An ergonomic assessment and development of a design intervention method in the unorganised sector based on physiological, postural, psychological and environmental (PPPE) scores with special reference to traditional brick making industry

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This dissertation is submitted for the degree of

Doctor of Philosophy

IDC-School of Design 28/07/2020

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Submitted in partial fulfilment of the requirements
For the degree of

Doctor of Philosophy

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2020

I would like to dedicate this thesis to my loving parents …

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other University. This dissertation is the result of my work.

Amar Kundu
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28/07/2020

Approval Sheet

This thesis entitled "**An ergonomic assessment and development of a design intervention method in the unorganised sector based on Physiological, Postural, Psychological and Environmental (PPPE) scores with special reference to traditional brick making industry**" by **Amar Kundu** is approved for the degree of **Doctor of Philosophy**.

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Date: 21 July 2020

Place: Mumbai

Acknowledgement

I would like to acknowledge my thesis Supervisor Professor Gaur G. Ray, for his valuable guidance and support throughout my research at IDC-School of Design, Indian Institute of Technology Bombay. His simple attitude, humorous nature and in-depth knowledge make him an ideal supervisor.

I would like to acknowledge my thesis Co-Supervisor Professor Swati. Pal for her valuable advice and generous guidance.

I am indebted to my doctoral committee, Professor N. Sadhu, Professor N. Shah, and Professor V.P. Bapat, who provided scholarly advice and thought-provoking analytical approach during the review of this work.

I must extend my sincere thanks and gratitude to Messrs of RB Industries & VS Bricks of Gujarat, as well as the Messrs of Sun Industries, Bihar for their wholehearted support throughout the study.

Special heartfelt thanks to Mr Bharat Bhai, Mr Binu Bhai, the owners of the VS Bricks, Mr Rabindra Bhai Prajapati the owner on the RB Bricks and Mr Siddharth Kumar, the owner of the Sun Bricks for their unparallel support, accessibility to the industry, and taking part as a research team member to make this project a success for the cause of the brick-making workers.

I also would like to thank Professor Prakash C. Dhara of Vidyasagar University, India, who introduced me to ergonomics, for his guidance and encouragement.

I further would like to thank Professor Kasturi Sen Ray of Tata Institute of Social Sciences and professor of SNDT Women's University, India, for her guidance in the area of nutritional study and encouragement throughout the study.

I offer my thanks and heartfelt best wishes to my past and present research colleagues Ms Lavanya Bachwal, Ms Priyanka Rawal, Dr V. Sai Praveen, Dr Saajan S, Ms Shika Agarwal, Dr Susmita Sharma and Dr Dhanashri Shinde towards their criticality and continuous support in this study, both in the field and inside the laboratory.

I would also like to thank Mr Quashif Qureshi, Mr Anshul Patle, Ms Sweeti Kumari, Ms Chaitrali Mhatre, Mr Amit Wani, Mr Chetan Dushane & Mr Prateen Dhara for their support during this research.

Sincere thanks to all the faculty members and workshop staffs, IDC School of Design, for their constant support during my research.

I would like to share my heartfelt acknowledgement and appreciation to Tata Centre and Technology Development, IIT Bombay, towards funding the project.

I would like to acknowledge my colleagues, especially Mr Ajay Disley, Mr Swaroop Gopal V. and Mr Gnanaval S.S. at Tata Elxsi, Bangalore, for their support during research.

Last but certainly not the least, I would like to extend my deepest gratitude to my elder brother Mr Akshay Kundu and my parents who sacrificed their time with me and for their lifetime support and encouragement, and to my wife Samapti Mondal for her patience and devotion. I am forever indebted to their unyielding support and endless love.

Abstract

India is the seventh-largest country by geographical area and second populated country in the world. Almost ninety-four percent of the Indian workforce is working in the unorganised sector. Unorganised activities are labour intensive, requiring low-level skills and uses age-old traditional primitive technologies that causes occupational hazards.

Occupational stress can be divided into four major classes, such as physiological stress, postural stress, psychological stress and environmental stress. The earlier research of unorganised sector recommended for ergonomic design interventions to make the workstation more ergonomic. Like the other developed country, mechanisation or automation in Indian unorganised sector is difficult. Therefore, it needs a context-specific low-cost design intervention from the viewpoint of sustainability, cost-effectiveness and manpower-employment, that can reduce occupational stress. It is essential to find out the most significant pain point to do the context-specific design intervention in the unorganised sector. Hence, the prioritisation of most painful stress, among all other occupational stresses is most important. Physiologically stressful job demands high physical workload and needs to be redesigned the work that provides leverage or low-cost mechanisation. The pastorally stressful job needs to change the working posture. Psychological stressful job needs to find out the causes of psychological stress, and reorganise the job, improve the employer-employee relationship. For environmentally stressful job, the working environment needs to be modified by worker acceptable limit. An environmental stressor can be managed at the source or in between source and subject (like using PPE).

The Minimum Wage Act, 1948 helps for fixation and execution of minimum wages to prevent exploitation of labour through the payment of low wages. The minimum wage rate can be fixed at a) time rate, b) piece rate, c) guaranteed time rate, and d) overtime rate. The Indian Labour Conference (1957) had come up with a norm that should be considered during minimum wage fixation. In Indian unorganised sector, minimum wages fixed on 2700 calories energy requirement. Ergonomics can revalidate the energy requirement among unorganised worker.

The minimum wage fixation committee considers four consumption units per earner. But in the Indian scenario, there are six consumption units per earner (worker, spouse, two kids and parents). Depending on that wage fixation norms need to be re-thought by the Social Scientists.

Depending on the proximity to research institute, availability and other factors, the brick kiln industry is selected to understand the ergonomic issues in the unorganised sector. The main aim of this study is 'minimisation of drudgery in the brick kiln industry by eliminating the ergonomic risk factors. The objectives of the present study are –

- To understand and comparison of the traditional brick making process in a different part of India.
- To measure the per brick human energy expenditure to make one single brick, that can help the social scientists to fix the minimum wage for brick kiln workers.
- To measure the per brick human time cost to make one single brick, that can help the social scientists to fix the minimum wage for brick kiln workers.
- To quantify the physiological stress, biomechanical stress, psychological stress and environmental stress among brick kiln workers
- To develop a more straightforward, simple method that will give the design direction guideline to the designer and engineers (novice/non-expert in ergonomics).

India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems faced by the respective brick kiln workers. From the three brick kiln industries, 259 participants (193 male and 66 female) were selected for the current study. In Indian traditional brick making industry, six types of workers are available such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi.

Energy expenditure study also says that Pathera activity is physiologically most demanding activity, and it demands 3394 Kcal energy per day per person. Nikashi (3370 Kcal) is the second physiologically demanding activity and followed by Bharai (3311 Kcal/day), Khadkan (3096 Kcal/Day), Jalaiya (3000 Kcal/day) and Kiln top coverer worker (2700 Kcal).

The study also says that Female workers demand less energy in comparison to the male worker. But it should be noted that the productivity (in terms of brick production) of female brick kiln workers also less than male brick kiln workers. The average per day energy expenditure, among brick kiln worker, is 3151 Kcal (range 2700 – 3394 Kcal), which is far more than 2700 Kcal. The above energy expenditure study proves that the minimum wage fixation method should be reconsidered based on 3151 Kcal/day/person.

According to the Factories Act, a worker should not be required to work more than 9 hours a day, spread over 10.5 hours due to rest periods. But the study results say that the average working hours for Pathera workers in VS brick kiln is 780 minutes (13 hours), which is far beyond the Factories Act recommended regular working hours. The same trend is followed for RB Pathera workers (15 hours) and SUN Pathera workers (11 hours and 30 minutes) also.

To make one single brick from raw material to final brick, Gujarat brick kilns are taking roughly 1.5 minutes (90 seconds), on the other side, Bihar brick kiln is taking 1.72 minutes (103 seconds). To make one single brick, Gujarat brick kiln is using 5.71 – 5.14 kcal, whereas Bihar brick kiln is using 6.32 kcal human energy.

As per workload classification and relative cardiac cost analysis, Digging, Mud preparation, Mud transfer, Coal breaking and Nikashi activities are falling under the heavy category. As per posture analysis study, moulding is maximising strenuous job and have highest Rapid Entire Body Assessment (REBA) score, that suggest 'very high risk, implement change'. As per Perceived Stress Scale (PSS) score, Pathera and Nikashi activities are psychologically more demanding job due to uncertainty of wage, lower-wage system, extended long time hours. Environmentally, Jalaiya is a more difficult job due to kiln temperature.

To prioritise the stress, **P-P-P-E** (**P**hysiological, **P**ostural, **P**sychological and **E**nvironmental stress) method was developed. Most dominated stress is measured from P-P-P-E score. As per P-P-P-E method, Brick moulding and Jalaiya activities are selected for design intervention. P-P-P-E method suggests that design intervention should be carried out among brick moulding workers to reduce the postural stress and on Jalaiya worker to reduce the environmental stress.

The results of P-P-P-E method says that Brick moulding (Pathera worker) is pastorally a stressful activity, and recommended to change the working posture towards to neutral posture. The current study took the initiative to improve the posture at the local level (i.e. wrist posture) as well as in system-level (whole-body posture). To reduce the postural stress, the brick moulding process is changed from a squatting posture to sitting-standing posture. A validation study says that new design intervention reduces the postural stress, working heart rate and increases productivity. Newly design brick making tools resolved the two major problem areas of workers (Squatting posture and Excess physiological stress on fingers due to repetitive turning of mould). To validate the design, a validation study was conducted among 32 brick moulding workers. The results say that new design can increase productivity by 23% (in terms of bricks) and decrease the physiological workload by 13%. The REBA analysis says that sitting posture is better posture than traditional squatting posture.

A design intervention also carried out on Jalaiya worker. The facial region of the Jalaiya workers are exposed to radiant heat; therefore, a face mask was designed to save the workers from high heat stress. Due to unavailability of brickfield, the facemask was validated in a laboratory situation. A radiant heater was used as a source of high temperature, and two temperature sensors were used on both side of the facemask. The validation study proved that; face mask can reduce the heat exposure 50^0 centigrade 35^0 centigrade. The newly designed mask will protect the Jalaiya workers from radiant heat. The mask will be cheap, maintenance-free and durable and will not hamper the normal activities and air circulation of the workers. The lab simulation study concludes that the newly designed headgear can reduce the radiant temperature by 30%.

The study also identified the limitation and future scope of the current research. The P-P-P-E method was developed in brick making environment. It needs to validate the sensitivity of P-P-P-E method in other unorganised sectors. WBGT index is considered as a representative of environmental stress in the brick kiln. It might be different in other unorganised sector depending on available environmental stress. The intervened products need to validate for long duration in a brick kiln to get best validation results.

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Abbreviations

ART	Assessment of Repetitive Tasks
BMI	Body Mass Index
BMR	Basal Metabolic Rate
BP	Blood Pressure
BPD	Body Part Discomfort
bpm^{-1}	Beats per Minutes
BSI	British Standard Institution
CAD	Computer-Aided Drafting
CAGR	Compound Annual Growth Rate
CBT	Core Body Temperature
CET	Corrective Effective Temperature
CG	Centre of Gravity
cm	Centimetre
COPD	Chronic Obstructive Pulmonary disorder
COPSOQ	Copenhagen Psychosocial Questionnaire
CR Scale	Category-Ratio Scale
DBP	Diastolic Blood Pressure
DBT	Dry Bulb Temperature
DMQ	Dutch Musculoskeletal Questionnaire
DUE	Distal Upper Extremity
e.g.	Example
ECG	Electrocardiogram
EE	Energy Expenditure
EMG	Electromyography
FCBTK	Fixed Chimney Bull's Trench Kiln
FEV1	Forced expiratory volume in one second
FVC	Forced Vital Capacity

GDP	Gross Domestic Product
GT	Globe Temperature
HR	Heart Rate
HRR	Heart Rate Reserve
HTA	Hierarchical Task Analysis
ILO	International Labour Organization
JCQ	Job Content Questionnaire
Kcal	Kilocalories
kg	Kilogram
LBD	Low Back Disorder
LI	Lifting Index
LMM	Lumbar Motion Monitor
LUBA	Postural Loading on the Upper Body Assessment
MCH	Modified Cooper Harper scale
MFA	Muscle Fatigue Assessment
min	Minutes
mm	Milligram
MMH	Manual Material Handling
MSD	Musculoskeletal Disorder
MW	Minimum Wage
MWL	Mental Workload
NASA TLX	NASA Task Load Index
NCC	Net Cardiac Cost
NCEUS	National Commission for Enterprises in the Unorganised Sector
NEQS	National Environmental Quality Standards
NIOSH	National Institute for Occupational Safety and Health
NSSO	National Sample Survey Office
OCRA	Occupational Repetitive Action
OWAS	Ovako Working Posture Analysis System
PEFR	Peak Expiratory Flow Rate
PI	Ponderal Index
PPE	Personal Protective Equipment

PPPE	Physiological Postural Psychological and Environmental
PSS	Perceived Stress Scale
PTO	Power take-off
QEC	Quick Exposure Checklist
RCC	Relative Cardiac Cost
REBA	Rapid Entire Body Assessment
RMR	Resting Metabolic Rate
RPE	Rated Perceived Exertion
RULA	Rapid Upper Limb Assessment
RWL	Recommended Weight Limit
SBP	Systolic Blood Pressure
SD	Standard Deviation
Sec	Second
SI	Strain Index
SPSS	Statistical Package for Social Science
SWAT	Subjective Workload Assessment Technique
TEA	Thermic Effect of Activity
TEF	Thermic Effect of Feeding
ULD	Upper Limb Disorders
USA	United States of America
VDT	Video Display Terminal
VSBK	Vertical Shaft Brick Kiln
WBGT	Wet Bulb Globe Temperature
WBT	Wet Bulb Temperature
WHO	World Health Organisation
WHR	Waist Hip Ratio
WMSDs	Work-related Musculoskeletal Disorder

Nomenclature

Bharai - The worker group, who shifts the Sun-dried bricks from moulding ground to kilns for baking, is locally known as Bharai.

Jalaiya - The worker group, who involves with brick firing process, like coal breaking, coal feeding, kiln temperature regulation, etc., are locally known as Jalaiya.

Khadkan - The worker group, who arranges the bricks in the kilns for firing, is locally known as Khadkan.

Nikashi - The worker group, who removes the fired bricks from the stacks in the kiln to the outside of the kiln, is locally known as Nikashi.

Pathera - The worker group, who involves mixing earth with water and shaping it into bricks, is locally known as Pathera.

Chapter 1 Introduction

In this chapter, the definition of the unorganised sector and its classification, characteristics etc. are presented. A review of literature on the current status of the unorganised sector and a comparison among the popular ergonomic methods, used by the previous researcher is then presented. The available ergonomics method comparison analysis says that there is no such method(s) that can give a design direction guideline to the designer. In the current chapter, the lacunae (problems in the unorganised sector) of the unorganised sector is highlighted.

1.1 Background

As per the number of populations, India stood in the second position, next to China, with over 1.3 billion people in 2015 (Population Reference Bureau, 2015). In 2012, there was 487 million working population; among them, 94% was working in unorganised sector (CIA, 2012). In the current decade, no change in Indian organised and unorganised workforce was noticed as compared to the last decade, which is shown in Figure 1-1, research by NSSO Surveys (National Sample Survey Office, 2012).

In 2005, 95% of the Indian workforce worked in the unorganised sector and generated 50.6 % of India's GDP (Datt, 2008). The unorganised sector's workers are not registered with the government and not bound by any governmental rules and regulations.

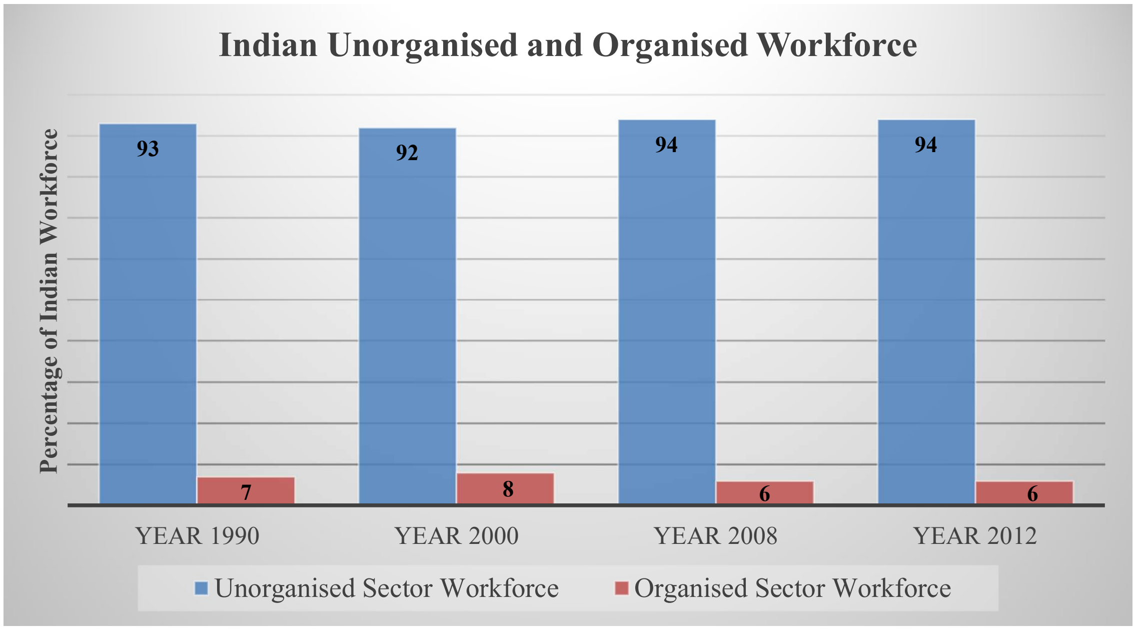


Figure 1-1: Indian organised and unorganised workforce

1.2 Unorganised Sector

The unorganised sector has grown-up by jumps over the years. The nature of the unorganised sector is multifarious. Covering numerous outlooks, many efforts have been taken to identify standard criteria for the identification of the unorganised sector. But the difficulty starts in defining the sector itself to confine them comprehensively. Some of the definitions of the unorganised sector are discussed in detail as follows:

Definition by Kenneth King

> *"Their unorganisedity derives from their being unrecognised in government employment statistics and operating in the main act of the makeshift shelters on urban wastelands, roadsides and forest fringes"*
>
> *(Kenneth, 1974).*

Definition by 15th International Conference of Labour Statisticians:

> *"The terms unorganised and informal sectors are often used interchangeably. The informal sector may be broadly characterised as consisting of units engaged in the production of goods or services with the primary objective of generating employment and incomes to the persons concerned" (ILO, 1993).*

Definition by National Commission for Enterprises in the Unorganised Sector:

> *"The unorganised sector consists of all unincorporated private enterprises owned by individuals or households engaged in the sale and production of goods and services operated on a proprietary or partnership basis with less than ten total workers".*
>
> *"Unorganised worker consists of those working in the unorganised enterprises or households, excluding regular workers with social security benefits, and the workers in the formal sector without any employment/social security benefits provided by the employers".*

Definition by Unorganised Workers' Social Security Act, 2008:

> *"Unorganised Sector means an enterprise owned by individuals or self-employed workers and engaged in production or sale of goods or providing service of any kind whatsoever, and where the enterprise employs workers, the number of such workers is less than ten".*

From the analysis of definitions, it can conclude that the unorganised sector is a term that eludes definition as the sector is vast and diverse to confine within a conceptual definition.

1.3 The Magnitude of the Workforce in the Unorganised Sector

The sector, which is not recorded with the government and does not follow any rules or regulations, is considered as unorganised sector. Unorganised sector denotes to all unlicensed, self-employed or unregistered economic activity (Swaminathan, 1991). The unorganised sector depends on locally available resources, small-scale setup and traditional skills & work method. (NCEUS, 2007).

