extremely strong

13. **Please indicate on the following scale, How you find your visual environment:**

Very Uncomf.	Moderately Uncomf.	Slightly Uncomf.	no effect	Slightly Comfor.	Moderately Comfor	Very Comfor.
1	2	3	4	5	6	7

14. **What is the degree of discomfort the weaver feels due to glare:**

Imperceptible	just perceptible	just acceptable	acceptable	just uncomfortable	Just intolerable	Intolerable
1	2	3	4	5	6	7

15. **Rate your sensation/perception for lighting on the loom**:

Invisible (-3)	V.Poor(-2)	Poor(-1)	Average(0)	Good(1)	V. Good(2)	Excellent(3)
1	2	3	4	5	6	7

16. **Rate your sensation/perception for lighting around the loom:**

Invisible (-3)	V.Poor(-2)	Poor(-1)	Average(0)	Good(1)	V. Good(2)	Excellent(3)
1	2	3	4	5	6	7

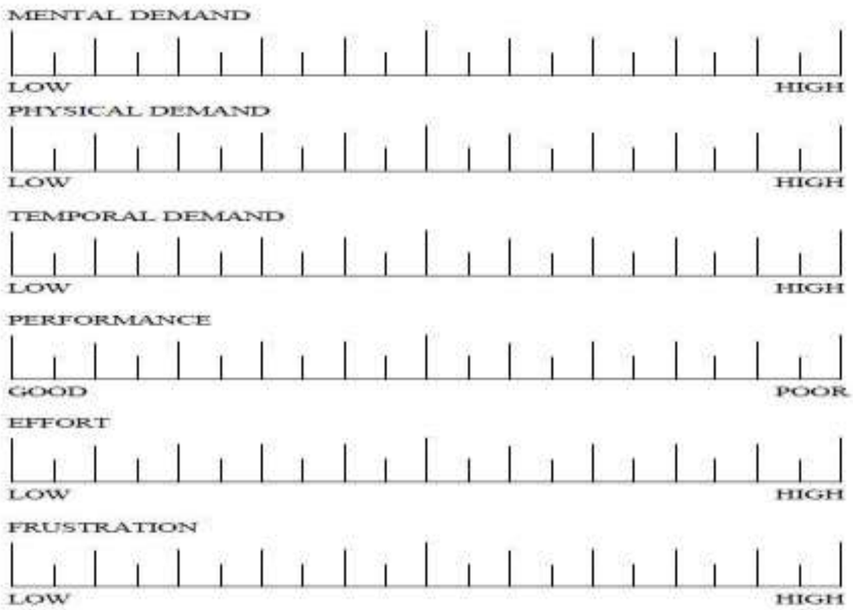
17. **Rate your satisfaction level for illumination at your Handloom:**

Very dissatisfied(-3)	Moderately dissatisfied(-2)	Slightly dissatisfied(-1)	No effect(0)	Slightly satisfied(1)	Moderately satisfied(2)	Very satisfied(3)
1	2	3	4	5	6	7

18. **Effect on job performance due to lighting conditions at the work place.**

Decrease (20%)	Decrease (10%)	Decrease (5%)	No effect (0)	Increase (5%)	Increase (10%)	Increase (20%)
1	2	3	4	5	6	7

19-24. **Mental Work Load with respect to Illumination.**



NASA-TLX Evaluation Strategy(Give Priority To Give Weight)

Effort/Performance, Temporal Demand/Frustration, Temporal Demand/ Effort, Physical Demand/ Frustration, Performance/ Frustration, Physical Demand/ Temporal Demand, Frustration/ Effort, Performance/Mental Demand, Performance/ Temporal Demand, Mental Demand/ Effort, Mental Demand/ Physical Demand, Effort/ Physical Demand, Physical Demand/ Performance, Temporal Demand/ Mental Demand, Frustration / Mental Demand.