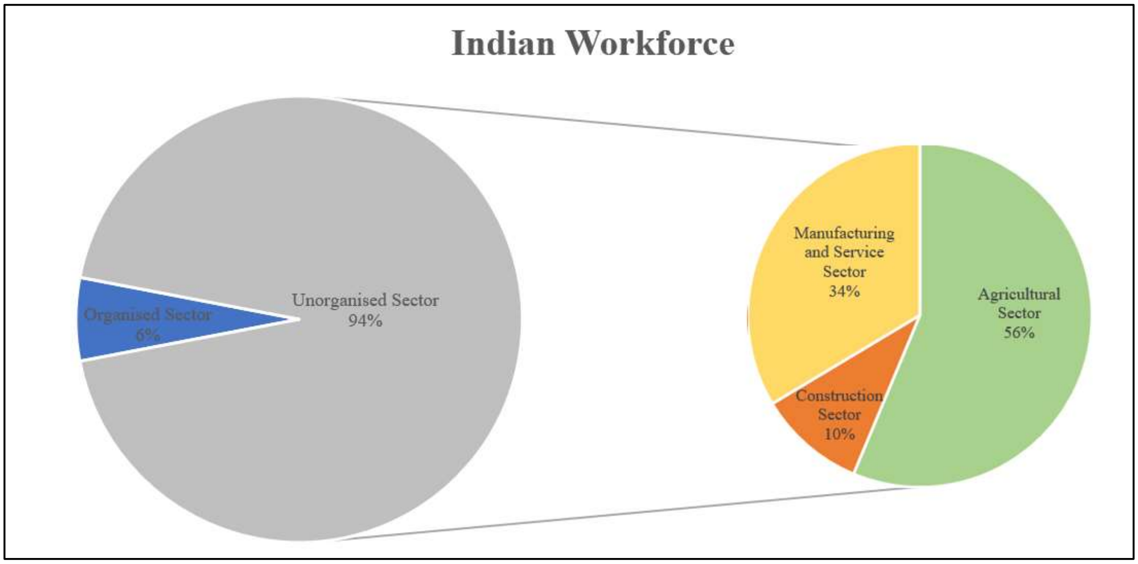


Figure 1-2: Indian organised and unorganised workforce

According to the NSSO report (2011-2012), shown in Figure 1-2, out of 46.5 crore employed persons, 2.8 crores (6%) are from the organised sector and rest 43.7 crores (94%) from the unorganised sector. Among the total unorganised workers, 24.6 crores (56.3%) workers are employed in the agricultural sector, 4.4 crores (10.1%) in construction, and rest 14.7 crores (33.6%) are in manufacturing, trade, transport, communication and services activities (National Sample Survey Office, 2012).

1.4 Characteristics of the Unorganised Sector

The unorganised sectors are labour-intensive, small-scale activities with local ownership, and operated by using primitive traditional technology-based methods. These sectors have inadequate or no access to government legislations (Migration Advisory Committee, 2018). The workers of the unorganised sector coming from the grass-root level. The characteristics of the unorganised sectors are given below –

a) Unorganised sector has inadequate or no access to government legislations.

b) No taxes are imposed from this sector, as the government does not regulate it.
c) Application of labour acts and legislation in the unorganised sector is inadequate.
d) There is no formal employer-employee relationship.
e) The amount of population under the unorganised sector is overwhelming, and they are constant throughout the country.
f) The unorganised labours are classified on caste and community considerations, especially in rural areas.
g) Migrant labour is involved in the unorganised sectors.
h) Due to the uncertain nature of the unorganised sector, most of the workers don't have a steady job.
i) As the unorganised workers suffer from cycles of the seasonality and irregularity of employment
j) The workplace of the unorganised sector is scattered and fragmented.
k) There is low-skilled employment in the unorganised sector.
l) There are no dedicated working hours and holiday in the unorganised sector.
m) The unorganised sector is, in general, a low wage and low earning sector.
n) The unorganised workers get relatively lesser wages than the organised sector, even for closely comparable jobs.
o) The unorganised workers are usually subject to indebtedness and bondage as their meagre income cannot meet with their livelihood needs.
p) Piece-rate payment and contractual work are common trends in the unorganised sector
q) The unorganised sector uses age-old traditional primitive technologies.
r) Primitive and outdated production technologies are rampant in the unorganised sector.
s) The unorganised activities are mostly labour-intensive.
t) Usually, the unorganised sector doesn't have any formal training as workers learn during job only.
u) There are no permissions or encouragement to imbibe and assimilate higher technologies in the unorganised sector.
v) The unorganised workers do not receive adequate attention from the trade unions.
w) The businesses in unorganised sectors require less investment.

x) Due to isolation and invisibility, the unorganised workers are unaware of their rights.
y) There is an increasing tendency to recruit workers through contractors in the unorganised sector.
z) Health hazards exist in the majority of unorganised occupations.

1.5 Problems in the Unorganised Sector

The large segment of the workforce has continued to be neglected even though the unorganised sector has a crucial role in the Indian economy in terms of employment. The unorganised sector's workers face various types of problems in their regular life. The unorganised labour faces the following issues and challenges –

Occupational diseases and disorder: Occupational health problem is widespread among unorganised workers due to pain or injury from physical overexertion, repetitive manual handling and awkward working positions. Occupational diseases and disorder like Work-related Musculoskeletal Disorder (WMSD), pneumoconiosis, tuberculosis, and asthmatic are out of control in informal sectors. In addition to that, the problem in the digestive system, circulatory system, urinary tract, blood pressure and effect on various sensory organs (like loss of eyesight, hearing etc.) are also very common happenings. They do not get proper facilities for treatment too. (Chatterjee, 2016).

Occupational Hazards: Unorganised workers are exposed to hazardous working conditions which adversely affect their health. Health problem increase due to low nutrition and heavy physical labour. Low income and inability to pay for health care leads the poor worker to be indebted. Studies reported that home-based beedi workers are affected with respiratory and body ache due to inhalation of the tobacco dust and peculiar posture at work, respectively. In tobacco processing units, who involve in plucking, winnowing, grading and packing etc., the mist containing tiny particles of tobacco spread in the workplace enters the respiratory tract and cause dangerous diseases like asthma, Tuberculosis etc. Salt Pan Workers suffer from severe eye problems due to the reflection of light from the heap of salt and skin diseases. The workers working in the fireworks, match works, leather tanning and construction are prone to accidents.

Inability to Secure Minimum Wages: The amputations, due to unguarded operations or unsafe machines. Unorganised workers don't have any knowledge about work hazardous and occupational safety. Introduction of different hazardous machinery, various toxic chemical, dust, etc. can lead to tragic accidents or deaths in the unorganised sector.

Hazards Connected to Accidents: Accident cause damage to the health, loss in the earning capacity, requires additional expenditure for hospitalisation and medical treatment. It causes partial or permanent disability from earning. Death of the breadwinner will put the whole family into trouble, making them indebted by spending entire savings and assets.

Supreme Court held that employing workers for a wage below the statutory minimum level will result in forced labour, which is prohibited under Article 23 of the constitution of India even though poverty forces anyone to work for a low wage. Studies in the unorganised sector reported that daily wages are paid much below than the minimum fixed by the government. The unorganised workers are denied from that rights (such as overtime, paid holiday or sick leave, etc.); however, the use of those laws is normal in the organised sector. It has observed that women and child labour are most vulnerable amongst the unorganised labour. The children and women workers are regularly made to work without nourishment and low wages. They are being paid low-wages as compare to adult male labour despite their commitment to the same working hours. The preference over multiple employers due to non-availability of work has deprived the unorganised workers of getting minimum wages and social security.

Insecurity in Job: High-level job insecurity is a common phenomenon unorganised sector. The job nature of the unorganised sector is temporary. Therefore, the unorganised workers depend on multiple employments due to uncertainty of work.

Lengthy working Hours: The long working hours beyond the regulatory norms affect their social and family life. Absence of laws to govern the working conditions of the unorganised sector resulted for lengthy working hours (Arjun Patel and Desai Kiran, 1995).

Poverty and Indebtedness: The unorganised workers are poor due to the low income and uncertain employments, facing problems to manage social and cultural life with poor economic status. Increased indebtedness in the unorganised sectors increased suicide of workers (Kannan K.P et al., 2012).

Lack of Health Security: Forty-eight percent (48%) of informal workers spend their Annual Household income for Medical Care. The paucity of Subsidy or Government support in health care has added vulnerability in their life. The inability to offer medical treatment have resulted in poor health status.

Insecurity during Old Age: Leading life during the old age has become a challenge among unorganised workers. The unorganised workers are not covered under the Provident Fund scheme. The nature of employment in the unorganised sector created a fear of displacement from work on age factor due to inability to work after a certain age.

Poor Working Environment: Maximum unorganised workers don't have any perfect living areas near to their workplace. Deficiencies in sanitation due to lack of washing facility, proper urinal and toilet facilities will affect the health of the workers. Even the physical conditions like space, lighting, ventilation available are deplorable compare to organised sectors. Therefore, the unorganised workers have to live in an appalling situation.

Problems of Migrant Workers: Most migrant workers are poor and migrating from one state to another state. Without adequate basic amenities, the migrant workers work under the adverse environment. For example, the Sugarcane labourers, brickkiln labourers, who live in the open field, facing steady problems from the menace of snakes, scorpions, mosquitoes etc. The workers do not have electricity, water supply and sanitation facility. The migrant workers have no right to bargain and works for less wage. Illiteracy, lack of awareness, lack of regulations and social isolation are the hurdles from unionising. They cannot voice their demands or object the adverse attitude of the employers to protect their self-interest (Arjun Patel and Desai Kiran, 1995).

Bonded labour (Dadan): Bonded labour is an obligatory bond between an employer and an employee. Migrant workers, bonded labours and child labours are the major vulnerable groups who are exploited and deprived in all spheres of life. The creditor grant loan to unorganised workers, on an agreement of forcing them to be under bondage till repayment of the sum forming a debtor-creditor relationship (Vidyut Joshi, 1995).

1.6 Role of Ergonomics to Prevent the Problem in the Unorganised Sector

Ergonomics is a multi-disciplined field in which the interactions between workers and their working environment are studied. In its application, work should be designed around the worker, taking into account their abilities and limitations, human behaviour, task demands, tools, equipment, and working environments. The International Ergonomics Association (IEA) defines ergonomics (or human factors) as:

> *"The scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system. Practitioners of ergonomics, ergonomists, contribute to the planning, design and evaluation of tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people"* (Schlick, 2009)

From Section 1.5, it can be concluded that the unorganised workers suffer under different types of problems. Government-imposed rules and regulation can manage some problem. Among them, occupational stress/hazard and wage fixation can be resolved via ergonomic intervention.

1.7 Wage Fixation in the Unorganised Sector

All labour laws applied by the Indian government directly or indirectly influence the wage level and structure of wages in the unorganised sector. The Table 1.1 gives a list of rules and regulations that have a direct influence on wages in the Indian unorganised sector.

Table 1.1 Available Indian Labour law imposed on the unorganised sector

Labour Act	Type of intervention
The Minimum Wages Act, 1948	To provide a minimum wage
The Trade Unions Act, 1926	Allow the workers to form trade unions, who can bargain for wages
The Industrial Disputes Act, 1947	To enable trade unions to find the loop faults on wages and settlement to intervene.
The Equal Remunerations Act, 1976	To assure equal wage irrespective to any gender
The Payment of Wages Act, 1936	To regulate the process of wage-payment
The Contract Labour (Regulation and Abolition) Act, 1970	The contractor should pay wages, and in case of failure of the contractor, the Principal Employer should be liable to pay the same.

Source: (Das, 1998)

The Minimum Wage Act, 1948 helps for fixation and execution of minimum wages to prevent exploitation of labour through the payment of low wages. The minimum wage rate can be fixed at a) time rate, b) piece rate, c) guaranteed time rate, and d) overtime rate. The Constitution of India gives place to the concept of the minimum wage fixation in the chapter on Directive Principles of State Policy. The Minimum Wages Act, 1948 is based on Article 43 of the Constitution of India which states that,

> "The State shall endeavour to secure by suitable legislation or economic organisation or in any other way to all workers, agricultural, industrial or otherwise, work, a living wage (emphasis added) conditions of work

> ensuring a decent standard of life and full enjoyment of leisure and social and cultural opportunities" (NCEUS, 2007).

The wage fixation in India depends on various factors like socioeconomic and agro-climatic conditions, prices of essential merchandises, paying capacity. Some local factors can also influence the wage rate. There are no specific criteria for minimum wage in the Minimum Wages Act. Therefore, the Indian Labour Conference (1957) had come up with the following norms that should be considered during minimum wage fixation (Ministry of Labour & Employment, Govt of India, 1957).

> *The norms for fixing minimum wage rate are (a) three consumption units per earner, (b) minimum food requirement of 2700 calories per average Indian adult, (c) cloth requirement of 72 yards per annum per family, (d) rent corresponding to the minimum area provided under the government's Industrial Housing Scheme and (e) fuel, lighting and other miscellaneous items of expenditure to constitute 20 per cent of the total minimum wage (f) Fuel, lighting and other miscellaneous items of expenditure to constitute 20% of the total Minimum Wages, (g) children education, medical requirement, minimum recreation including festivals/ceremonies and provision for old age, marriage etc. should further constitute 25% of the total minimum wage.*

In Indian unorganised sector, minimum wages fixed on 2700 calories energy requirement. Ergonomics can revalidate the energy requirement among unorganised worker. The minimum wage fixation committee considers four consumption units per earner. But in the Indian scenario, there are six consumption units per earner (worker, spouse, two kids and parents). Depending on that wage fixation norms need to be re-thought by the Social Scientists.

1.8 Occupational Hazards

Occupational hazards prevention: Ergonomics is designing a job to fit the worker, so the work is safer and more efficient. Implementing ergonomic solutions can make employees more comfortable and increase productivity. It looks at the interaction between humans and other aspects of their environment so that changes can be made (if needed) to maximise their well-being and performance within the office. Ergonomics is the art of designing the workplace with the limitations and abilities of workers in mind. Ergonomic practices in the workplace optimise employee interactions and make performing duties efficient and comfortable. The effect of health and safety on productivity cannot be adequately discussed without touching on the concept of ergonomics. Ergonomic interventions can reduce the potential for strains and sprains that decrease a worker's productivity level and may lead to more severe injuries. Ergonomic intervention is used to determine how the workplace can be designed or adapted to the worker to prevent health problems and to increase productivity; in other words, to make the job suitable for the worker, instead of forcing the worker to continue the job. Here are ways that ergonomics increase productivity.

Ergonomic Workstations Help Reduce the Risk of Injury: One of the biggest threats to productivity at the workplace is an increase in injuries, causing an increase in the number of employees who are absent at the workplaces. Surprisingly, most of the accidents do not result from lifting heavy items or slip and falls, but the strain that comes from repetitive work or postures.

Ergonomics minimises Work-related Errors: The workers who work in ergonomic workstations concentrate better at what they are doing. In contrast, the uncomfortable workers tend to get distracted from their work by the discomfort and end up making errors that they would have otherwise not made. Simple errors when operating machinery can lead to wastage of raw materials or severe injuries. On the other hand, mistakes when doing calculations, making measurements, and other industrial activities may hurt the quality of the products.

Ergonomics Reduces High Force Requirements: While all jobs require some level of physical workload, other tasks demand workers to use some extra strength. High force requirements are not only damaging to the workers' health but also slow down work.

Modern workplaces need ergonomic equipment to help reduce muscle exertion and work effort, which will, in turn, increase productivity. This includes using mechanical assists, adjustable height lift tables, counterbalance systems, as well as powered equipment and tools designed to improve workplace environment and ergonomics.

Ergonomics Reduces Highly Repetitive Tasks: Task repetition, especially coupled with other risk factors such as awkward postures, slows down work progress. Excessive and unnecessary motions should, therefore, be reduced as much as possible to achieve efficiency at the workplace.

Comfortable workers are more energetic: Most of the workers who fall sick due to discomfort usually start by complaining of fatigue and muscle aches. This discomfort makes them less capable of performing their jobs quickly and efficiently. The problem deteriorates with time until they are unable to work at all. They are then forced to take frequent breaks to lie down and stretch to ease aches and muscle strain.

An Ergonomically Designed Workplace Shows You Care about Employees' Welfare: Positive workplace design improvements show that you care about workers' health and well-being. A mere thought that the employer cares about them can have a profound impact on motivation and productivity. One of the ways to motivate the workers is to show them that you care. It makes them feel indebted to reciprocate with a similar positive gesture.

Ergonomically-Designed Products Allow Workers to Work More Quickly: Ergonomic equipment, optimizes postures, reduce high force requirements make a worker's job much easier to do. Such as, ergonomic computer monitors are designed to reduce eye strain, which allows employees to focus more on their screens without the risk of developing headaches; an ergonomic keyboard can help you type faster. The ergonomic cleaning equipment enables workers to clean without needing to bend so frequently. All this increases the quality and quantity of work, leading to higher productivity.

Ergonomic hazards refer to workplace conditions that pose the risk of injury to the musculoskeletal system of the worker. Ergonomic hazards include repetitive and forceful movements, vibration, temperature extremes, and awkward postures that arise from improper work methods and improperly designed workstations, tools, and equipment. Examples of hazards include unsafe behaviour, unsafe objects, or unsafe conditions. Concerning occupational health and safety, the term 'hazard' is used synonymously with the term 'risk factor'.

The British Standards Association (1991) **defines a hazard** as:

> *"A situation that could occur during the lifetime of a product, system or plant that has the potential for human injury, damage to property, damage to the environment, or economic loss."*

(British Standards Association 1991)

Risk is defined as:

> "the likelihood than a hazard will cause harm, the potential severity of that harm and considers the number of people who might be exposed to the hazard."

(Safety Health and Welfare at Work Act, 2005)

A **hazard** can be any variable, or a combination of variables, that has the potential to contribute to a negative outcome such as an injury/illness or a financial loss (British Standards Institution, 2007).

An **occupational hazard** is a condition that may adversely affect the well-being or health of the exposed persons due to work/occupational activity. An occupational hazard is a response when people may have presented with demanding work, which is not corresponding to their knowledge and capabilities. The work pressure is inevitable due to the demands of the current work environment. Sometimes perceived pressure becomes excessive or unbearable, which causes occupational stress. Occupational hazard/stress can be caused by poor work design, poor work organisation, poor management, lack of support from colleagues and supervisors and unsatisfactory working conditions and work expectation. There are three components in a work-system. In this system, “Man” refers to working people as the subject in the workplace (e.g. users, decision-makers); “Machine” is the general name for any object controlled by Man (including tools, machinery, computers, systems and technologies), and “Environment” describes the specific working conditions under which Man and Machine interact (e.g. temperature, noise, vibration, hazardous gases etc.). The three goals of optimisation are to ensure "Safety, High efficiency and Economy" of man-machine-environment systems. Any imbalance between the above three-component creates occupational stress.

Any mismatch between man’s physical strength, capabilities and work demand causes **physiological stress**. The mismatch between bodies emotional strength and work demand causes **psychological stress**. The mismatch between man and machine generates **postural stress**. The unsuitable environment creates **environmental stress** among users.
Occupational stress can be divided into four major classes, such as physiological stress, postural stress, psychological stress and environmental stress.

a) **Physiological Stress** occurs when a person is doing work beyond his physiological capacity. Physiological stress has a short-term effect on the human body as due to physiological stress lactic acid produced in the muscle leading to a reduction of muscle contraction properties for a particular time. Lactic acid from the cell removes with due rest which in turn revert the contractile properties of the muscle. Heart Rate (HR) is a perfect indicator to determine physiological stress.

b) **Postural stress** is the stress on workers bodies as a result of inefficient posture, repetitive movements or prolonged time in the same position; often as a result of work environments. Postural stress can arise due to sustained, awkward posture. Postural Stress accumulated on the body due to awkward or un-ergonomic working posture, call postural stress. Postural stress has a long-term effect on the human body. High level of postural stress can create Work-related Musculo-Skeletal Disorders (WMSDs). WMSDs is an umbrella term applied to a broad range of disorders and injuries (e.g.

sprain, strain) of the musculoskeletal system. Symptoms of MSDs include numbness, tingling, aches and pain, localised inflammation, weakness, and/or difficulty in moving joints, which can significantly reduce the ability to do work or carry out daily activities. MSDs can occur suddenly due to a single incident (e.g. handling a heavy load or due to a sudden movement (slip/trip/fall)). Alternatively, they develop gradually over long periods and are frequently referred to as Cumulative Trauma Disorders (CTD) or Repetitive Strain Injury (RSI), e.g. tendonitis, bursitis and carpal tunnel syndrome. As the disorder progresses, individuals experience symptoms on a more frequent basis, symptom severity increases in intensity, and symptoms are experienced for longer durations. In the most severe cases, symptoms are continuously experienced, and the individual becomes permanently disabled.

c) **Psychological stress** can occur when a person feels unfitted to handle a situation or thinks negatively or exaggeratedly about the work/occupation. Psychological Stress accumulated on the body due to job insecurity, high production demand, inadequate wage, isolated work and work-life balance, unsupportive supervision, bullying/harassment and violence in the unorganised sector. Psychosocial risk factors are attributed to an individual's perception of their environment and their coping ability to deal with a given situation, e.g. the demands of a task and the workers' ability to control or have input into their work (Buckle & Devereux, 2002). Examples of psychosocial factors include monotonous or repetitive work, too high/low a workload, lack of support from superiors or colleagues, low decision input, time pressure and job satisfaction (Bongers, et al., 2006; Buckle & Devereux, 2002).

d) Stressors that are found in the surrounding environment are called environmental stressors. When the stressors are found in the workplace environment, known as work-related **environmental stress**. Extreme temperatures, noise, glare, dusty air are the common reason for work-related environmental stress. Environmental Stress can modify the performance/productivity of a worker, when the worker exposed under an environmentally stressful situation, e.g. Thermal stress, Dust, Noise, Light illumination, Glare and Vibration. India is a country with very hot summer seasons, and millions of poor workers likely to be affected by excessive workplace heat (Dash & Kjellstrom, 2011). People working in various industries are exposed to excessive heat burden in addition to environmental temperature (Parsons, 2002). Excessive heat during work creates occupational health risks; it restricts a worker's physical functions and capabilities, work capacity and productivity. Temperatures above 24–26°C are associated with reduced labour productivity. At 33–34°C, a worker operating at moderate work intensity loses 50 percent of his or her work capacity. Exposure to excessive heat levels can lead to heatstroke, sometimes even with a fatal outcome. Workers in all sectors are affected, but certain occupations are especially at risk because they involve more physical effort and/or take place outdoors. Such jobs are typically found in agriculture, brick kiln, construction, emergency repair work, transport, tourism and sports.

Several previous studies said that the workers of the unorganised sector suffer under occupational stress. To investigate the current situation of the unorganised sector regarding occupational stress, available literature (journal, conference proceeding) being reviewed and presented below.

1.9 Current Status of Unorganised Sector (Literature Review)

There are several studies among the unorganised workers that carried out to identify ergonomics related problem and attempted to highlight the issues. The details of the prominent works are presented chronologically.

In Nigeria, Ferraira and Tracy compared workers of two brick kilns and found that MSDs were very high among brick moulding workers of both sectors, mainly on the back, shoulders and wrist. However, the study found that the methods of handling, also influenced the injury rates, describing workers with more injuries, as having less handling techniques, whereas on the other hand, had less MSDs illnesses due to versatile and wide variety of handling techniques (Ferreira & Tracy, 1991).

Lemasters et al. conducted a study to find out the prevalence of WMSDs among 522 carpentry workers. The symptom question had been assessed if carpenter experienced pain, numbness or tingling in the particular body region. An adjusted logistic regression analysis applied among them and results showed that the group with the most extended (20 years) duration of employment in carpentry was significantly associated WMSDs of the shoulders hands or wrist, and knees (Lemasters, et al., 1998).

AICRP report of HAU Hisar (1999) [cited in Gaikwad 2012] reported a study on fetching water- a strenuous obligation of rural women in India. The physiological stress of the activity measured by using heart rate count per minute. Results indicated that the average and peak heart rate of women worker was 103.7 bpm^{-1} and 111.3 bpm^{-1} while fetching water during morning and a slight increase in average and peak heart rate (104.6 bpm^{-1}; 111.4 bpm^{-1}) during the evening. Energy expenditure was calculated based on average and peak heart rate and was found 17.7 kj/min and 9.0 kj/min, respectively. However, energy expenditure increases with the increase in age and as the day progressed to the evening (Gaikwad, 2012).

A study was conducted to investigate postural stress among 531 construction workers in northern Taiwan. Direct, indirect observation and interview methods were applied to measure the postural stress. Results indicated that the most problematic working postures found for the four jobs were bending of the back and squatting/kneeling on one or both legs (Li & Lee, 1999).

Pinder found high-level musculoskeletal trouble in wrists, hands and lower back among the brick kiln workers. The study also recommended design intervention to reduce the amount of reaching, bending and twisting during brick making activity by using mechanisation. The study also said that the working day and working week should be organised to spread load handling to reduce the risk of cumulative injury (Pinder, 2000).

A study was done to revelled WMSDs among the workers in the brick kiln industry in South Africa. A semi-structured interview was conducted regarding subjective pain and discomfort on different body parts and psychosocial situations. Physical exposure to risk for potential

MSDs had been assessed by using the OWAS method. Lifting index (LI) based on NIOSH equations, was also calculated. The results showed that the participants were having pain and discomfort on the lower back, followed by the wrists/hands, shoulders, neck and upper back (Edith, 2003).

A study among brick moulding workers was conducted to identify ergonomics risk factors for the development of MSDs in South Africa. The results revealed that the body parts, usually affected, were lower back, and followed by wrist/hands, shoulders, neck and upper back. The study also found frequent twisting and bending of the trunk, that causes pain/ discomfort on the lower back (Ndivhudzannyi, 2003).

Another ergonomic assessment study was carried out to estimate the physiological cost of activities done by the female construction worker. Postural analysis, while performing operations, revealed that when a basket of mud was transported in standing-cum-bending posture, angle of deviation was found 1.8^0 in the upper part, 1^0 in the lower part and 1^0 in the younger group. When the same activity was performed by the older group, the angle of deviation was 2.7^0 in the upper portion and 1.3^0 in the lower part. The heart rate was noticed during load-carrying activity 138 bpm^{-1} for head mode and 140 bpm^{-1} for shoulder mode (Chauhan, 2004).

A study was conducted among 906 female semiconductor workers in peninsular Malaysia. A self-administered questionnaire on sociodemographic and work characteristics, work section, prolonged postures and movements, and body pain were applied among the participants. Results indicated that neck, shoulder and lower limb pain were significantly higher for workers with longer working duration (Chee & Rampal, 2004).

A study was carried out among 264 brick kiln workers to investigate the physical risk factors for MSDs injuries. The study showed that the brick moulding workers were significantly exposed to high physical risk and reduced the worker's productivity. The study also revealed that the brick kiln workers experienced MSDs injuries as a result of exposure to ergonomic risk aspects. The brick moulding activity involved an extensive range of physical activity from positions and postures that developed MSDs among the brick moulding workers (Bridgers, 2005).

A study was conducted among 155 female bamboo workers in Madurai, India, to investigate the musculoskeletal problems while the workers were engaging in bamboo basket-making activity. Physical examination, Body Part Discomfort (BPD) mapping and workers' responses had been used to assess the musculoskeletal problems of women bamboo workers. The results revealed that low back pain was the major problem for women workers (99%), followed by pain in the upper arm (98%) and shoulder (93%) (Parimalam, et al., 2006).

A study was conducted to inspect the impact of drudgery reducing technology, among 30 farm women workers, to design and test some improved tools for performing the activity of cleaning animal shed for reducing ergonomic cost. The results showed that the enhanced tools (such as dung collector, long-handled broom, spade and the double wheelbarrow) reduced the ergonomic cost significantly in terms of heart rate, energy expenditure, total cardiac cost of work, Physiological cost of work and Rated Perceived Exertion (RPE) (Borah & Oberai, 2007).

A study was conducted to measure the prevalence of upper limb MSDs among brass metal workers in West Bengal, India. In this study, fifty male brass metal workers (experimental group) and fifty male office workers (comparison group) were selected. It was revealed that upper limb MSDs was a significant problem among brass metal workers, primarily involving the hand, wrist, fingers and shoulder and significantly higher in the experimental group than in the comparison group (Gangopadhyay, et al., 2007).

A study was conducted among 99 participants (56 depot workers and 43 rice mill workers) in West Godavari district, India. Physiological assessment of workload was measured by recording the heart rate during work, and the subjective workload was assessed by using a five-point rating scale (Light, moderate, heavy very heavy and extremely heavy). The result showed that the average value of peak working heart rate for carrying 50 kg sack of food grain in the depot was 125.8 ±10.97 bpm^{-1} and the workload was categorised as heavy. Energy expenditure values were 4.24 ± 0.49 $Kcal.min^{-1}$ which indicated the workload as moderate. The mean values of peak working heart rate varied from 115.2 ± 4.38 to 151.0 ± 18.58 bpm^{-1}. As per workload classification, the above jobs were classified as heavy and extremely heavy, respectively (Pradhan, et al., 2007).

Another study was done in Indian brick kiln industry among 48 female brick kiln workers. Results indicated that the maximum pain and discomfort was experienced in the lower back (30%) and followed by upper-back (25%), shoulder (15%), elbow (10%) and wrist/hand (10%). Pain and discomfort in the knees were highest (5%) followed neck (2.5%) and ankle (2.5%). Pain in shoulder and forearm was possibly the result of repetitive movements of upper limbs. Body parts of specific postures were vulnerable to injury and musculoskeletal disorders (Mukhopadhyay P., 2008).

A study had been carried out in Karnataka district among 60 brick kiln workers. The study said that the jobs in brick kilns involved an extensive range of physical actions from postures and positions that might not be ideal and can create accidents and injuries. This stressful work situation can be made worse by physical discomforts in the workplace and cause MSDs. The prolonged stress and strain caused during the various activities with different load conditions is a cause for work-related MSDs (Qutubuddin, et al., 2008).

A study was conducted in Hisar, India, among 30 female brick kiln workers, having age range 25 to 40 years. Average time spent in brick making activity was six hours per day and on an average participant travelled two km distance while brick carrying activity. The postural stress analysis showed the highest angle of curve and deviation on for cervical and lumbar region. The study also recommended for periodic training programmes that should be organised to emphasise on educating workers regarding the recognition of muscular-skeletal disorders, importance of rest pauses and maintaining proper posture during brick making activity (Singh, et al., 2008).

A study was conducted among female building construction workers belonging to the age group of 28-32 years with 5-7 years' work experience, to investigate the physical workload. Results indicated that the building construction workers were not getting sufficient rest, and they were lifting 12 kg load every time, which is higher than the recommended weight limit (7.19kg). The study also suggested for modification of workplace and work methods to compensate for the health hazard condition (Maiti, 2008).

Sett and Sahu (2008) reported a study on ergonomic evaluation of workload of female labourers working in the unorganised sectors of the brickfields. Results showed that the workers had a lower body mass index (BMI) and indicated that they were suffering from chronic energy deficiency. Almost 94% of workers complained about pain in different body parts. The study also said that most of the jobs performed by the participants were classified as moderate to heavy. Moreover, the workers were lifting and carrying the load above the recommended level. The postural analysis showed that some of the postures adapted during work required immediate corrective measures. Apart from this, the female labourers were continuously exposed under the sun, radiant heat from the brick kiln, the dusty and noisy environment that made their workplace more hazardous. The study recommended immediate ergonomic design interventions to improve the quality of life of those female labourers working in the unorganised sectors of the brickfields (Sett & Sahu, 2008).

A study was conducted to investigate the musculoskeletal problems faced by the working women of different professions, namely sweepers, venders and construction workers. Ninety randomly selected participants were surveyed to understand the general background, frequency of postural changes and muscular-skeletal problems. The results showed that the activities were time-consuming, and creating high level perceived exertion, that caused muscular pain in the body, particularly in the upper back and lower back. The activities also increased heart rate and energy expenditure among the participants (Upadhyay, et al., 2008).

An ergonomic evaluation study was carried out among 200 construction workers (120 male and 80 female) to determine postural stress. Results showed that MMH and equipment handling task imposed maximum physical exertion and discomfort among all participants. The posture analysis showed that most of their working postures were highly unsafe (Chattopadhyay, et al., 2009).

Sau et al. investigated work-related stress among 100 (40 female and 60 male) brick kiln workers with the age range 18-50 years. Results showed that both male and female workers felt discomfort in lower back, thigh, knee and waist region. The spinal curvature in different working postures (squat and bend) showed a significant variation with that in normal standing posture. The grip strength of both male and female workers decreased significantly, which proved that the brick kiln workers become fatigued more rapidly. The results also showed that the postural discomfort might be due to the lifting of load with an awkward posture (Sau, et al., 2009).

A study was conducted on 120 male and 105 female brick kiln workers with age range 18 - 45 years, to evaluate postural stress. The results showed that the brick kiln workers spend a maximum percentage of time (male 15.36%) in squat-straight posture which was followed by squat-twisting posture (male 15.36% and female 13.41%) and squat-bend posture (male 8.41% and female 10.46%). According to BPD scale, the lower-back had the highest level of discomfort. The deviation of the centre of gravity (CG) and the changes of lumbar spinal angle indicated the high level of postural stress among the workers (Sau, et al., 2009).

Varmazyar conducted a study to evaluate postural stress and prevalence of MSDs in packaging workers. A questionnaire and body map chart were used to examine the musculoskeletal problems and upper limb disorders among 18 male and 20 female pharmacy packaging workers. Results indicated that 44.7% had been reported knee pain and 36.6% back pain and neck pain, respectively (Varmazyar, et al., 2009).

Gangopadhyay et al. (2010) conducted a study to investigate the postural stress on the occurrence of MSDs among 50 sand core making workers of West Bengal. The study showed that most of the working postures were awkward and affected by MSDs like pain at low back

(100%) hand (40%) shoulder (30%) wrist (20%) and neck (20%). The study found significant ($P<0.05$) correlation between discomfort level and risk level of the individual with working postures (Gangopadhyay, et al., 2010).

A cross-sectional survey was done among randomly selected construction workers on different discomfort of the body parts. Results indicated that for all construction workers, the most of common location of pain and discomfort were the lower back. The construction workers also suffered for pain and discomfort in ankles/feet (range: 12%-22.99%) in the neck (range: 6.25%-19.63%) in the shoulder (range: 12%-16.61%) and knees (range 4.55%-14.63%) (Kaminskar & Antanatis, 2010).

An ergonomic evaluation study was carried out on two types of female brick kiln workers, moulders and carriers. Modified Nordic Questionnaire and BPD scale were applied to identify the MSDs and discomforted zone of the body. Proper methods also used to measure postural stress among the participants. Results showed that the maximum discomforted region for the female moulders was lower back, followed by the calf muscles, trunk, ankle, and wrist. On the other side, the maximum discomfort zone in the brick carriers was head followed by the neck, trunk and lower back. The study also suggested for ergonomic design interventions to prevent the MSDs (Sahu & Sett, 2010).

An ergonomic study was conducted on teenage girls working in the unorganised sectors like a brick kiln, in West Bengal, India. This evaluated the workload and its consequent effect on the health of the workers. Results showed that 86 % participants suffered from work-related pain in different body parts and there was an increase in their physiological and psychological parameters after work, due to frequent use of awkward postures while at work (Sahu, et al., 2010).

Stone carving at Jaipur, Rajasthan, India, is a traditional craft employing a large number of local workers. An ergonomic assessment had been carried out to identify different ergonomic risk factors associated with this profession. Twenty-five male workers were selected in each of the three sections of a stone carving unit. Still-photography and video photography were used to record different activities. Different types of non-invasive tools like REBA, RULA, OCRA were used to measure postural stress. Psychophysical measures were investigated by BPD map, RPE scale and visual analogue scale. Objective measurements (heart rate and skin temperature) were recorded with a stopwatch and a digital thermometer. The working heart rate after 30 minutes of work was 112.4 beats per minute, categorising the work as moderately heavy. Postural analysis by REBA indicated high score (13/13). Similarly, postural analysis by RULA showed high score (7/7). The study demonstrates that the majority of the activities are in the high-risk category and demands immediate ergonomic intervention in the form of tool, workstation and process design. This could be done by involving different Non-Government Organizations (NGOs), political parties, and the Human Rights Department both at the centre and at the state level. (Mukhopadhyay & Srivastava, 2010).

Singh and Arora conducted an ergonomic intervention study for preventing WMSDs among the farm women. The study concluded that various types of WMSDs were consequences of the occupational risk factors in agriculture, including static positioning, forward bending, heavy lifting and carrying kneeling and vibration. It also said that an ergonomics intervention (designing of women-friendly tools and equipment, improved work processes and stipulation of shorter rest periods) has the potential to reduce WMSDs among farm women. The study, however, said that there is a need to increase awareness of WMSDs and associated risk factors and to train farm women periodically for the proper and safe ways of handling tools and equipment to avoid WMSDs (Singh & Arora., 2010).

Singh and Kumar (2010) investigated the effect of mechanical lifting aid in a single task lifting among 30 industrial workers with no history of acute illness low back pain. Recommended Weight Limit (RWL) and LI (lifting index) were calculated by using the revised NIOSH lifting equation. Results said that mechanical lifting aid was more beneficial as it not only saved task time by increasing the frequency of lifting but also it reduced the physiological stress (Sing & Kumar, 2010).

An ergonomic study had been carried out to investigate the risk factors associated with WMSDs in three craft sectors (blue pottery, handloom and gota patti) of Jaipur in India. Observational methods like Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA) and OVAKO for postural analysis were applied to investigate the risk factors associated with WMSDs. The Occupational Repetitive Action Index (OCRA) and Strain Index (SI) were also used to gauge the extent of repetitiveness and strain during work. Results said that many of the working conditions were hazardous and demanded immediate intervention. It also indicated that the physical design of tools and workstations alone would not solve the problems. The designer needs to look into non-physical design issues like the work/rest cycle, process design, physical exercise and training to effectively control the different risk factors in the genesis of WMSDs. (Mukhopadhyay & Srivastava, 2010).

A study was conducted among 100 construction workers to investigate the working postures and associated health status of the workers. Results showed that about 65.47% of workers were suffering from moderate to intolerable pain, whereas 16% of worker have no complained regarding the discomfort or pain. A survey on working postures and occupational health hazards of masonry workers were conducted to highlight the risk factors related to construction activities. It was found that 84% of the workers have experienced musculoskeletal related problems after day-long hard work. Out of six common observed postures, five postures were found harmful (Bhattacharya & Biswas, 2011).

Johnson conducted a cross-sectional study on the prevalence of upper extremity MSDs among 219, both male and female participants, having minimum one-year work experience, in the unorganised sector, in Tamilnadu, India. An increased prevalence of severity was observed in women (36.1 %) and in individual who performed moderately strenuous tasks (52.8 %) (Johnson, et al., 2011).

Thirty (30) participants having age ranged between 20-50 years were selected to investigate the impact of physical work exposure on musculoskeletal problems among tribal women of Udaipur district. Study results showed that WMSDs affect all the parts of the body especially on hand, elbow shoulder and back in the upper body region and hip, knees and calf muscles in lower body region (Suthar & Kaushik, 2011).

The wage and employment policies concerning unorganised workers have been a subject of considerable discussion among union leaders and labour experts in India. The workers of the unorganised sector get lower wages. However, India's unorganised sector considered for over 94 percent of workers, but originating just 57 percent of India's GDP in 2006, or about 9-fold less per worker than the organised sector (Kulshreshtha, 2011).

A study was done among 40 female farmworkers to reveal the incidences of WMSDs during farm-related activities. It showed that maximum percentage women of all age groups felt severe pain in the neck and followed by shoulder joint, upper arm, elbows, lower arm, low back, wrist /hands knees, calf muscles and ankles feet. However, 10-30 % of women of older age groups also felt severe pain in the muscles involved in the activity. This might be because of the more weight of the load carried by the women of the older age group (Gaikwad, 2012).

A study was conducted among 220 female the brick kiln workers, age range 28-45 years with more than ten years' work experience, in West Bengal, India. The study found pain/discomfort mainly at the lower back (90%), neck (72%) and wrist (62%). Seventy-two percent of workers reported high-level pain intensity according to body part discomfort scale. The impact of pain decreased productivity by reducing grip strength which also led to absenteeism, loss of working days (4.5/month), injuries (in 33% of workers) and monotony (85% workers). The study also suggested for redesigns the load-carrying job by pulling carts etc. to minimise the spinal compression (Ray Chaudhuri, et al., 2012).

Neha Mittal (2012) in her Research Paper Women Workers In ‘Unorganized Sector: Socio-Economic Perspective’ has discussed the problems of unorganised women worker. The unorganised women workers work for a long hours every day, messy working conditions, meagre wages and above all, they keep on working without proper social security measure (Mittal, 2012).

Another study has been carried out among construction workers to know the socio-economic status and the psychosocial stress & strain faced by the workers due to occupational exposure. The study says that the construction workers were the victim of different health impairment like occupational hazards, psychosocial stress & strain etc., due to long working hours (73.3%), lower wages (60.4%), job uncertainty (56.9%), poor communication among workers with supervisors (22.7%). The study also found the exploitation by the labour contractor, gender discrimination and sexual harassment. The study also said that the low job satisfaction (42.4%), injuries & accidents (47%) was the cause of psychological stress among construction worker (Tiwary, et al., 2013).

A study was conducted to identify the psychological stress among the construction workers, in Vadodara. The study revealed that almost 76% (28.6 male & 41.3 female participants had extreme high stress and 37.1 male & 43.5 female had high-level stress) construction workers had exposed to high-level psychological stress. The study also found that headache, backache & sleeping problems were present in both male and female participants. The study revealed that stress score was positively correlated with age & experience of participants, but the relation is not significant ($p > 0.05$). The study also said that the work-related stress could be prevented by ergonomics, work environment design, organisation & management development, work education & training, sensitive & responsive management system and enhanced occupational provision (Gaurav J.D., 2013).

Another study was conducted to assess the occupational health problems and physiological stress among the brickfield workers of West Bengal, India. The study showed that brickfield workers were suffering from WMSDs, especially in the hands, lower back and knees due to awkward posture (stooping, squatting and twisting) for a prolonged period. The study also indicated that brickfield workers had lower hand-grip strength due to strenuous hand-intensive activity. Brickfield workers suffered under high environmental stress due to temperature (Das, 2014).

A study was conducted among 111 brick kiln workers, and results showed that the prevalence of WMSD and BPD were very high, and the most affected body parts were the necks, shoulder, back and knee. The study also showed that there was high-level postural stress in all tasks of brick making activity, that causes WMSD. The study suggested for immediate ergonomic interventions to reduce the work stress (Maity, et al., 2014).