25. **Rating of Perceived Exertion (RPE) due to Illumination.**

Nothing(0) Extremely(.5) Very(1) Weak(2) Moderate(3) Strong(5) Very(7) Extremely(10)

at all weak weak strong strong strong

0 0.5 1 2 3 5 7 10

Note-Present questionnaire on Light has been prepared by compilation and modification of available questionnaire developed by other researchers.

Date: (Signature of Weaver)

8.2 Appendix B

QUESTIONNAIRE FOR STUDY OF IMPACT OF NOISE ON WEAVING ACTIVITIES IN HANDLOOM SECTOR.

Weaver's Code No. --------------------- **Date of Data Collection. --------------------**

Name & Address of Cluster ____

1. Perception of noise level at the work place(Handloom)

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

2. Headache due to noise of the handloom

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

3. Fatigue DUE TO NOISE of the handloom

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

4. **Nausea due to noise of the handloom**

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

5. **Pain in ear due to noise of the handloom.**

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

6. **Hearing problem (chance of threshold shift temporary or permanent)**

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

7. **Rating of Perceived Exertion (RPE) due to noise.**

Nothing(0) at all	Extremely(.5) weak	Very(1) weak	Weak(2)	Moderate(3)	Strong(5)	Very(7) strong	Extremely(10) strong
0	0.5	1	2	3	5	7	10

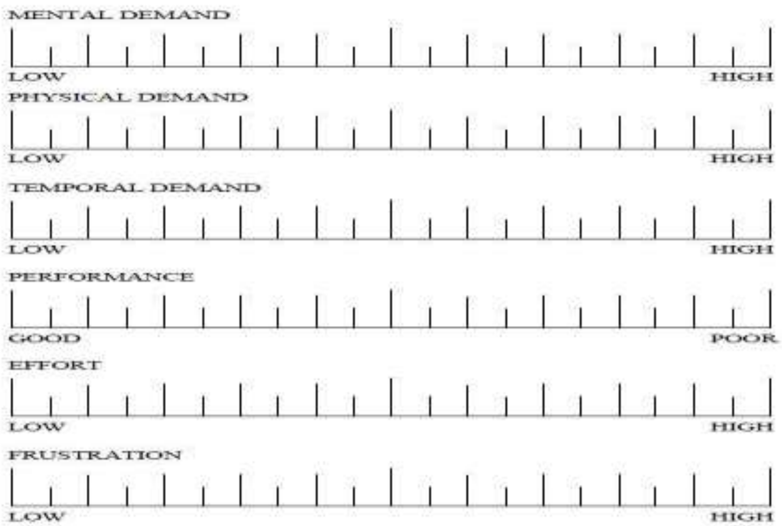
8. **Level of satisfaction with the working condition in the loom shed:**

Nil/Very Low	moderately Low	slightly Low	no effect	slightly high	Moderately high	very high
1	2	3	4	5	6	7

9. **Degree of impact of noise on working efficiency:**

Nil/Very low	Low	Moderately low	Medium	Moderately high	High	Very High
1	2	3	4	5	6	7

Duration
- Not at all
- Daily(Whole day/Sometime)
- Weekly(Once /Twice /Thrice /Many Times)
- Monthly(Once /Twice /Thrice /Many Times)

10	**Impact of sound level on weaver during the weaving process:** Not Tolerable Not Tolerable But Accustomed Tolerable 1 2 3 4 5 6 7 If not tolerable, Whether they use any ear plug during weaving process: Yes/ No
11 - 16	**MENTAL WORK LOAD with respect to noise.**  **NASA-TLX Evaluation Strategy**(Give Priority To Give Weight) Effort/Performance, Temporal Demand/Frustration, Temporal Demand/ Effort, Physical Demand/ Frustration, Performance/ Frustration, Physical Demand/ Temporal Demand, Frustration/ Effort, Performance/Mental Demand, Performance/ Temporal Demand, Mental Demand/ Effort, Mental Demand/ Physical Demand, Effort/ Physical Demand, Physical Demand/ Performance, Temporal Demand/ Mental Demand, Frustration / Mental Demand.

Note-Present questionnaire on noise has been prepared by compilation and modification of available questionnaire developed by other researchers.