Another study had been carried out among manual meat cutters in Jabalpur, India, to measure the ergonomic risk factors for WMSDs. Manual meat cutters in India are at high risk of WMSDs for a variety of reasons including holding awkward postures, repetitive forceful exertions, and inadequate rest. Ovako working posture analysis indicated high scores (four for the back in peeling, six for the arms in cutting, and six for the arms during mincing tasks). Rapid entire body assessment method (REBA) scores were also high at 10/10 for deboning and mincing tasks, all associated with repetitive movements of the arms and awkward posture of the upper part of the body. The study suggested for ergonomic interventions that address retooling and workstation and process redesign would be useful in reducing WMSDs. (Mukhopadhyay & Khan, 2015).

A comparative study on psychological well-being employees working in the organised and unorganised sector has been carried out by Mohan et al. The study concluded that overall psychological wellbeing of the employees working in organised conditions are better than unorganised conditions (Mohan, et al., 2015).

Hand-made snacks (locally known as papadam) manufacturing is a popular profession in Central India employing a large number of women workers. The objective of this study was to identify the ergonomic risk factors for WMSDs in this sector. Direct observation, activity analysis was applied along with postural analysis methods. Pre and post-exercise heart rate were measured by the ten beats method. Lower back (30%), upper arm (30%) and shoulder were the zones where maximum post-work pain and discomfort was reported in the dough cutting section. The maximum post-work heart rate was at 116.3 beats per minute in the dough cutting section. High REBA score of 15/15 was observed in the grading, kneading and dough cutting sections. Similarly, the RULA scores were very high at 7/7 in the majority of the sections. Strain Index scores were very high at 60.8 in the dough cutting section. (Mukhopadhyay, 2017).

From the above literature studies, it can be concluded that most of the unorganised activities demand a higher heart rate and energy consumptions, that create high **physiological stress**. The unorganised workers work with sustained, awkward posture (bending, twisting, etc.) with repetition job nature, that causes WMSDs. The handled loads are above the recommended weight-lifting limit (RWL) and accumulate stress on the body and create WMSDs among the workers. The awkward posture and repetition of job generate high **biomechanical/postural stress** among the workers. The workers of the unorganised sector also suffer from high **mental/psychological stress** due to job demands. The workers also suffer under **environmental stress** due to dusty work environment, noise, prolonged exposure to heat (in summer) and cold (in winter). They are not using any **personal protective equipment** (PPE) due to unavailability of PPE and lack of knowledge/awareness about them (PPE). Therefore, the workers face many health problems because of high heat exposure. Research in occupational heat stress is much needed to find out the health impacts and suitable intervention to protect worker's health which subsequently reduces the morbidity. Heat stress can be defined as the sum of environmental and metabolic heat loads which increases the core body temperature (CBT) of an individual that may potentially cause physiological decrements. Occupational heat stress is a well-known hazard in workplaces with strong local heat sources (such as brick kiln industry due to furnace) and outdoor work situations with strong sunlight and hot environmental conditions (such as in a certain agricultural, brick kiln, construction industries etc.) (Parsons, 2002; Nag, et al., 2007). During the hot season in tropical and sub-tropical countries, the general environmental heat conditions can reach levels that create occupational health risks and reductions of worker productivity in any outdoor workplaces

The previous study also says that the ergonomic risk factors reduce the worker's productivity. The above literature studies also said that the unorganised sector workers also suffer due to **low wages**. They didn't get the proper wage.

In the studies discussed above, the majority provide evidence on the problems related to ergonomics in the unorganised sector and emphasise the need for design intervention. But still, the issues of the unorganised sector remain unchanged, i.e. no design intervention is happening. A limited number of studies, however, have attempted developing knowledge and tools that can improve the status of the unorganised sector by design intervention. Therefore, the above literature review studies emphasise to continue further research to find out the reasons for why the design interventions are not happening in the unorganised sector.

1.10 Problem to Conduct Design Intervention in Unorganised Sector

An ergonomic evaluation is a process of performing a scientific investigation of an individual's work station and the environment to provide recommendations for an improved workstation based on the results of these findings. An ergonomic evaluation aims to minimise or prevent injury to the individual and to promote workplace efficiency through the application of ergonomics. An ergonomic assessment can help reduce the rate of injuries, increase individual productivity, and improve employee comfort.

Most of the previously carried out study in the unorganised sector **recommended for ergonomic design interventions** to make the workstation more ergonomic. Design intervention strategies include the use of proactive and preventative measures to eliminate ergonomics risk factors or to reduce risk factors to acceptable levels when a risk factor cannot be eliminated. Researchers recommend a hierarchy of controls which includes –

a) Elimination – the hazard is removed completely
b) Substitution – replace the hazard with a different option that has a lower level of risk, NB substitution can result in risk transference, i.e. introduce new risk into the environment
c) Engineering Controls – changes are made to the operating process or equipment to reduce the level of risk associated with a hazard, e.g. adding guards to a piece of machinery, installing ventilation systems

d) Administrative Controls – putting measures into place that will decrease workers exposure to hazard and reduce the level of risk, e.g. job rotation, manual handling training
e) Personal Protective Equipment (PPE) – barriers between the user and the hazard, e.g. breathing protection, face and eye protection, hearing protection, hard hats, clothing, and footwear

Mechanisation is a widespread design intervention (Combine harvester, Automated brick moulding machine, etc.) in a developed country to reduce occupational stress like WMSDs. But in a developing country like India, true actual mechanisation/automation is not acceptable from the brick kiln due to different reasons (described below). The main factors that have been identified by various studies as the main barriers to actual mechanisation are (Maithel, et al., 2012; Heierli, et al., 2008):

a) **Ampleness of labour:** Due to unemployment in the organised sector, populated country, like India, labour cost is cheap. Presence of the sufficient number of labours demotivates the mechanisation in the unorganised sector.
b) **Higher investments:** Modern and semi-mechanised sector require new costly machines. The owner of the unorganised sector is not ready to invest in mechanisation.
c) **Absence of proper infrastructure:** To run the high-end machinery require the continuous availability of their primary fuel, water, electricity and natural gas. This means there must be near gas lines, water supplies and power grids. In rural areas, such infrastructure is not available, limited or non-functional.
d) **Lack of technical know-how:** There is limited technical knowledge and availability of off-the-shelf technology packages and a shortage of training opportunities and trained human resources to implement new techniques or operate modern machines. This lack of technical know-how can result in inadequate quality production.
e) **Traditional beliefs:** There are assumptions that the quality of production using modernised technology will not be as good as traditionally made. E.g., straw production will be nil, when used mechanised paddy harvester. The farmer uses straw as cattle food.

f) **Legal and regulatory framework:** The Policies and laws concerning the unorganised sector are weak and poorly enforced/implemented. As such, owners of the unorganised sector have very little motivation to change their traditional practices.

g) **Lease related issues:** Some unorganised industries (e.g. Brick kiln) are located on leased land. This is expected to be a considerable barrier in making investments in the construction of new facilities and machinery. A shift to new technologies would require investment in land or renegotiating lease agreements. Due to the high price of property around cities, brick enterprises are likely to relocate further from towns and cities.

h) **Limited or no access to grid-electricity:** Semi-mechanisation or mechanisation requires grid electricity. Most of the Indian unorganised sectors either do not have access to grid electricity or are located on rural electricity feeders, which are prone to power shortage and poor power quality. This grid-electricity inaccessibility is a significant barrier in adopting new technologies.

i) **Lack of financial support:** The banker and other financial institutions are hesitant to sanction loans to unorganised industries owners due to insecurity about the return.

j) **Lack of availability of a trained workforce:** Any new technology requires a trained workforce to operate, which is in short supply. Currently, there is no such training centre to train the workforce for the unorganised sector.

k) **Unemployment due to mechanisation:** Without the development and promotion of alternative means of livelihoods for the existing workers, replacing or introducing more mechanised tools instead of manual labour will lead to unemployment of workers who rely exclusively or mainly on the unorganised sector to make a living.

l) **Low-profit margins for mechanisation:** In a developing country, like India, manual material handling is cheaper than automation. For example, the higher production cost of machine-moulded bricks faces stiff competition from lower-priced manually produced bricks.

Context-specific low-cost design intervention will be useful for the unorganised industry. There are few studies among the unorganised sectors that proposed context-specific design intervention that reduced ergonomic risk factors.

An ergonomic study has been carried out in a zarda manufacturing industry. A considerable number of zarda manufacturing workers complained of respiratory problems. The workers were also exposed to high ambient environmental temperatures and relative humidity. Because of the harmful effects of tobacco dust on the respiratory system, the study suggested preventive measures to control of the dusty environment and wearing proper masks. Medical surveillance should be part of this preventive program, and it should include lung function testing before the beginning of employment and regularly during employment in this industry. Workers with respiratory disorders or atrophy should be closely monitored while working in the tobacco industry. Finally, since smoking is an additional risk factor affecting the respiratory system in this setting, tobacco workers should be strongly discouraged from smoking. (Ghosh & Barman, 2007).

One of the main activities of the goldsmiths is Blowing Pipe. A large number of goldsmiths complained of respiratory symptoms in the jewellery making industry. Reduced lung volumes and peak expiratory flow rates (PEFR) of goldsmiths was found, presumably from heavy pressure generated by using a blowpipe. Blowing-pipe work habit also increases the fatigue of facial muscles. The study introduced a mechanical hand air pipe, that can reduce or can give relief the goldsmiths from various occupational hazards. The newly developed mechanical hand pipe design will significantly reduce facial muscle fatigue, respiratory discomfort and physiological stress of the goldsmiths (Ghosh & Gangopadhyay, 2012).

Rice mill workers are exposed to organic and inorganic dust and synthetic chemicals that may have adverse effects on their respiratory health. The rice mill workers complained about different respiratory disorders like phlegm (40.8 %), dyspnoea (44.2 %), chest tightness (26.7 %), cough (21.7 %), and nose irritation (27.5 %). Rice mill workers exposed to dust presented significantly (p\0.05) lower levels of FVC (3.44 ± 0.11), FEV1 (2.73 ± 0.15) and PEFR (304.95 ± 28.79) than the controls. The rice mill workers had significantly higher absolute eosinophil counts, total IgE and ESR than control groups. The haematological findings suggested that the harmful effects may be linked to both non-specific irritation and allergic responses to rice husk dust among rice mill workers. The results showed that rice mill workers need for preventive measures. It is advisable, therefore, the rice mill workers to adopt technical preventive measures, such as having well-ventilated workplace and wearing appropriate respiratory protective devices. For this target in this study, face musk was prepared by considering different head dimensions of rice mill workers, affectivity, shape and cost. A modified Cup shape Face Mask (Non-Woven) was designed and compared with one Cotton Face Mask and Cotton cloth. These measures will help to prevent respiratory disorder (Ghosh, et al., 2014).

Another ergonomic study had been carried out to investigate the heat stress among rural youths. Two (2) low cost ergonomically designed headgears were designed for teenagers working outdoor or exposed to the Sun and were tested on 11 male subjects. Subjective assessment through questionnaires revealed satisfactory results with newly designed headgears. Two dependent variables, discomfort score and forehead skin temperature were recorded. A One-Way repeated measures ANOVA as well as paired t-test, on both parameters, showed significant headgear effect ($p=0.001$). Plots of forehead skin temperature and discomfort score showed a marked decline with the use of headgears, compared to bare head. (Mukhopadhyay, 2009).

An ergonomic study had been carried out among the incense stick (locally known as agarbatti) makers of Ahmedabad, Gujarat, India, to improving productivity and facilitating the occupational health. There were incidences of work-related musculoskeletal disorders amongst the workers. Thirty-three (33%) percent of respondents complained about pain in the lumbosacral segment of the spinal cord, and 30 percent reported pain in the upper arm at the end of the day's work. Based on the observations, four workstation prototypes were fabricated. Each was tested in the field by actual workers, as well as in the laboratory. Only after a prototype was accepted in principle by the users was the next prototype fabricated. Based on user feedback, the final prototype was produced which was capable of increasing productivity by approximately 15 percent and reducing pain in different parts of the body; this was only after 15 days of user testing. (Mukhopadhyay & Ghosal , 2008).

Another study was done by Ray G.G., on the construction worker to reduce the accident rate, falling of Ghamella during load handling. Ghamella is a handy primitive age-old tool to carry the cement mixture, sand in the construction industry. Traditional Ghamella is an accident-prone tool due to its smooth and slippery surface. The low-cost design intervention of Ghamella reduced the occupational stress among the construction workers.

An ergonomic intervention study was carried out in citrus harvesting worker, in Sao Paulo, Brazil. The workers were exposed to high WMSDs due to manual citrus fruit harvesting process. As an intervention process, manual fruit harvesting process compared with mechanised harvesting process and found that mechanisation in the harvesting process helped to increase the productivity and reduced WMSDs. But manual fruit picking method, the fruit had been in better condition than when automation is used. As a result, the study introduced some mechanical supporting device to assist the farmers during harvesting, while ensuring and preserving the quality of the fruit removed from the trees. A time study and comparison between manual and semi-mechanised-harvesting was done by using the stopwatch technique. In-depth observation showed that the semi-mechanised harvesting speeded up the activity compared to a manual one (Costa, et al., 2012).

Vyas conducted a study about WMSDs among 120 Indian farmers (60 male & 60 female) and also developed an educational intervention to improve conditions for workers in terms of safety. The results showed that all of the respondents had some degree of MSDs, especially in the neck, shoulder, upper arm, and fingers. The overall discomfort rating showed that the workers reported a higher discomfort rate during agricultural activities. This study showed that educational intervention improved the workers' knowledge about WMSDs (Vyas., 2012).

An ergonomic study was conducted among the 180 Indian female workers, during tea plucking operation. As plucking needs some severe body effort, ergonomics interventions were recommended to make safer work conditions. A new basket was designed to reduce ergonomic risks. The traditional basket and newly designed baskets were compared during usage in terms of specific physiological indicators, such as heart rate, energy expenditure, and rating of perceived exertion. These indicators showed the effectiveness of the new basket design in terms of work physiology and ergonomics (Bhattacharyya N., 2012).

An assessment of work-related ergonomic problems was carried out among 20 youth, aged 11 to 18 years old (10 girls, 10 boys), who had already worked on farms. During the study, four different wheelbarrows were evaluated while trunk flexion and back inclination were also measured. The Borg scale was also used in this study. Furthermore, the level of comfort among the youth during the use of wheelbarrows was assessed. This study confirmed that the new design for a wheelbarrow based on ergonomics changed some awkward postures to neutral ones and also some parts of the body motions during handling the wheelbarrow were modified (Kotowski, 2009).

An ergonomic design intervention study has been carried out among thirty stone polishing unorganised workers. The study found that workers had been exposed to a high level of hand-arm vibration, adopting awkward postures, performing strenuous repetitive activities for prolong duration, which ultimately imposed adverse impact on occupational health. The stone polishing machine was redesigned to reduce biomechanical stress associated with the hand and arm of the operators. A supportive mechanism was included, which avoid sustained load holding during polishing activity and reduce hand-arm fatigue. As rubber is a vibration dampening material, was coated on the handle grip of the stone polishing machine which reduces the vibration transmission to the arm. The users liked the modified design with better usability and the aesthetic look. It was evident from their higher comparative ratings against the existing design (Nath, et al., 2018).

Strategy for finding the appropriate plan for design intervention has become a crucial issue in occupational wellness of varied nature of women workforce of Northeast India. This study deals with ergonomic intervention through a sustainable process. The workers who frequently change to different activities require different work tools relevant to specific tasks. Mostly the unorganised workers manage work tools of their own with available local resources. Whereas in contrast the tea-leaf pluckers are engaged in a single activity throughout the year, and the work schedule and work equipment are decided and supplied to them based on the corporate decision where the workers do not have any individual control. The study confirmed that the need for organising participatory workshops specific to trade based occupational well-being and different work tools for various tasks in the most private owned unorganised sector (Chakrabarti & Bhattachheriya, 2012).

1.11 Importance of Prioritisation of Occupational Stress

Considering the above example, the worker of the unorganised sectors needs some low-cost ergonomic intervention. Depending on dominating stress, the design intervention needs to be carried over (shown in Table 1.2).

Table 1.2: The dominating stress and suggested design intervention

Dominating stress	Problem	Suggested Design Intervention
Physiological Stress	Demands high physical workload	Redesign the work that provides leverage or mechanisation.
Postural Stress	Awkward posture and Work-related Musculoskeletal Disorder (WMSD)	Change the posture towards neutral posture. Generally, posture is adopted due to tools. Therefore, redesign the tools that help to adopt an ergonomic posture.
Psychological Stress	Mental workload	Reorganise the job, Improve employer-employee relationships, etc
Environmental Stress	Unsuitable environment	Make the environment ergonomically good. Reduce the environmental stress by using personal protective equipment (PPE)

Therefore, it is important to identify the dominating stress among all available stresses such as physiological, postural, psychological and environmental stress. There are no as such ergonomic methods that can prioritise the stresses as per dominating nature. There are lots of ergonomic methods to identify the individual stress, but comparison among them is not possible. Therefore, there is a scope to develop a more straightforward method that can prioritise the stresses as per dominating nature and will give the design direction guideline to the designer and engineers.

Before developing any method, currently available ergonomic methods (Table 1.3) and its advantages and disadvantages need to be investigated to determine the most dominating stress among the unorganised workers.

Table 1.3: Currently available ergonomic method

Type of stresses	Ergonomic Risk Analysis Method	Reference	Tools Needed
Physiological Stress Analysis Method	Heart Rate (During work and rest)		HR monitor, Polar belt, Stopwatch (for manual method)
	Energy Expenditure Study		K4b2 Gas Analyser with software installed computer system
	Stress/exercise electrocardiogram		ECG apparatus with software installed computer system
	Blood Pressure (During work and rest)		Sphygmomanometer and Stethoscope
Postural Stress Analysis Method	Rapid Upper Limb Assessment (RULA)	(McAtamney & Corlett, 1993)	RULA sheet, Pen, Paper and Photographs (taken from the side and back to avoid parallax error)
	Rapid Entire Body Assessment (REBA)	(Hignett & Mcatammey, 2000)	REBA sheet, Pen, Paper and Photographs (taken from the side and back to avoid parallax error)
	Ovaco Working Analysing System (OWAS)	(Karhu, et al., 1977)	OWAS sheet, Pen, Paper and Photographs (taken from the side and back to avoid parallax error)
	Quick Exposure Check (QEC)	(David, et al., 2008)	QEC checklist and questioner, Pen & Paper
	Occupational Repetitive Action (OCRA)	(Occhipintini, 1998)	OCRA checklist and questioner, Pen & Paper
	Postural Loading on the Upper Body Assessment (LUBA)	(Kee & Karwowski, 2001)	LUBA checklist and questioner, Pen & Paper

	Assessment of Repetitive Tasks (ART)	(Ferreira J, 2009)	ART scoresheet and Flow chart, Pen & Paper
Psychological Stress Analysis Method	Perceived Stress Scale (PSS)	(Cohen, et al., 1983)	Pen, Paper, Perceived stress scale
	Nasa TLX	(Sandra & Lowell, 1988)	Pen, Paper and NASA Task Load Index sheet
	Bedford Scale	(Roscoe, 1984)	Pen, Paper and Bedford workload scoresheet
	Copenhagen Psychosocial Questionnaire (COPSOQ)	(Kristensen, et al., 2005)	Pen, Paper and COPSOQ Questionnaire
	Job Content Questionnaire (JCQ)	(Karasek, et al., 1998)	Pen, Paper and JCQ Questionnaire
Environmental Stress Analysis Method	Temperature, Corrective Effective Temperature (CET) WBGT Index	(Yaglou & Minard, 1957)	Dry-bulb thermometer, Wet-bulb thermometer, Globe thermometer, Kata thermometer, Psling psychometric nomograph
	Noise		Noise level meter
	Light/Glare/Illumination		Lux meter
	Dust		Spirometer and accessories
	Vibration		Vibration meter

1.11.1 Physiological Measures

Physiological measures of workload attempt to associate physiological changes with levels of the workload

1. **Heart Rate (HR)**

The heart rate is the number of times the heartbeats in the space of a minute. Perhaps the most straightforward and most time-honoured physiological measure of workload is heart rate. Heart rate can be measured using a simple heart rate monitor during work as well as rest. Numerous researchers have studied the extent to which heart rate correlates to human task performance and other measures of workload. Roscoe (Roscoe, 1992) reviews several studies in which heart rate was used to measure workload among pilots.

2. Energy Expenditure during rest and work

Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or physical movement. Daily energy expenditure is composed of three major components –

a) Resting Metabolic Rate (RMR);
b) Thermic Effect of Feeding (TEF); and
c) Thermic Effect of Activity (TEA).

Resting Metabolic Rate constitutes 60 to 75% of daily energy expenditure and is the energy associated with the maintenance of significant body functions. TEA is the most variable component of daily energy expenditure and constitutes 15 to 30% of 24-hour energy expenditure. This component includes energy expenditure due to physical work, muscular activity, including shivering and fidgeting, as well as purposeful physical exercise. Exercise Energy Expenditure can measure the physiological workload.

3. Stress/exercise electrocardiogram (EKG or ECG)

A stress or exercise electrocardiogram (EKG or ECG) is a test that checks for changes in heart during exercise. The physiological stress of exercise/job elicits a predictable cascade of responses on the ECG. The stress ECG (or exercise ECG) test is a screening tool used to evaluate the effect of exercise on the subject's heart and lungs. Generally, the test utilises a treadmill or stationary bicycle (job simulator) to produce results that can be tracked and measured. The level of exertion is increased increasingly during the test to determine whether or not the heart and lungs are receiving enough oxygen and performing correctly.

4. Blood pressure (BP)

Blood pressure is the pressure of circulating blood on the walls of blood vessels. Most of this pressure is due to work done by the heart by pumping blood through the circulatory system. Blood pressure is usually expressed in terms of the systolic pressure (maximum during one heartbeat) over diastolic pressure (minimum in between two heartbeats) and is measured in millimetres of mercury (mmHg), above the surrounding atmospheric pressure. Exercise can increase BP, but the effects are typically temporary. BP should gradually return to normal after the activity. Exercise raises systolic blood pressure (SBP). Aerobic activities put additional demands on the cardiovascular system.

1.11.2 Postural measures

1. **Rapid Upper Limb Assessment (RULA) Method**

This diagnostic tool assesses biomechanical and postural load requirements of job tasks/demands on the neck, trunk and upper extremities. A single-page form is used to evaluate required body posture, force, and repetition. Based on the evaluations, scores are entered for each body region in section A for the arm and wrist, and section B for the neck and trunk. After the data for each region is collected and scored, tables on the form are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk. (McAtamney & Corlett, 1993).

2. **Rapid Entire Body Assessment (REBA) Method**

This tool uses a systematic process to evaluate whole-body postural MSD and ergonomic design risks associated with job tasks. A single-page form is used to evaluate required body posture, forceful exertions, type of movement or action, repetition, and coupling. A score is assigned for each of the following body regions: wrists, forearms, elbows, shoulders, neck, trunk, back, legs and knees. After the data for each region is collected and scored, tables on the form are then used to compile the risk factor variables, generating a single score that represents the level of MSD risk (Hignett & Mcatammey, 2000).

3. **Ovaco Working Analysing System (OWAS) Method**

The OWAS method is a method of posture monitoring. It is a practical method for identifying and evaluating working postures. The OWAS procedure consists of two parts: an observational technique for classifying body postures, and a set of criteria for the redesigning of working methods and workplaces. Body postures are classified into 28 positions including the positions of the back (four positions), upper limbs (four), hands (three), lower limbs (nine), head and neck (five), as well as the load or force handled (three). Each of these positions has pre-defined high risk and low-risk postures that are coded by the observer. After calculating the amount of time the worker maintains these postures, the final step is to assign a four-level action code for task improvement (changes are not needed, changes needed immediately, changes needed in near future and needed intensive observation) (Karhu, et al., 1977).

4. Quick Exposure Checklist (QEC) Method

QEC is an ergonomic assessment tool to measure the exposure of four body regions quickly (back, shoulder/arm, hand/wrist and neck) to the musculoskeletal risk factors. It considers the risk factors and work conditions including working body posture and movements; weight handled manually, hand force exertion, task duration, workplace, vibration and visual demands. Each body part gets a risk score separately, which defines its risk level. QEC divides the risk levels into four levels as low, moderate, high and very high risk. The total score is the sum of each body part's score divided by the maximum possible score (David, et al., 2008).

5. Occupational Repetitive Action (OCRA) method

The OCRA method was developed in Italy to analyse the worker's exposure to tasks featuring various upper-limb injury risk factors. OCRA describes the risk factors of repetitive actions at work. The OCRA index quantifies the relationship between the daily numbers of actually performed by the upper limbs in repetitive tasks and the corresponding number of recommending actions (Occhipintini, 1998).

6. Postural Loading on the Upper Body Assessment (LUBA) method

LUBA is a method to code the sitting or standing postures by giving additional weights for the postures according to the experimental results of discomfort felt in these postures in individual joints. All scores are summed up to one score to describe the urgency of actions (Kee & Karwowski, 2001).

7. Assessment of Repetitive Tasks (ART)

The assessment of repetitive tasks (ART) tool is designed to assess the tasks that require repetitive moving of the upper limbs (arms and hands). It helps to determine some of the common risk factors in repetitive work that contribute to the development of upper limb disorders (ULDs) (Ferreira J, 2009).

1.11.3 Psychological Measures

1. **NASA Task Load Index**

The NASA Task Load Index (TLX) measurement technique was developed to help mitigate several problems that arise from differences in the way people think about the workload. The NASA TLX technique is similar to the instantaneous self-assessment technique in that the experimenter must periodically ask the human operator for subjective estimations of his/her workload (Sandra & Lowell, 1988).

2. **Bedford Scale**

The Bedford Scale is a unidimensional rating scale designed to identify a worker's mental capacity while completing a task. The single dimension is assessed using a hierarchical decision tree that guides the worker through a ten-point rating scale, each point of which is accompanied by a descriptor of the associated level of workload (Roscoe, 1984).

3. **Perceived Stress Scale (PSS)**

The PSS is the most widely used psychological instrument/tool for measuring the perception of stress. The questions in this scale asked about the subject's feelings and thoughts. In each case, the subjects were asked to indicate their feeling. Based on their answers to the questions, a final score was generated, that represented the level of psychological stress (Cohen, et al., 1983).

4. **Copenhagen Psychosocial Questionnaire (COPSOQ)**

The Psychosocial Department (NIOH, Copenhagen, Denmark) has developed COPSOQ. The scales of the COPSOQ are designed by adding the points of the individual questions of the scales by giving equal weights to each question. Among psychosocial risk assessment tools, COPSOQ is unique because it includes population-based reference values to assess the need for action and to help the decision-making process on preventive measures at the workplace level (Kristensen, et al., 2005).

5. **Job Content Questionnaire (JCQ)**

The Job Content Questionnaire (JCQ) is designed to measure scales assessing psychological demands, decision latitude, social support, physical demands, and job insecurity (Karasek, et al., 1998).

1.11.4 Environmental Measures

Unorganised workers suffer under various types of environmental stress. According to the presence of environmental stress, the below methods can be used.

1. Sound Level Meter for noise measurement
2. Dry-bulb temp (DBT), Wet-bulb temp (WBT), Globe temp (GT), Kata thermometer, Psling psychometric nomograph for heat stress analysis
3. Spirometer and accessories for the study of the impact of dust
4. Vibration meter for the study of the effects of hand-arm vibration on the body, and many more.

1.12 The Popular Ergonomic Method Used by the Researcher

Twenty-seven (27) recently published research paper was review to understand the popular ergonomic methods used by the previous ergonomic researcher. The results of the review study are shown in Figure 1-3. The results say that the popular method from physiological stress measurement is Heart rate. RULA, REBA, OWAS and Nordic Questioner are the most popular methods to analyse the postural stress. Heat stress and Spirometry are another two famous methods to measure environmental method in the Indian context. The merit and demerit of the popular methods are shown in Table 1.4.

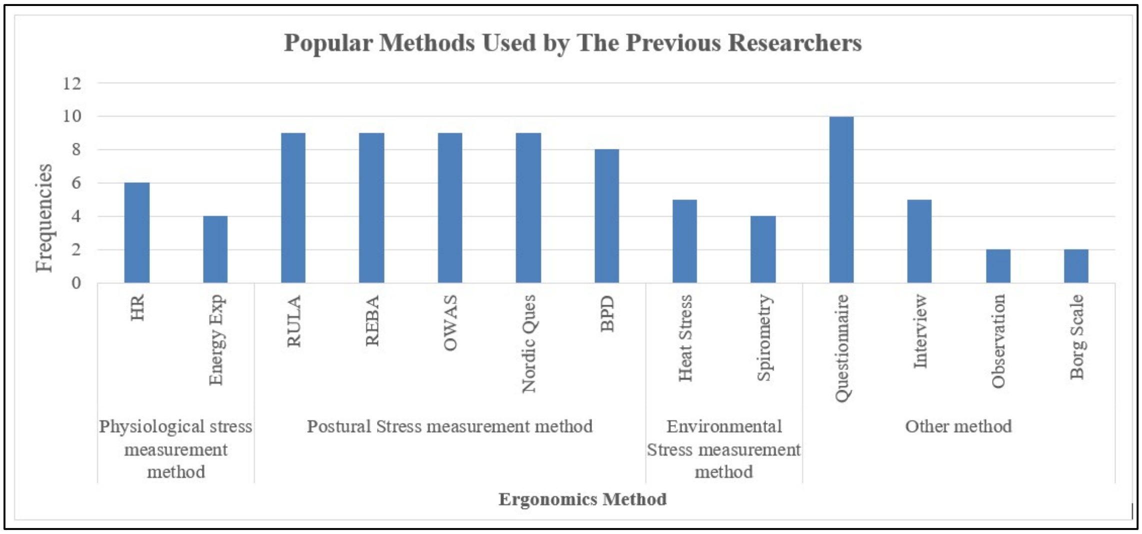


Figure 1-3: Popular ergonomics method applied in the Indian unorganised sector

Table 1.4: The merit, demerits of popular ergonomics method in the unorganised sector

Category	Method	About the methods	Tools needed	Merits	Demerits
Physiological Stress measurement method	HR	Heart rate is the speed of the heartbeat measured by the number of contraction (beats) of the heart per minute (bpm^{-1}). Resting and working heart rate is the measurement of heart rate during rest and work. $HRmax = 220 – Age$ $HRR = Max\ HR – HR_{Rest}$ $NCC = HR_{Work} – HR_{Rest}$ $RCC = (NCC/HRR) *100$	• HR monitor • Polar belt • Stopwatch (for manual method)	• Easy to measure • Can measure during activity • Less time consuming and economical	• At rest, heart rate is a vague indicator of internal activity at best and inconsistent • Difficult to measure during exercise or while moving (when measured manually) • Accuracy requirements limit the use of some trendy wearable HR monitors (when using heart rate monitor)
	Energy Expenditure Study	Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or physical movement.	• K4b2 Gas Analyser, • Heart rate monitor	• Can measure accurate results	• Costly • Time-consuming method • Need expert people to use the method
Postural Stress measurement method	RULA (McAtamney and Corlet 1993).	RULA provides an easily calculated rating of musculoskeletal loads in tasks where people have a risk of neck and upper-limb loading. RULA is used to assess the posture, force, and movement associated with sedentary	• RULA sheet, • Pen • Paper and	• Easy to use • No need for expert people to use the method	• When using RULA, either right or left side is assessed at a time. • RULA does not include assessment of fingers and thumb.

Category	Method	About the methods	Tools needed	Merits	Demerits
		tasks. The four main applications of RULA are to: a) Measure musculoskeletal risk, b) Compare the musculoskeletal loading of current and modified workstation designs c) Evaluate outcomes such as productivity or suitability of equipment	• Photographs were taken from the side and back to avoid parallax error	• Less time consuming and economical	• RULA does not provide exact engineering controls or work activity change. It gives a total job assessment • RULA does not provide an integrated assessment of all biomechanical risk factors. • RULA's scoring system may be too general in nature to differentiate various levels of risk (low, moderate, high)
	REBA (Hignett and Mcatammey 2000)	REBA was developed to assess the type of unpredictable working postures. Data are collected about the body posture, forces used, type of movement or action, repetition, and coupling. A final REBA score is generated to give an indication of the level of risk and urgency with which action should be taken. REBA can be used when -the whole body is being used -posture is static, dynamic, rapidly changing, or unstable	• REBA sheet, • Pen • Paper and • Photographs were taken from the side and back to avoid parallax error	• Easy to use • No need for expert people • Less time consuming and economical	• Subjective method; covers three important risk factors: Force, repetition and posture • Some factors (e.g., twisting, lateral bending, abduction) are weighted equally by REBA regardless to what degree they exist (e.g., 5° twisting or 20° of twisting).

Category	Method	About the methods	Tools needed	Merits	Demerits
		-loads are being handled either frequently or infrequently			
	OWAS (Karhu, Kansi and Kuorinka 1977).	The OWAS method was intended to identify the frequency and time spent in the posture adopted during a particular activity. OWAS method evaluated the working postures and recommended corrective actions.	• OWAS sheet, • Pen, • Paper and • Photographs were taken from the side and back to avoid parallax error	• Easy to use • No need for expert people to use the method • Less time consuming and economical	• Does not separate right and left upper extremities • Assessment of neck and elbow /wrist is missing • Does not consider repetition or duration of the sequential postures • Decisions rules based on frequency distribution are arbitrary
	Nordic Questioners	The NMQ can be used as a questionnaire or as a structured interview. The questionnaire can be used to measure musculoskeletal issues among subjects. Section 1: a general questionnaire is identifying areas of the body, causing musculoskeletal problems.	• Nordic Questioners sheet, • Pen, • Paper	• Standardised questions. • Worldwide recognition. • Relatively quick identification of the symptoms.	• Obligatory answering of the questions. • The difficulty of determining the truthfulness of the responses • Restriction of exhaustive questions to three areas of the body (lower back, neck, and shoulders) • Identification only of symptoms

Category	Method	About the methods	Tools needed	Merits	Demerits
		Section 2: additional questions relating to the neck, the shoulders and the lower back further detail relevant issues		• Applicability in large populations. • Frequent use together with other evaluation methods such as RULA, REBA, OWAS, etc.	• Complex data analysis for large populations
	Body Part Discomfort Scale (BPD) (Corlett 1976)	BPD scale is a subjective symptom survey tool that evaluates the respondent's direct experience of discomfort at different body parts.	• Pen, • Paper • BPD scale	• Easy to use • No need for expert people to use the method • Less time consuming and economical	• Obligatory answering of the questions. • The difficulty of determining the truthfulness of the responses
Psychological Stress measurement method	PSS (Cohen, Kamarck and Mermelstein 1983).	The PSS was the most widely used psychological instrument/tool for measuring the perception of stress. The questions in this scale asked about the subject's feelings and thoughts during the last month. In each case,	• Pen, • Paper • Perceived stress scale	• Easy to use • No need for expert people to use the method	

Category	Method	About the methods	Tools needed	Merits	Demerits
		the subject was asked to indicate feeling or thought.		• Less time consuming and economical	
	Nasa TLX (Hart and Staveland 1988)	The NASA TLX is a multi-dimensional rating scale for operators to report their mental workload. It uses six dimensions of workload to provide diagnostic information about the nature and relative contribution of each dimension in influencing overall operator workload. Operators rate the contribution made by each of the six dimensions of workload to identify the intensity of the perceived workload.	• Pen, • Paper and • NASA Task Load Index sheet	• A quick and simple technique for estimating workload • Can be applied to any domain. • Most widely used technique • A multi-dimensional approach to workload assessment.	• When administered on-line, the TLX can be intrusive to primary task performance. • When administered after the fact, participants may have forgotten high workload aspects of the task. • Workload ratings may be correlated with task performance, e.g. subjects who performed poorly on the primary task may rate their workload as very high and vice versa. • The sub-scale weighing procedure is laborious and adds more time to the procedure.
	Bedford Workload Scale	The Bedford Workload Scale is a unidimensional scale that ranks whether it was possible to complete the task if the	• Pen, • Paper and	• Very quick and easy to use,	• There is little evidence of actual use of the technique.

Category	Method	About the methods	Tools needed	Merits	Demerits
	(Roscoe A.H. and Ellis G.A. 1990).	workload was tolerable for the task and if the workload was satisfactory without reduction. The Bedford scale was developed for pilots, but it could be used in similar contexts.	• Bedford workload scoresheet	requiring minimal analyst training • The scale is generic, and so the technique can easily be applied in different domains. • May be useful when used in conjunction with other techniques of MWL assessment. • Low intrusiveness	• Limited validation evidence associated with the technique. • Limited output. • Participants are not efficient at reporting mental events 'after the fact'
Environmental Stress Measurement method	Heat Stress: CET (Parsons 2003)	The CET index was established to provide a method for determining the relative effects of air temperature and humidity on comfort. This method considered the absolute temperature, humidity, and speed of the air. The effects of radiant heat can be included in during assessment of effective temperature instead of the dry-bulb temperature when the	• Dry-bulb temp (DBT) • Wet-bulb temp (WBT), • Globe temp (GT) • Kata thermometer	• Easy to use • No need for expert people to use the method • Less time consuming	• Costly Instrumentation

Category	Method	About the methods	Tools needed	Merits	Demerits
		radiant temperature is higher than the dry-bulb temperature.	• Psling psychometric nomograph		
	Heat Stress: WBGT index (Yaglou and Minard 1957)	The Wet Bulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). WBGT Index (Outdoor) = 0.7 (WBT)+0.2(GT)+0.1(DBT) WBGT Index (Indoor) = 0.7 (WBT)+0.3(GT)	• Dry-bulb temp (DBT) • Wet-bulb temp (WBT), • Globe temp (GT) • Kata thermometer	• Easy to use • No need for expert people to use the method • Less time consuming	• Costly Instrumentation
	Spirometry	Spirometry is the most common of the pulmonary function tests. It measures lung function, specifically the amount and/or speed of air that can be inhaled and exhaled. Spirometry is helpful in assessing breathing patterns that identify conditions such as asthma, pulmonary fibrosis, cystic fibrosis, and COPD.	• Spirometer and accessories	• Can measure accurate results	• Costly • Medium level time-consuming method • Need expert people to use the method

Category	Method	About the methods	Tools needed	Merits	Demerits
Other ergonomic methods	Borg scale (Borg 1982)	The level of perceived exertion is measured with a 15-category scale. The Borg 15-point RPE scale is a modified 6-20-point RPE scale. The Borg 15-point RPE scale has been used to measure the level of perceived exertion. A rating of 6 was to be associated with no exertion, i.e. rest, and a score of 20 with maximal exertion, i.e. the most stressful exercise performed.	• Pen • Paper and • Borg scale	• The RPE scale is easy to use, and the instruction is simple. • Linear relations are obtained for work with high aerobic demands. The scale gives an individualised measure of exercise intensity.	• Responses obtained by the RPE scale do not reflect "true" growth functions. • The RPE scale can only be used for perceived exertion and related symptoms.
	Observation	Observations are based on visits to the 'field' of the study. Two types of observations: 'direct observation' and 'observation as a participant	• Camera and accessories	• Cover events and their context in real-time • Hand experience of a particular job • Record information as it occurs and notices unusual aspects	• Time and cost consuming • Might introduce selectivity related bias when observing • The job might proceed differently because the participants are aware that they are observed. • There might also be situations where sensitive information, for instance,

Category	Method	About the methods	Tools needed	Merits	Demerits
				• Give an insight into the participants, which might be awkward to discuss in interviews	private, is not suitable for being reported
	Interview	An interview is a procedure designed to obtain information from a person's oral response to oral inquiries.	• Pen • Paper	• Possible to reach many people at the same time, • Easy for the candidates to answer, • The researcher has more control over the questioning	• provides information filtered through the eyes and memory of the respondent, • may also be affected by the presence of the researcher, • maybe biased, • poorly constructed questions, which can confuse
	Questioners	Questionnaire survey is a quantitative method for data collection. The survey can be based on questionnaires	• Pen • Paper • Questioners sheet	• An inexpensive data collection method. • Possible to send the questionnaire too	• Risk of a serious loss of responses. • Uncertainty about who answered the questionnaire • It is challenging to get answers to open questions.

Category	Method	About the methods	Tools needed	Merits	Demerits
				many respondents at the same time. • The respondents can take sufficient time. • The interviewer does not directly affect the respondent.	

1.13 Selection of Methods from Different Stress Category

The unorganised sector workers suffer under physiological, postural, psychological and environmental stresses during work. Previous ergonomic studies suggest for ergonomic intervention. The above literature surveys also suggest for context-specific low-cost design intervention in the Indian context. The last section also describes different ergonomic methods and the tools needed to conduct the ergonomic assessments. The advantages and disadvantages and sensitivity of the currently available ergonomic methods are investigated. Some methods are very simple and easy to apply with short training and don't need costly instruments. It can be measured by pen-paper only. But some other methods need expertise contribution to apply as well as a costly instrument. All the methods are focused on measuring a definite type of stress. There is no such method that can prioritise job stress among multiple stresses. The ergonomic method review study says that there are no such methods that can prioritise the stress among physiological, postural, psychological and environmental stresses. Therefore, it is important to identify the most severe pain, where design intervention can be focused on the specific pain point. To develop a **combined method**, one method selected from each category, i.e. Physiological, Postural, Psychological and Environmental stress analysis, keeping in mind that the application of method chosen should be straightforward, effortless and applied by locally available instruments. There are no expert safety officer or ergonomist in the unorganised sector. The assessment in the unorganised sector will be done by a person who can assess that with short-duration training and lower financial support. Keeping on mind that, simple, low-cost methods are selected from each group (Physiological, Postural, Psychological and Environmental stresses) (Table 1.5).