Place: Signature of the Weaver & Date:

Sound Level Meter Reading

Code No. of the Weaver:-________

Name of the weaver:____

Month	Location of the sound level meter	Sound Level meter reading			Heart Rate/ min.
		Min.	Avg.*	Max.	
April-2014	Near the weaver's Right ear				
	Centre of the shed				
May-2014	Near the weaver's Right ear				
	Centre of the shed				
June-2014	Near the weaver's Right ear				
	Centre of the shed				
July-2014	Near the weaver's Right ear				
	Centre of the shed				
Aug.-2014	Near the weaver's Right ear				
	Centre of the shed				
Sept.-2014	Near the weaver's Right ear				
	Centre of the shed				
Oct.-2014	Near the weaver's Right ear				
	Centre of the shed				
Nov.-2014	Near the weaver's Right ear				
	Centre of the shed				
Dec.-2014	Near the weaver's Right ear				
	Centre of the shed				
Jan-2015	Near the weaver's Right ear				
	Centre of the shed				
Feb.-2015	Near the weaver's Right ear				
	Centre of the shed				
Mar.-2015	*Near the weaver's Right ear*				
	Centre of the shed				
April-2015	Near the weaver's Right ear				
	Centre of the shed				

*Average reading of the data recorded for 3 minutes near the weaver.

8.3 Appendix C
NASA TLX - Sources of workload comparison charts

Effort or Performance	Temporal Demand or Frustration
Temporal Demand or Effort	Physical Demand or Frustration
Performance or Frustration	Physical Demand or Temporal Demand
Physical Demand or Performance	Temporal Demand or Mental Demand
Frustration or Effort	Performance or Mental Demand
Performance or Temporal Demand	Mental Demand or Effort
Mental Demand or Physical Demand	Effort or Physical Demand
Frustration or Mental Demand	

8.4 Appendix D

NASA TLX - Rating Scale Definitions

Title	End Points	Descriptions
Mental Demand	Low/High	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting, or forgiving?
Physical Demand	Low/High	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) accomplish your level of performance?
Frustration Level	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

8.5 Appendix E

NASA Task Load Index (TLX) Scale

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

8.6 Appendix F

Borg CR10 Scale

0	Noting at all
0.3	
0.5	Extremely week
0.7	
1	Very week
1.5	
2	week
3	moderate
4	
5	Strong
6	
7	Very strong
8	
9	
10	Extremely strong

Borg CR10 (Category Ratio) scale (Borg, 1982a, 1998,)

Reference:

Borg G. A category scale with ratio properties for intermodal and inter individual comparisons. In: Geissler H-G, Petzold P, eds .Psychophysical judgment and the process of perception. Berlin: VEB Deutscher Verlag der Wissenschaften, 1982a: 25–34

8.7 Appendix G

Publications related to doctoral research

1. **Kumar, S.,** Abhirup Chatterjee and Sougata Karmakar (2017).Impact of exposure to high noise level on occupational health of the weavers engaged in handloom sectors in India: A case study from Bargarh district 15th International Conference on Ergonomics and Human Factors, HWWE - 2017 Department of Mechanical Engineering, Aligarh Muslim University, Aligarh, U.P., India, 8th –10th December 2017.

2. **Kumar, S.,** Chatterjee A., Karmakar S. (2016), Low Illumination Level in Indian Handloom Sector leading to high cognitive work load: A case study from Bargarh, Odisha,14th International Conference on Ergonomics and Human Factors, HWWE - 2016 Department of Industrial Engineering, National Institute of Technology Jalandhar, India, 8th –11th December 2016.

3. **Kumar, S.,** Patel, T., and Karmakar, S. (2014). Scenario of Handloom Industry: Indian Perspective. 12th ISE Annual Conference, Proceedings of International Ergonomics Conference on “User Centered Design and Occupational Wellbeing", HWWE-2014, Department of Design. Indian Institute of Technology Guwahati, India, 3th–5th December, pp. pp. 234-238. [ISBN 978-93-392-1970-3]

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