- From physiological stress assessment group, Heart Rate is selected because of the simplicity of the method. Heart rate monitor and polar heart rate belt are needed to record the heart rate during exercise and resting.
- From postural stress assessment group, REBA method is selected for further study. RULA, QEC, OCRA and ART can do the assessments of the upper body. REBA scoresheet, pen paper and the working photographs (taken from the side and back view

to avoid parallax error) are needed for REBA analysis. Moreover, the REBA is more user friendly from the viewpoint of usability as discussed with the designers

- For psychological stress assessment group, PSS is chosen due to the simplicity of the method. PSS scoresheet, pen and paper are needed for PSS analysis.
- Unorganised workers suffer from different types of environmental stress. For environmental stress assessment group, currently, no method is selected. Environmental stress assessment method will be chosen after selecting the worker.

Table 1.5: Selection of methods and cause of selection

Type of stresses	Selected Method	Cause of selection	Tools needed
Physiological stress	Heart Rate (HR)	Moderate cost, Easy to use, Can be applied with limited training	Heart rate monitor, Polar heart rate belt
Postural stress	REBA	Low cost, Can measure entire body postural stress, Easy to use, Can be applied with limited training	REBA scoresheet, Pen, Paper, Workers working posture photographs (side view and back view)
Psychological stress	PSS	Low cost, Easy to use, Can be applied with limited training	REBA scoresheet, Pen, Paper,
Environmental stress	Depends on available stress among studied workers, such as temperature, heat, noise, vibration etc	Possible environmental stress among particular unorganised worker	Can be selected during testing

1.14 Research Objectives

Prioritisation of Stress

In a developing country, like India, low-cost design intervention is expected by the user group. There are no as such ergonomic stress analysis method that can find dominating stress. The current study is trying to develop a method that can identify the dominate stress from all available stress, that will help in design intervention in the unorganised sector.

Wage Fixation

Literature survey also says that lower wages are one of an important problem in the unorganised sector. Currently, available minimum wages values are not appropriate from the unorganised sector worker's viewpoint. Ergonomics has a vital role in fixing the minimum wages among Indian unorganised sector. Energy expenditure is one of the major components to determine the monthly wages. The current study is also taking the initiative to measure the energy expenditure to help the social scientist.

1.15 Summary and Conclusion

India is the second most populated country, and 94 percent of the Indian workforce belongs from the unorganised sector. The sector which is not registered with the government and whose terms of employment are not fixed and regular is considered as unorganised sector. There is fifty-six percent of unorganised workers employed in the agriculture sector, ten percent in the construction sector and remaining thirty-four percent in manufacturing and service sector. The common features of unorganised sectors are - ease of entry, a small scale of operation, uncertain legal status, local-ownership, labour-intensive and operating using lower technology-based methods, flexible pricing, less sophisticated packing, absence of a brand name, unavailability of proper storage facilities and an active distribution network, inadequate access to government schemes, finance and government aid, lower entry barriers for employees, a higher proportion of migrants with a lower rate of compensation. The workers of the unorganised sector coming from the grass-root level. They are a home-based or self-employed or wage workers in the unorganised sector. The unorganised sector has lower productivity and offers lower wages. Even though it accounted for over 94 per cent of workers, India's unorganised sector created just 57 percent of India's national domestic product in 2006, or about 9-fold less per worker than the organised sector. The productivity gap sharply worsens when the unorganised rural sector is compared to the unorganised urban industry, with gross value-added productivity gap spiking an additional 2 to 4-fold depending on the occupation. Some of the lowest income jobs are in the rural unorganised sectors. Poverty rates are reported to be significantly higher in families where all working-age members have only worked in the unorganised sector throughout their lives.

The unorganised sector is the most unsafe sectors in both the developing and the developed worlds. Unsafe work condition cause work-related accidents and illness. The workers of the unorganised sector suffer under occupational stress, body pain in different body parts, WMSDs due to awkward posture. Occupational stress can be classified as Physiological, Postural, Psychological and Environmental stress. The ergonomic intervention can reduce occupational stress. Ergonomics can improve the worker's productivity, job quality etc. The ergonomic intervention also reduces Injury-related absences. Prioritisation of stress is important for design intervention. The current study focused on the prioritisation of stress and work-related energy expenditure that can help wage fixation in the unorganised sector.

1.16 The organisation of the Dissertation

This dissertation is organised into seven chapters, as follows:

The chapter-1 contains the Introduction which highlights problems and current status of unorganised sectors. The chapter also includes the relevant review of literature that shows merits, demerits of popular ergonomics methods in the unorganised sector. Based on this, the scope of the current research also justified in this chapter.

The Chapter-2 exhibits details of Brick Kiln industry in India. The Chapter clearly explains type of brick kiln and brick manufacturing scenario in India. Description of activities in the brick kiln has been specified in this chapter.

The Chapter-3 contains research scope and objectives. In this chapter, a review of the literature on the current status of the brick kiln industry has been presented. The researcher has brought out the main factors that have been identified from various studies as the main barriers to actual mechanisation in Indian brick kiln industry. Based on this, the aims and objectives and research framework for the current study have been established.

The Chapter-4 contains research methodology. This chapter explains in detail about the selection of subjects for the study, instrumentation for data collection, tools and techniques used for physiological stress analysis, postural stress analysis, psychological stress analysis as well as environmental stress analysis. The ergonomic methods to the development of the P-P-P-E method also explained here.

The Chapter-5 contains the details about three selected Indian brick kiln industry. The work process in those brick kiln industry also highlighted. At the end of the chapter, a comparative analysis of three studied brick kiln was done.

Chapter-6 is about the results and discussions. In this chapter, selected subject's height and weight were compared with Indian anthropometric data. Human energy expenditure was also calculated for different brick kiln sub-activities, that will help for wage fixation in the unorganised sector. Besides this, per brick human energy cost and time cost also determined for brick kiln workers. The chapter also quantified the physiological, postural, psychological and environmental stress among the subject group. The researcher has derived the P-P-P-E score from the study parameters to bring out the design direction for the intervention process. In the design intervention, the researcher has designed and tested i) Moulding workstation for making of brick with less effort and fatigue and ii) Headgear to protect the face of the Jalaiya workers from radiant heat.

Chapter-7 is about the conclusion of the study. The overall thesis was briefed in this chapter. The limitation and future scope of the study were also highlighted in this chapter.

Chapter 2 Brick Kiln Industry - A Representative of Unorganised Sector

In this chapter, the Indian traditional brick making industry is selected as a representative of the Indian unorganised sector. The general information about Indian traditional brick kilns, types of the brick kiln, the brick manufacturing scenario are presented. The description of the brick making activity is also presented.

2.1 Introduction

In the previous chapter, occupational hazards and getting the minimum wage are identified as the main problems in the unorganised sector. To understand the difficulty in the unorganised sector, it needs to conduct an ergonomic study in an unorganised sector. The unorganised sector is vast. It is near to impossible to conduct a study in the whole unorganised sector. Therefore, it needs to select an unorganised sector as a representative of the unorganised sector.

2.2 Selection of Unorganised Sector for Further Study

Agriculture has the maximum proportion of the workforce (56%) of the unorganised sector. But agriculture activity depends on the region and weather-specific. In a different part of India, different types of cultivation happen. The process of farming in a different part of India, also not the same. Therefore, agriculture is not suitable to conduct this kind of study. Manufacturing sectors have the second largest (after agriculture) unorganised workforce (14%) in India. Manufacturing sectors are a combination of different small-small unorganised sector. Only brick kiln accounts (5% of Indian unorganised workforce) maximum workforce of the manufacturing workforce. There are 23 million workers employed in brick kiln sector.

Considering the high volume of worker is working in the brick kiln industry, the brick kiln industry is selected for details study as a representative of the unorganised sector (Figure 2-1).

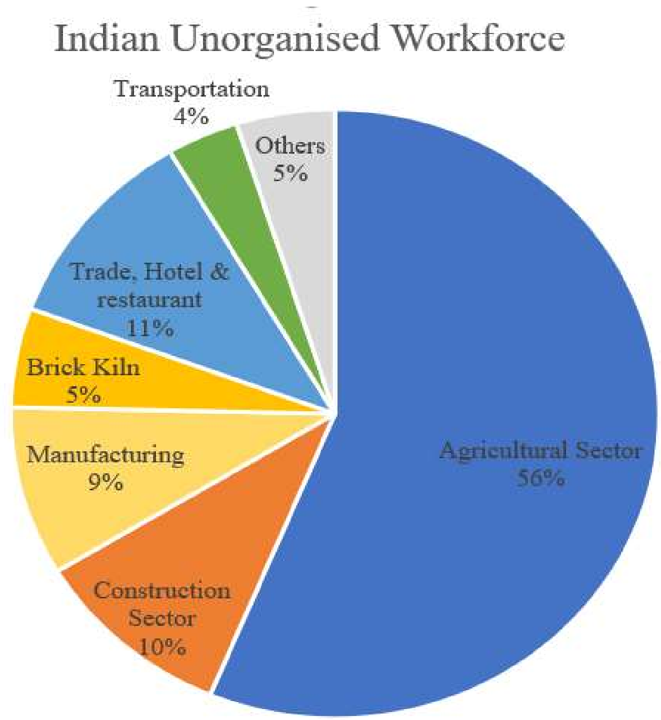


Figure 2-1: Percentage of Indian unorganised workforce

2.3 Understanding the Brick Kiln Industry

2.3.1 About Brick

A brick is a slab of mud or other similar material, usually in the shape of a rectangle that is baked in high temperature so that it becomes hard enough and used for making houses and other structures. Bricks are one of the primitive building blocks. They are an ideal building material because they are relatively cheap to make, very durable, and require little maintenance. Brick is one of the primary building materials used in India.

2.3.2 Brick Kiln Industry

The Indian brick industry, the second-largest producer of brick in the world, accounting for more than 10% of global production, is next to that of China (Sameer, 2003). Based on the limited information available on the brick industry in India, it is estimated that more than 100,000 kilns produce around 150-200 billion bricks per year and the present employment capacity is more than 10 million (Development Alternatives, New Delhi, India, 2012). Day by day, the demand for bricks is increasing in India due to urbanisation; construction of houses, roads and bridges etc.

The workers in the brick industry are uneducated and migrated from different parts of the country. The workers are employed for a short time on a seasonal basis (mainly for the dry season in between the months from November to April), without proper training and sufficient experience. Therefore, they do not have any prior knowledge about hazardous acts related to this work, or they ignore the safe working process. Both male and female member of the families is engaged in brick making activity. Children are not employed as such, but usually, they accompany their parents to the workplace. The workforce is paid based on significant work and against the completion of specific tasks.

2.3.3 Types of Brick Kiln

Different types of kilns are used for firing bricks. The brick kiln can be classified in various kinds, e.g. according to the production process (intermittent and continuous kilns); the direction of airflow (up-draught, down-draught and cross-draught kilns); or according to the method of production of draught (natural draught and induced/forced draught kilns).

2.3.3.1 Classification Based on The Nature of The Production Process

Depending upon the nature of the production process, brick kilns can be classified as intermittent kilns and continuous kilns. The classification is represented in Figure 2-2 below:

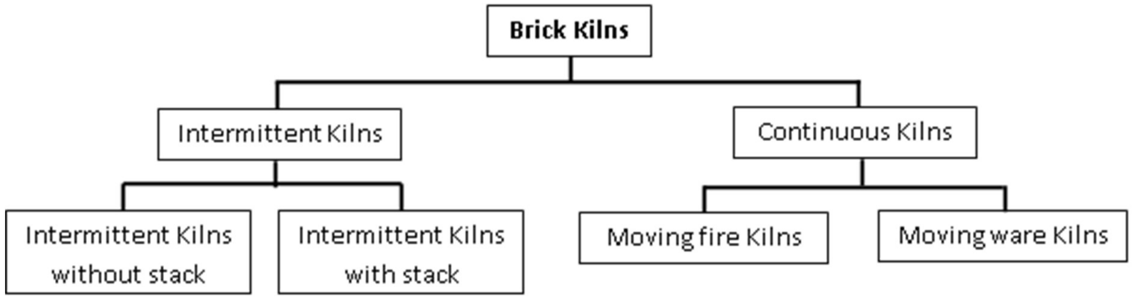


Figure 2-2: Classification of brick kilns based on the production process

2.3.3.1.1 Intermittent Kilns

In intermittent kilns, the bricks are baked in batches; fire is allowed to die out, and the bricks are allowed to cool after they have been baked. The kiln must be emptied, refilled and a new fire has to be started for each batch/load of bricks. In intermittent kilns, most of the heat contained in the hot flue gases fired bricks, and the kiln structure is thus lost. The intermittent kilns are still widely used in several countries of Asia, Africa and South and Latin America. The intermittent kilns can be further sub-divided into two categories – Intermittent kilns without stack & Intermittent kilns with stack (Maithel S., Kumar S., 2016).

2.3.3.1.2 Continuous Kilns

In a continuous kiln, fire is always burning, and bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Fired bricks are continuously removed and replaced by green bricks in another part of the kiln which is then heated. Consequently, the rate of output is approximately constant. Heat in the flue gas is utilised for heating and drying of green bricks, and the heat in the fired bricks is used for preheating air for combustion. Due to the incorporation of heat recovery features, continuous kilns are more energy efficient. Continuous kilns can be further sub-divided into two categories: moving fire kilns and moving ware kilns (Maithel S., Kumar S., 2016).

2.3.3.2 Classification Based on Airflow

Based on the direction of airflow to the brick setting in the kiln, brick kilns can be classified as up draught kilns, down draught kilns and cross draught kilns. The classification is represented in Figure 2-3 below:

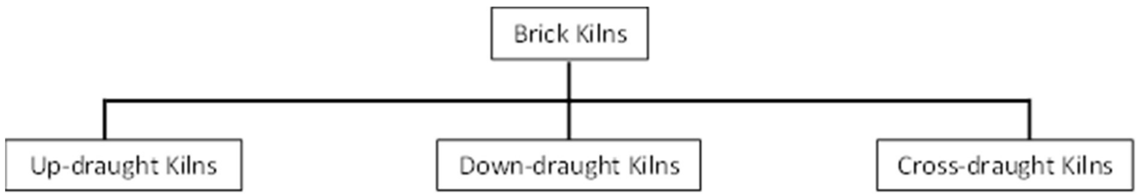


Figure 2-3: Classification of brick kilns based on airflow

2.3.3.2.1 Up-draught Kilns

In an up-draught kiln, air enters the kiln from below, gets heated from the fire and moves upward through the brick setting, transferring the heat to the bricks. The upward movement of heated air is a natural phenomenon, and it does not require a stack or fan to cause the airflow. Clamps and vertical shaft brick kiln (VSBK) are examples of up-draught kilns (Maithel S., Kumar S., 2016).

2.3.3.2.2 Down-draught Kilns

In a down-draught kiln, the air is first heated up with the fire. The hot air is then made to enter the kiln from the top and is brought down through the brick setting with the help of draught created by a stack. In this type of kilns, usually, bricks are not in direct contact with fire. Down-draught kiln, as the name suggests, is an example of this category of kilns (Maithel S., Kumar S., 2016).

2.3.3.2.3 Cross-draught Kilns

In the cross-draught kiln, air flows horizontally through the brick stacking. The air movement is caused by either the draught created by the chimney (natural draught) or the draught provided by a fan (forced draught). These are also called horizontal draught kilns. Hoffman kiln, fixed chimney Bull's trench kiln and tunnel kilns are an example of cross draught kilns (Maithel S., Kumar S., 2016).

2.4 The Brick Manufacturing Scenario in India

The Gangetic Plains account about 65% of total brick production. Bihar, Haryana, Punjab Uttar Pradesh and West Bengal are the major brick manufacturing states in Gangetic Plains. Brick kilns are in clusters, an outcast of towns and cities. Peninsular and coastal India (except Gangetic Plains) accounts for the remaining 35% of brick production. In coastal India region, bricks are produced in numerous small units (production capacities generally range from 0.1 to 3 million bricks per year). Gujarat, Orissa, Maharashtra, and Tamil Nadu are essential brick manufacturing states in coastal India. Coal is the primary fuel used for firing bricks. Apart from coal, a variety of biomass fuels (such as firewood, dry dung and rice husk) are also used for firing bricks (Asgher S. Md., 2005). Table 2.1 shows the different types and an approximate number of brick kilns available in India.

Table 2.1: Different types of brick kiln in India

Indian Kiln	Down Draught	Clamps	Tunnel Kiln	Hoffman Kiln	Zigzag ND Kiln	(VSBK)	Zigzag HD Kiln	FCBTK
No of Kiln	3,000	1,00,000	5	500	50	110	2,000	35,000

Source: (Maithel, 2014)

Table 2.2 provides details about the types of brick firing technology and approximate contribution to brick production in India. Currently, Fixed Chimney Bull's Trench Kiln (FCBTK) is the leading technology for brick-firing activity. FCBTK accounts for around 70% of the total brick production in India and is prevalent in the Indo-Gangetic plains (Figure 2-4), as well as in some pockets in the rest of the country (Maithel, 2014).

Table 2.2: Brick firing technologies and approximate contribution in India

Kiln Type	Regional spread	Approximate contribution in brick production
Clamps	West, Central, and Southern India	25%
Fixed chimney BTK	Indo-Gangetic plains (East and North India) and several clusters in West and South India	70%
Zig-zag	West Bengal, a few clusters in North India	2-3%
VSBK	Central India	1-2%

Source : (Maheshwari H., 2017)

Figure 2-4: Distribution of different type of kilns in India

Source: (Maheshwari H., 2017)

The following features characterise the brick making in India –

Brick making is a small-scale, traditional industry (a traditional industry is defined as "*an activity, which produces marketable products, using locally available raw material and skills and indigenous technology*"). Most of the Indian brick kilns are situated in the rural and peri-urban areas. It is common to find large brick making clusters located around the towns and cities, which are the vast demand centres for bricks. Some of these clusters have up to several hundred kilns.

The brick production process is based on labour-intensive manual activity. Brick making is a seasonal activity, as the brick kilns do not operate during the rainy season. Most of the workers migrate with their families from different parts of the country. Families, including young children, work in low and daily-wage conditions. There is typically a lack of necessary facilities, such as access to clean drinking water, sanitation etc.

Bricks are fired to a temperature of 700^0C -1100^0C, requiring a large amount of fuel for the firing operation. Brick kilns are estimated to consume roughly 25 million tonnes of coal per year, thus making them among the highest industrial consumers of coal in the country (Maithel, 2014).

2.5 Fixed Chimney Bull's Trench Kiln (FCBTK)

Fixed Chimney Bull's Trench Kiln (FCBTK) technology is a continuous, moving fire kiln in which the fire is always burning and moving forward in the direction of airflow due to the draught provided by a chimney. The bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Figure 2-5 shows a schematic diagram of FCBTK (Greentech Knowledge Solutions Pvt Ltd, 2014). It is the most popular technology to produce bricks in India. The main reasons for its popularity are:

a) Low construction cost
b) Availability of trained workforce for operation
c) No need for electricity for its operation

The main characteristics, advantage and disadvantage of FCBTK technology are as given below –

Characteristics

a) It has an oval shape in which the chimney is located at the centre, and the bricks are fired in the space around the chimney, between the central part of the kiln and the outer wall. This space is called 'trench' or 'dug'.
b) It is a continuous moving-fire kiln in which the fire burns continuously and moves in a closed circuit through the bricks stacked in the trench.
c) The chimney creates the draught required for the flow of air in the kiln.
d) The bricks are stacked in the kiln in 'column-blade' brick setting in which the bricks are stacked in vertical columns in a row along the width of the trench. The rows of brick columns are arranged one ahead of the other in the direction of airflow.
e) The air flows through the passages left in between the brick columns in a straight-line path.
f) Usually, solid fuels such as coal, wood, sawdust, and agriculture residues are used in FCBTKs.
g) Seasonal operation: the kiln operates during the dry season only.

Advantages

a) Being a continuous kiln, it has better heat recovery features and is more efficient as compared to intermittent kilns.
b) Low cost of the technology.

Disadvantages

a) Higher fuel consumption compared to other efficient continuous kilns because of incomplete combustion and heat losses in the kiln.
b) Only about 60% of the bricks produced are of Class-1 quality.
c) Relatively higher emission compared to other continuous kiln technologies.

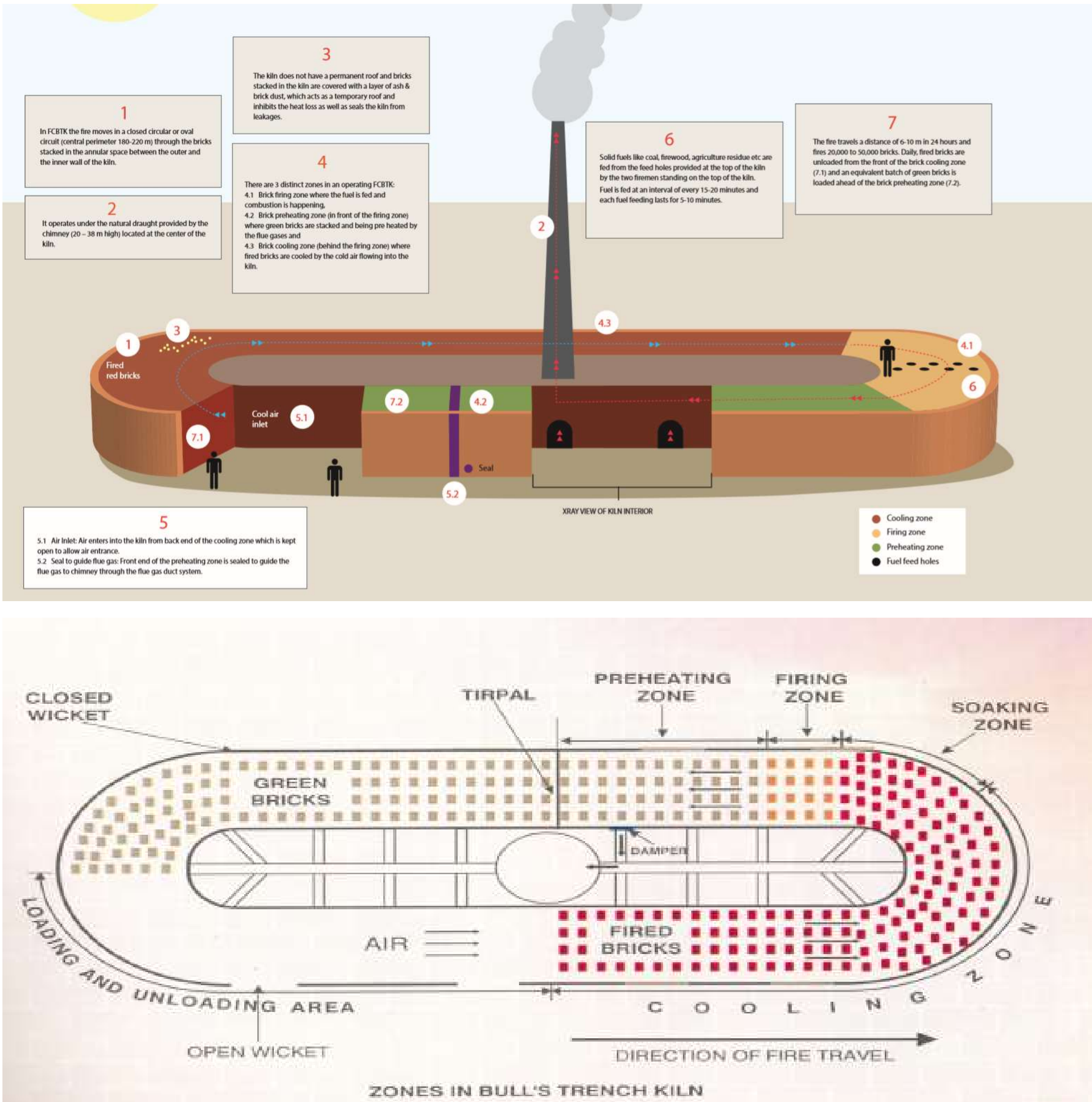


Figure 2-5: Schematic diagram of FCBTK

Source: (Greentech Knowledge Solutions Pvt Ltd, 2014)

Green bricks to be fired are placed in the trench and covered with a layer of ash and brick dust over the top to seal the kiln and to provide thermal insulation. The bricks are stacked in a column and blade brick arrangement. The brick-unloading end is kept open for air entry into the kiln. The brick-loading end is sealed with tarpaulin. During operation, there are three distinct zones in an FCBTK. The first zone is the brick cooling zone. In this zone, the air picks up heat from fired bricks, resulting in heating of air and cooling of fired bricks. The next zone is the fuel feeding zone (burning zone), in which the coal is fed from the peepholes, provided on the roof of the kiln. Coal meets hot air and burning takes place. The last zone is the brick-preheating zone; in this zone, heat available in the flue gases is utilised for preheating of green bricks (Greentech Knowledge Solutions Pvt Ltd, 2014).

2.6 Description of Activity

The brick manufacturing in brick kilns has a low technology base and labour-intensive job. The sequence of activities in a typical brick-kiln is discussed below (Figure 2-6):

Pathera activity: The first process involves mixing earth with water and shaping it into bricks that are then sun-dried.

Bharai activity: Sun-dried bricks are shifted for stacking in kilns for baking.

Khadkan activity: Bricks are arranged in kilns for firing.

Jalaiya/Jalaai activity: This process involves the firing of chimneys.

Nikashi activity: Fired bricks from the stacks under the chimney are removed and transported in wooden hand-propelled carts.

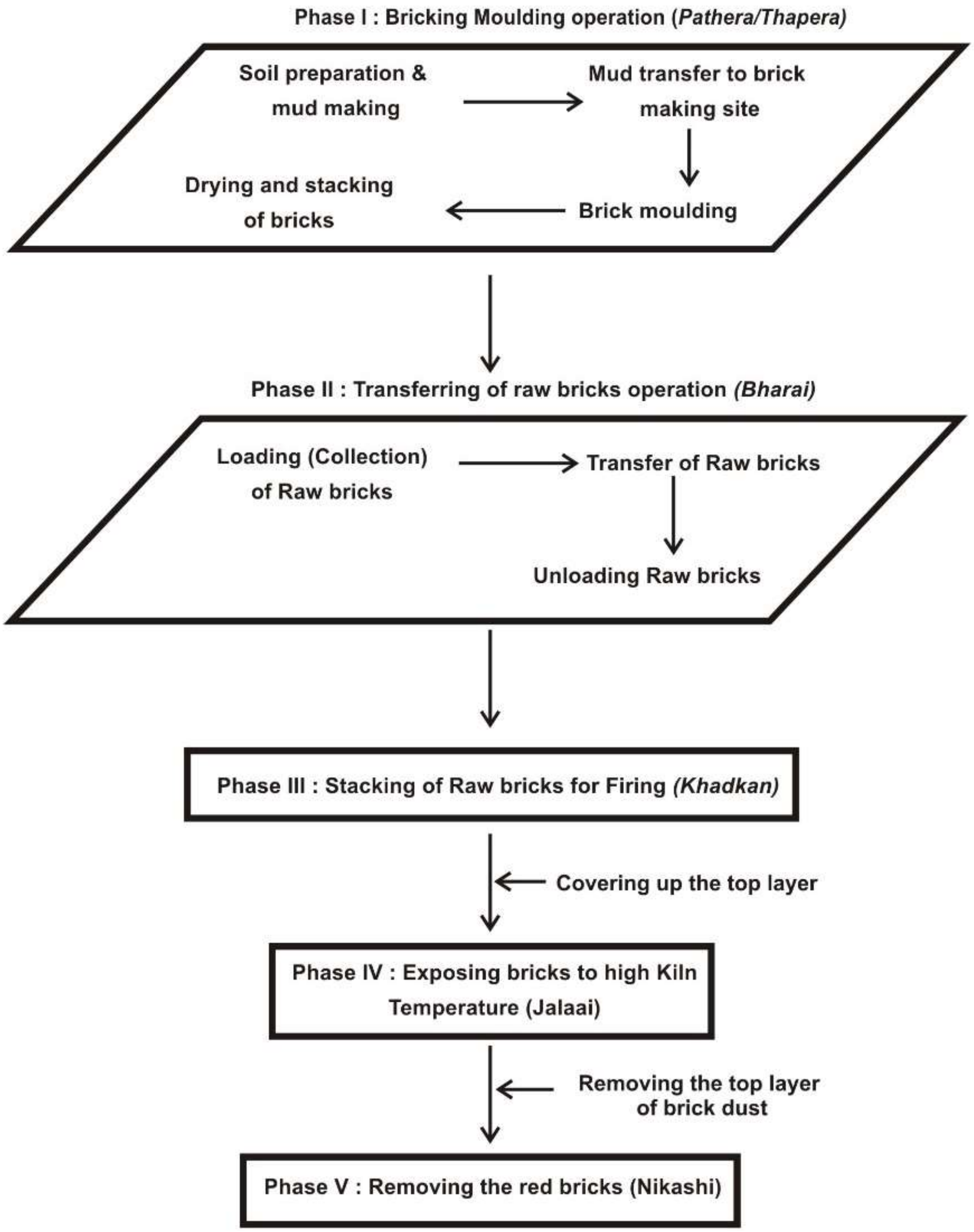


Figure 2-6: Diagrammatic representations of the brick-making operation at different phases in the brick kilns

2.7 Summary and Conclusion

Brick kiln industry is selected to understand the problem in the unorganised sector. The Indian brick industry, the second-largest producer of brick in the world, accounting for more than 10%

of global production, is next to that of China. Based on the limited information available on the brick industry in India, it is estimated that more than 100,000 kilns produce around 150-200 billion bricks per year and the present employment capacity is more than 10 million. FCBTK is the leading technology for firing bricks. FCBTK accounts for around 70% of the total brick production in India and is prevalent in the Indo-Gangetic plains, as well as in some pockets in the rest of the country. There are five types of brick kiln workers in Indian brick kiln industry such as Pathera, Bharai, Khadkan, Jalaiya and Nikashi.

Chapter 3 Research Scope and Objectives

In this chapter, a review of the literature on the current status of the brick kiln industry is then presented. Then the need and scope, specifically in traditional Indian brick kiln industry of current research are established. The brick-making process and its lacuna concerning ergonomics are presented. Various aspect like low-wages, different occupational stress such as physiological, postural, psychological and environmental stresses are identified. The scopes of current research and research frameworks are highlighted in the present chapter.

3.1 Introduction

In the earlier chapter, the brick making process and its lacuna concerning ergonomics are presented. Various aspect like low-wages, different occupational stress such as physiological, postural, psychological and environmental stresses are identified. The scopes of current research and research frameworks are highlighted in the present chapter.

3.2 Literature Review on Brick Kiln Industry

The comprehensive review of literature is an important part of any scientific study. The primary purposes of literature reviews are determining the actual work done to provide a basis for a theoretical framework, insight into methods and procedures and also form a basis for the interpretation of the findings. Therefore, a review of literature on brick kiln industry is taken up to identify research methodologies useful for the current research.

Adverse environmental and physical conditions affect the health status of brickfield workers who also perform other types of activities, e.g. they have to walk on a hot surface (top of the furnace). At the same time, monitoring and regulating the fire — physiological responses to such events, mainly involve the musculoskeletal and cardiovascular systems. Since the environment is unfriendly, it hinders excess heat elimination by the circulatory system, making the heart work harder to transport energy to the muscles for successful completion of the job. The brick kiln workers are living in a poor environment near to brick making units. They have poor access to health care. They are at risk of various types of illnesses.

A study conducted in Karnataka district on 60 workers highlighted that jobs in brick kilns involve an extensive range of physical actions from postures and positions that may not be ideal and could place workers at risk for accidents and injuries. This stressful situation can be made worse by physical discomforts in the workplace and cause MSDs. The prolonged stress and strain caused during the various activities with different load conditions is a cause for work-related MSDs (Qutubuddin, et al., 2008).

Sett and Sahu (2008) reported a study on ergonomic evaluation of workload of female labourers working in the unorganised sectors of the brickfields. In this study, 122 female labourers were selected from West Bengal India. A detailed questionnaire study, along with direct observation of work postures, was studied. Physical parameters such as body weight, height; physiological parameters like heart rate response, blood pressure and psychophysiological parameters such as perceived exertion rating were considered during rest and while performing different tasks in the field. The BMI of the workers indicated that 32 per cent of them were suffering from chronic energy deficiency. About 94 per cent of workers complained about pain in different body parts. Other chief health complaints were gynaecological problems (74%), skin diseases (68%) and respiratory problems (85%) from physiological responses. It was observed that most of the jobs performed by the female workers were classified as moderate to heavy. Moreover, they lift and carry the load, which was more than the recommended level. Postural analysis in OWAS method showed that some of the postures adapted during work required immediate corrective measures. Apart from this, the female labourers are continuously exposed under the radiant sun heart from the brick kiln, dusty and noisy environment, making their workplace more hazardous. Thus, immediate ergonomic interventions are required to improve the quality of life of these female labourers working in the unorganised sectors of the brickfields (Sett & Sahu, 2008).

Sau et al. (2005) studied the work-related stress of brick making workers. For the present study, 60 male and 40 female subjects were selected. The age range of subjects was 18-50 years. Questionnaire techniques studied WMSDs and the segmented pain of the workers. The spinal curvature of each subject was measured with the help of Flexi curve for assessing the work postures. The goniometry and photographic techniques studied the changes in joint angles in different working postures. The grip strength was also taken throughout the working period with a one-hour interval. Results indicated that both groups of workers felt discomfort in lower back, thigh, knee and waist region. The spinal curvature in different working postures (squat and bend) showed a significant variation with that in healthy standing posture ($P<0.001$). The grip strength of both groups of workers decreased significantly with work intensity, which indicated that the workers become fatigued more rapidly. The results showed that the postural discomfort might be due to the lifting of load by both hands with an awkward posture. It is concluded that the musculoskeletal disorders of the brick kiln workers may be caused due to bad working posture as well as repetitive tasks and fatigue problems (Sau, et al., 2009).

Ray Chaudhuri et al. (2012) conducted a study on a subjective and objective analysis of pain in female brick kiln workers of West Bengal, India. This study was conducted on 220 female brick making workers, the age range of 28-45 years with a work experience of more than ten years. It showed that pain/discomfort was mainly at the low back (90%), neck (72%) and wrist (62%). Seventy-two per cent of workers had the pain of >20 in the pain scale of the pain detect tool & 80% of workers were not satisfied with treatments with analgesics/antipyretics which indicate the involvement of neuropathic component of pain in them. The effect of pain was revealed on functional and productivity endpoints like reduced grip strength which also lead to absenteeism, loss of average working days [4.5/month], injuries [in 33% of workers] and monotony (85% workers). This study suggested that OWAS should be conducted for postural analysis and redesigns the load-carrying job by pulling carts etc. so that spinal compression is minimised (Ray Chaudhuri, et al., 2012).

In India, Manoharan et al. investigated the physical risk factors for MSDs injuries among two hundred and sixty-four (N=264) brick Kiln workers using psycho-physiological study method. Their study revealed that workers in clay and mould process were significantly exposed to high physical risk as compared to workers engaged in rimming and a clay making process which generally affected worker productivity. The study showed that 12.5% per 100 workers in the kiln manufacturing sector experience MSDs injuries as a result of exposure to ergonomic risk aspects. Kiln Brick moulding involves an extensive range of physical activity from positions and postures that present workers with the risks of developing Musculoskeletal Disorders (Manoharan, et al., 2012).

During this process, brickfield workers have to face a lot of problems. Brick kiln workers are directly exposed to dust which contains a mixture of inorganic compounds including free silica, iron oxide, etc. The brick kiln workers (firemen) have to face very high temperature along with more proximal exposure to smoke and some toxic gases (like sulphur dioxide, hydrogen sulphide, carbon dioxide and carbon monoxide), as well as particulate air pollutants while burning biomass fuels (Shaikh, et al., 2012).

The study (Inbaraj, et al., 2013) shows that awkward postures adopted by brick kiln workers during work are directly related to their MSD, which also affect their ADL. Prolonged years at service and overwork also have a significant impact on the prevalence of MSD. This study recommends detailed research, health education to the workers, implementation and monitoring of laws in unorganised sectors to tackle morbidity related to MSDs.

Maity, Pal and Dhara (2014) reported on to evaluate the musculoskeletal disorder (MSD) and postural stress of brick kiln workers. The study was carried on 111 male and female workers who were engaged in brick kiln work. The prevalence of MSD and body part discomfort (BPD) among the workers was very high, and the most affected body parts were the neck, shoulder, back and knee. Postural analysis indicated that the workers were subjected to postural stress in all tasks of brick making job, and that might be the reason for the occurrence of MSD. The squatting posture was the dominating posture in most of the brick-making tasks. This study suggested for immediate ergonomic interventions to reduce their work stress by correcting awkward postures (Maity, et al., 2014).

Another study in Haryana showed that the brick kiln workers were suffering from musculoskeletal discomfort as the activities require the labourers to work in a very uncomfortable position. The prolonged working hours contribute to increasing the rate of discomfort among brick kiln workers (Gahlot, et al., 2016).

Above studies said that the worker of brick kiln industry, are suffering under WMSDs due to awkward posture. The workers of the unorganised sector like a brick kiln, people, were handling higher load than recommended weight handle limit. Most of the brick kiln activities are high demanding according to energy requirement. The brick kiln workers also suffer under high psychological/mental stress, because of insecure job nature, insufficient daily wages. Brick making activities are done under the open sky. Due to the rough environment, workers are suffering from high environmental stress. Working under hot and humid environment damages health of workers, especially the brick kiln workers, daily wage labourers and other vulnerable groups. The Indian workers engaged in physical work are highly exposed to the detrimental effects of environmental stress. Combined effects due to excessive heat stress and ergonomic hazards (like heavy lifting, physical exertion, and others) pose great challenges for workers in being able to optimise their productivity, with the potential risk of ensuing heat-related disorders like heat stroke, heat exhaustion, heat cramps, and heat syncope.

Almost all studies suggested that design intervention is needed. There are thousands of ergonomic assessment study had been carried out in the unorganised sector of developing and develop the country. Most of the studies identified the problems in the unorganised sector and recommended for design intervention. But there are very few studies available that end with design intervention and solved the problems. Literature reviews identify the scope of further research about the lacunae to do the design intervention to eradicate the problems related unorganised sector.

3.3 Scope of Current Research

The Indian brick kilns are characterised by traditional modes of production, low capital-intensity and lack of adequate regulations. While there are no official approximations of brick production in the country, some previous studies suggest that there are over a lakh brick kiln in India, producing about 250 billion bricks annually (Lalchandani, 2013). India holds about 10% of global brick production, next to China. As per RBI database, brick kiln industry takes an essential role in the Indian economy, as it contributed to 7.7% of the country's GDP (10, 64,068 crores). Between 1999-00 and 2011-12, the brick-kilns workforce has grown at a rate of 5.80% (see Figure 3-1). The ILO estimates that approx. 10 million workers are employed in brick manufacturing (cited in (PCLRA, 2012), p.10). The frequency distribution of the brick-kiln workforce shows that they are distributed, and are intense across some particular belts in the country: areas around Delhi-NCR which extend up to Gujarat through the eastern part of Rajasthan; Uttar Pradesh; coastal and inland Maharashtra; Gangetic West Bengal; Odisha, and parts of Andhra Pradesh and Tamil Nadu (Figure 3-2). This highlights the patterns of distribution of the brick-kiln workforce in the country. Due to locally distributed industry, there are no sufficient data related to brick making process/method, the ingredient of bricks etc. The standardisation and optimisation of the brick making process will help to make the same quality of bricks throughout the country. A comparative analysis of different brick kilns will help to standardise and optimise the brick making process regarding brick property, brick making process.

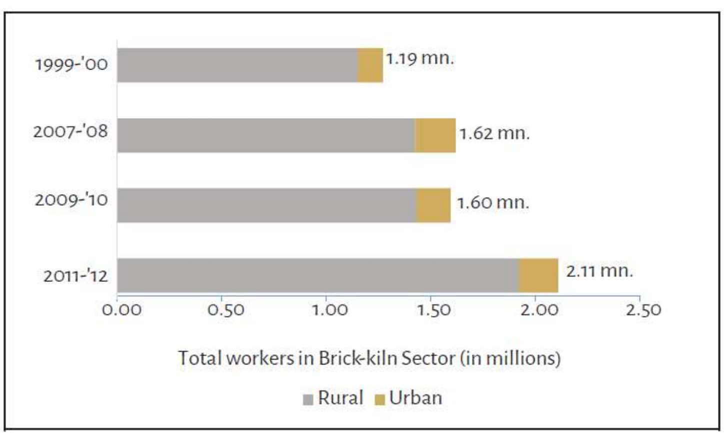


Figure 3-1: Change in the size of Brick-kiln workforce

Source: *(NSSO, 2010)*

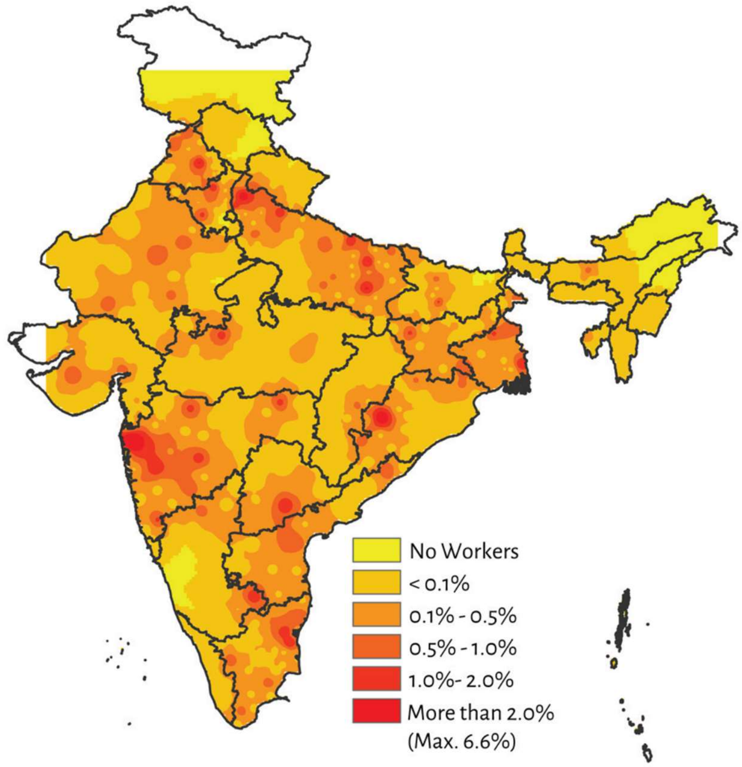


Figure 3-2: Intensity of Brick-kiln Workforce

(Source: NSS Employment, Unemployment and Migration Survey 2007-08, cited in *(Roy & Kunduri, 2018)*

3.3.1 Wage Fixation in Indian Brick Kiln Industries

Paying workers per 1000 bricks made and paying as a family unit

The brick kiln workers are not paid according to their time but on a piece-rate basis. This means that the brick kiln workers are salaried for every 1000 bricks made as a 'working unit'. The women brick kiln workers are invisible as the wages are only paid to the male head of the working unit, despite working the same hours as men (Anti-Slavery International Volunteers for Social Justice, 2017).

The minimum wage is not applied

There is a minimum piece rate wage per 1000 bricks in Indian brick kiln industries; however, this is often not applied. Almost 33% of brick kiln workers reported being paid less than the minimum piece-rate wage for 1000 bricks (Anti-Slavery International Volunteers for Social Justice, 2017).

The piece-rate system of payment is keeping workers poor and vulnerable

The piece-rate wage system is meant to be based on time. Therefore, a 'time-motion study' is needed. The time-motion study determines the time it takes to make a certain number of bricks in a typical working day and can determine the expected minimum wage per brick should be. Unfortunately, no government time-motion study could be found to demonstrate how the piece rate minimum wage (Anti-Slavery International Volunteers for Social Justice, 2017).

Long work hours

According to the Factories Act, the rules regarding several working hours are as follows:

a) A worker will not be required to work more than 48 hours a week under normal circumstances.
b) A worker should not be required to work more than 9 hours a day, spread over 10.5 hours due to rest periods.
c) Workers working more than 48 hours a week or nine hours a day are entitled to be paid an overtime wage.
d) The Act further states that a worker should not be allowed to work more than ten consecutive days without a rest day.

All kind of brick kiln activities are very rigorous job and have extended working hours. As per previous research study, on an average, the brick kiln workers are working 13 hours a day in summer (March-June and September to December) and 10 hours a day in winter (December – February).

The previous research states that a brick moulder couple (male and female worker) made 1300 bricks per day (750 produced by the male worker; 550 produced by the female worker) and used 21 hours and 15 minutes jointly (13 hours by the male worker and 8 hours 15 minutes by the female). As per calculation, brick moulding workers took 16 hours to make 1000 bricks (minimum wages fixed on 1000 bricks), which is far beyond the government recommended work duration, i.e. 9 hours per day (Indian Factories Act). To put this another way: it takes one worker approximate two long days (or 16 hours) to make 100 bricks, i.e. to get one day's minimum wage. As per the same study brick kiln worker can make only 557 bricks within 9 hours duration (Kundu A, 2014).

In India, the Minimum Wages Act, 1948 is applicable in the brick kiln industry as it employs more than 1000 workers in the states where it operates. The minimum wage is set at a level that can provide for the basic needs of a small working-class family. This contains a minimum of 2700 calories per adult, 18 yards of cloth per person, up to 72 yards for a family of four per year, minimum house rent as charged by government subsidised industrial housing scheme for low-income groups, fuel and lighting and other expenses (20%) (Ministry of Labour & Employment, Govt of India, 1957). In 1991, the Supreme Court of India gave the judgment that 'it is necessary to add the following additional component as a guide for fixing the minimum wage in the industry "children's education, medical requirement, minimum recreation including festivals/ceremonies and provision for old age, marriages etc. should further constitute 25 percent of the total minimum wage (25%)." The minimum wage fixation committee considers four consumption units per earner. But in the Indian scenario, there are six consumption units per earner (worker, spouse, two kids and parents). Ergonomics can revalidate the energy requirement among unorganised worker. From the above, it can be concluded that the unorganised workers are getting wages either piece-rate basis or as per government-approved minimum wage act. Both the payment systems keep the unorganised workers consistently restricted from earning minimum wages, keeping them poor and vulnerable to further exploitation and slavery-like practices. Depending on that, wage fixation norms need to be re-thought by Social Scientists.

3.3.2 Prioritisation of Stress

The 21st century is called "century of the stress" because there will not be a single person without stress. Stress is a nonspecific response of the body any demand. Stress is defined in terms of physical and physiological effects on a person and can be psychological as well as emotional too. Like other unorganised workers, the brick kiln workers are suffering under high WMSDs due to awkward posture. Most of the brick kiln activities are high demanding according to energy requirement. The brick kiln workers also suffer under high psychological/mental stress, because of insecure job nature, insufficient daily wages. Brick making activities are done under the open sky. Due to the rough environment, workers are suffering from high environmental heat stress. The brick kiln workers also handle more than the government-recommended load.

Many ergonomic assessment studies had been carried out in the unorganised sector of developing and developed country. Most of the previous studies identified the problems in the brick kiln industry. Almost all previous studies suggested for design intervention in the brick kiln industry. But there are very few studies available that end with design intervention and solved the issues. Like other unorganised sectors, brick kiln industry also needs context-specific design intervention, that needs to identify the dominating stress. This justifies the need for new methods to identify the dominating stress from all available stress (physiological, postural, psychological and environmental stress), that will help in design intervention in the unorganised sector. Therefore, there is a scope to develop a more straightforward method that can prioritise the stresses as per dominating nature and will give the design direction guideline to the designer and engineers.

3.4 Aims and Objectives

The research scopes of the current study are identified in the earlier section, i.e., Section 3.3. The main aim of this study is ‘minimisation of drudgery in the brick kiln industry by eliminating the ergonomic risk factors. The objectives of the present study are –

a) To understand and comparison of the traditional brick making process in a different part of India.
b) To measure the per brick human energy expenditure to make one single brick, that can help the social scientists to fix the minimum wage for brick kiln workers.
c) To measure the per brick human time cost to make one single brick, that can help the social scientists to fix the minimum wage for brick kiln workers.
d) To quantify the drudgery in following issues like
    - Physiological stress

- Biomechanical stress
- Psychological stress
- Environmental stress

e) To develop a more straightforward, simple method that will give the design direction guideline to the designer and engineers (novice/non-expert in ergonomics).

3.5 Research Framework

To meet the above-said objectives, the following research strategy has been taken and presented below based on the primary knowledge and literature survey.

a) Research methodology
b) Understanding the traditional brick making process in India
c) Measuring the per brick energy expenditure in Indian traditional brick kiln
d) Estimating the per brick time cost in Indian traditional brick kiln
e) Quantifying the drudgery in following issues like
   - Physiological stress
   - Biomechanical stress
   - Psychological stress
   - Environmental stress
f) Developing a more straightforward method that will give the design direction guideline to the designer and engineers (novice/non-expert in ergonomics)
g) Validating the newly developed method through design intervention

3.6 The Uniqueness of the Study

There are many studies has been carried out in the Indian brick kiln industry. The previous studies highlighted the ergonomics issues among brick kiln worker and proposed for the design intervention. Unfortunately, there are few studies that came out with a possible solution in the brick kiln industry. The uniqueness of the current study is highlighted below –

Ergonomic input in minimum wage fixation among brick kiln worker

The Minimum Wage Act, 1948 helps for fixation and execution of minimum wages to prevent exploitation of labour through the payment of low wages. The minimum wage rate can be fixed at a) time rate, b) piece rate, c) guaranteed time rate, and d) overtime rate. The Indian Labour Conference (1957) had come up with a norm that should be considered during minimum wage fixation. In Indian unorganised sector, minimum wages fixed on 2700 calories energy requirement. The previous studies say that brick kiln workers vulnerable to sufficient source of income. There is no such proved base of 2700 kcal energy requirement of brick kiln workers. Brick kiln activity demands a high workload. Ergonomics can revalidate the energy requirement among brick kiln worker. Depending on that wage fixation norms need to be re-thought by the Social Scientists. The brick kiln workers are not paid according to their time but on a piece-rate basis. This means that the brick kiln workers are salaried for every 1000 bricks made as a ‘working unit’. The women brick kiln workers are invisible as the wages are only paid to the male head of the working unit, despite working the same hours as men. The piece-rate wage system is meant to be based on time. Therefore, a ‘time-motion study’ is needed. The time-motion study determines the time it takes to make a certain number of bricks in a typical working day and can determine the expected minimum wage per brick should be. Unfortunately, no government time-motion study could be found to demonstrate how the piece rate minimum wage. The current study will be focused on the energy expenditure study and time-motion study among brick kiln worker.

Developing a straightforward, simple method for design direction guideline

Occupational stress can be divided into four major classes, such as physiological stress, postural stress, psychological stress and environmental stress. Indian brick kiln industry needs a context-specific low-cost design intervention, that can reduce occupational stress. Hence, the prioritisation of most painful stress, among all other occupational stresses is most important. The current study aims to develop a simple method that will give the design direction guideline to the designer and engineers.

3.7 Summary and Conclusions

In this chapter, the scopes and aims and objectives of the current study are highlighted. The brick-making process and its lacuna with respect to ergonomics are presented. Various aspect like low-wages, different occupational stress such as physiological, postural, psychological and environmental stresses are identified. A comprehensive literature study has been done to understand the problem specifically in the brick kiln industry. The previous studies said that the worker of the brick kiln industry, are suffering under high WMSDs due to awkward posture. Most of the brick kiln activities are high demanding according to energy requirement. The brick kiln workers also suffer under high psychological/mental stress, because of insecure job nature, insufficient daily wages. Brick making activities are done under the open sky. Due to the rough environment, workers are suffering from high environmental stress. The workers of the unorganised sector like a brick kiln, people, were handling higher load than recommended weight handle limit. Almost all studies suggested that design intervention is needed. There are thousands of ergonomic assessment study had been carried out in the unorganised sector of developing and develop the country. Most of the studies identified the problems in the unorganised sector and recommended for design intervention. But there are very few studies available that end with design intervention and solve the problems. Literature reviews identify the scope of further research about the lacunae to do the design intervention to eradicate the problems related unorganised sector. Before conducting the ergonomic design intervention, a literature review on currently available methods has been carried out to understand the lacunae of those ergonomic methods from the viewpoints of design interventions. There is no such method that can prioritise job stress among multiple stress factors.

Chapter 4 Research Methodology

In this chapter, the research methodology is presented. Firstly, the subject selection process and physical characteristics measurement method are highlighted. Secondly, physiological, postural, psychological and environmental stress measurement methods are presented.

4.1 Introduction

This methods section describes actions to be taken to investigate the research problem and the rationale for the application of specific procedures and techniques used to identify, select, process, and analyse information applied to understand the problem. The research methodology section of this study explains the data collection/generation process.

4.2 Selection of Site

A cursory look at the distribution of the brick-kiln workforce shows that they are locally distributed, and are concentrated across some particular belts in the country: areas around Delhi-NCR which extend up to Gujarat through the eastern part of Rajasthan; Uttar Pradesh; coastal and inland Maharashtra; Gangetic Bihar and West Bengal; Odisha, and parts of Andhra Pradesh and Tamilnadu (NSSO, 2010). Out of the 187 districts where brick kiln workers are existing, only 26 (about 14 %) are not neighbouring to each other, means they do not share a mutual boundary. This highlights the clusters of distribution of the brick kiln workforce in India (Roy & Kunduri, 2018).

Table 4.1: Brick kiln technologies currently prevalent in India

Kiln Type	Regional spread	Approximate contribution in brick production
Clamps	Central, West and Southern India	25%
FCBTK	Indo-Gangetic plains (North and East India) and several clusters in South and West India	70%
Zig-zag	West Bengal, a few clusters in North India	2-3%
VSBK	Central India	1-2%

Source - (Greentech Knowledge Solutions Pvt Ltd, 2014)

Table 4.1 provides details about the several types of firing technology currently available in India. FCBTK is the leading technology for brick production in India. FCBTK accounts for about 70% of the total brick production in India and is prevalent in the Indo-Gangetic plains, as well as in some pockets in the rest of the country. Therefore, three brick kilns were selected from Indo-Gangetic plains (North and East India) for the current study.

Depending on the geographical proximity, constrained budget, limited resources, and managements' willingness to conduct the research study, three brick kiln industries were selected from the above-said cluster. Name and location of studied brick kilns are given below (Table 4.2) –

Table 4.2 Name and location of selected brick kilns for the study

Name of the Brick kiln	Location
VS Brick Kiln Industry (VS)	Mehasana District, Gujarat
RB Brick Kiln Industry (RB)	Kheda District, Gujarat
Sun Brick Kiln Industry (SUN)	Bhagalpur District, Bihar

Gujarat brick kilns are the representative of North-West India, and Bihar brick kiln is the representative of Eastern India. An attempt was made to conduct a study in Hyderabad. But due to some unforeseen situation, it was finally abandoned.

4.3 Selection of Subject

Brick kilns are located in small scale manufacturing units on the outskirts of urban areas. The NSSO survey says that the intensity of the overall brick kiln workforce is closely correlated with the intensity of migrants' workers. More than one-fourth of workers employed in brick kilns are migrants. The seasonal work attracts migrant labourers from surrounding rural areas and forms a vast bulk of inter-state as well as an inter-district migratory labour force.

Sampling is a method that permits researchers to assume the information about a population based on the results from a subgroup of the population, without having to investigate each individual. Minimisation the number of individuals, in a study, minimises the cost and workload. It may make it easier to obtain high-quality information, but this has to be balanced against having a large enough sample size with enough power to detect a true association. During sampling, the selected individuals must be representative of the whole population.

For physical characteristics and anthropometric study, all the 259 participants (193 male and 66 female), of studied three brick kilns were selected. All the participants were within the age group of 20 to 60 years and having minimum two years of experience in the brick kiln industry. The participants were free from any physical deformity and illness, not consuming any medicine and drug (except smoking tobacco).

As the energy expenditure and working heart rate measurement studies needed a longer duration (one & half hours per participant). Therefore, it was not possible to include all the participants for energy expenditure and working heart rate measurement study within a limited time. Hence, purposive random sampling was followed for energy expenditure study. Purposive random sampling is a process in which the samples are selected randomly from the population by the investigator to meet a specific purpose. The purposive (or judgement) sampling relies on the judgement of the researcher when choosing who to ask to participate. The researcher ensured the representation from all six subgroups, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. The judgement sampling has the advantage of being time-and cost-effective to perform while resulting in a range of responses. For energy expenditure and working heart rate measurement study, 103 participants (84 male and 20 female), of studied three brick kilns were selected.

4.4 Physical Characteristics of the Subjects

Before the study, verbal consent was taken from brick kiln owners as well as each participant. The anthropometric kit was used to measure the physical characteristics of the participants.

4.4.1 Anthropometric Instruments

A number of instruments had been devised by anthropometric for taking accurate measurements on the participants. The use of proper equipment is very important for anthropometric measurements. The present research study used the following instruments.

1. **Bathroom Weighing Scale:** Bathroom weighing scale (shown in Figure 4-1) is a very popular machine to measure body weight. The machine is calibrated with accuracy up to 50 gm.
2. **Anthropometric Rod:** It is the most used instrument for many of the anthropometric measurement on human participants. It is used to take height measurements of the body. It consists of four segments (shown in Figure 4-1) which, when joined together and form a right bar of 200 cm. There is a fixed sleeve on the top of the rod. An adjustable graduated crossbar passes through it. There is also a moveable sleeve with an adjustable graduated crossbar, which registers the height measurements.

Figure 4-1: Martin type anthropometric rod & Bathroom weighing scale

3. **Tape:** It is used to measure the circumferences of various parts of the body and skeleton. It is made of steel and is graduated in mm. Width of the tape should be about 1 cm.
4. **Jamar Hand Dynamometer:** The Jamar Hand Dynamometer is used for measuring handgrip strength. The Jamar Hand Dynamometer has a dual scale readout which displays isometric grip force from 0-90 kg (0-200 lb). The outer dial registers the result in kg, and the inner dial registers the result in pound (unit). It has a peak hold needle which automatically retains the highest reading until the device is reset. The handle easily adjusts to five grip positions from 35-87 mm (1½ - 3¼") in 13 mm (½") increments. Always use the wrist strap to prevent the dynamometer from falling on the floor if accidentally dropped.
5. **Sphygmomanometer and stethoscope:** A sphygmomanometer (shown in Figure 4-2) is a device that measures blood pressure. It is composed of an inflatable (capable of being filled with air) rubber cuff, which is wrapped around the arm. A measuring device indicates the cuff's pressure. A bulb inflates the cuff, and a valve releases pressure. A stethoscope is used to listen to arterial blood flow sounds. As the heartbeats, blood forced through the arteries causes a rise in pressure, called systolic pressure (SBP), followed by a decrease in pressure as the heart's ventricles prepare for another beat. This low pressure is called diastolic pressure (DBP). Systolic and diastolic pressures are commonly stated as systolic 'over' diastolic — for example, 120 over 80. Blood flow sounds are called Korotkoff sounds.

Figure 4-2: Blood pressure measurement apparatus, Sphygmomanometers and Stethoscope

4.4.2 Test Procedure

1. **Age:** The researcher asked the age of the participants during the anthropometric study and noted on the anthropometric datasheet. The age of the participant was recorded in years.
2. **Height**: It is the vertical distance between vertex to the horizontal floor on which the participant stands. The subject was asked to stand erect with bare foot touching each other. Arms hanging naturally by the side, the participants head was kept in Frankfort. Horizontal plane and asked to stretch body upward (this is possible only when the visual axis is parallel to the ground on which the subject stands). The anthropometry rod was held vertically in the back of the subject in the midsagittal plane. The horizontal movable arm of the anthropometry was brought down to the point vertex. The height was recorded in centimetre (Figure 4-3).

Figure 4-3: Measurement of height of a female brick kiln worker

3. **Bodyweight:** The body mass is taken in kilograms. Before weighing, asked the participant to remove any 'heavy' items from their pockets (key's, wallets etc.) and

remove any bulky items of clothing or apparel (big jackets, shoes etc.). The pointer was adjusted at zero, and the participant was asked to stand at the centre of the platform with equal pressure on both feet with a minimum possible clothing. The weight was taken up to the unit of 0.5 kilograms.

4. **Calculating Body Mass Index (BMI):** A popular method of measuring body weight as a risk factor (cardiovascular disease, diabetes, etc.) is BMI (Body Mass Index). The calculation is based on comparing a person's weight against their height. It applies equally to men and women. The equation for BMI is –

$$\boldsymbol{BMI = \frac{Body\ Weight\ (kg)}{Body\ Height\ (m)2}}$$

Table 4.3: Body Mass Index reference table

BMI Score	Risk Category
<18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 - >40	Obesity

Source: WHO Classification

5. **Waist circumference**: Waist circumference is measured at the narrowest point above the iliac crests, half the distance between the iliac crests and the lower edge of the ribs. The participant stands erect with the abdomen relaxed. Using the tape, the circumference was measured of the body at the waist level. The measurement value was recorded in centimetre.
6. **Hip circumference:** Hip circumference is measured horizontally in a standing position with feet together, at the level of the greatest protuberance of the buttocks. The hip circumference was measured with the help of tape at a level from the maximal protrusion of the buttocks to the symphysis pubis. The measurement was recorded in centimetre.
7. **Calculating the waist-hip ratio:** The waist-hip ratio or waist-to-hip ratio (WHR) is the dimensionless ratio of the circumference of the waist to that of the hips. WHR is

one of several measurements that can be used as a risk factor of overweight, and if that excess weight is putting participants health at risk. It determines how much fat is accumulated on participants waist, hips, and buttocks. The equation for the waist-hip ratio is –

$$\boldsymbol{Waist - Hip\ ratio} = \frac{\boldsymbol{Waist\ Circumference\ (cm)}}{\boldsymbol{Hip\ Circumference\ (cm)}}$$

Table 4.4: Waist-Hip ratio reference table

Health Risk	Women	Men
Low	0.80 0r lower	0.95 or lower
Moderate	0.81 – 0.85	0.96 – 1.0
High	0.86 or higher	1.0 or higher

8. **Hand Grip Strength:** Handgrip strength can be quantified by measuring the amount of static force that the hand can squeeze around a dynamometer. The force has most commonly been measured in kilograms and pounds. The handgrip strength was measured by using a calibrated hydraulic handgrip dynamometer (Baseline, USA) shown in Figure 4-4. The participants were asked to squeeze the dynamometer as tightly as possible in their left and right hands and giving maximum isometric effort for 3–5 seconds. The participants were not allowed to move the position of the arm or any body part during the trial. Following a practice attempt, three tests were attempted with each participant, between 30 and 40 s rest given between attempts to account for muscle fatigue. The maximum value obtained was used for analysis. The handgrip strength value (kg) noted down on datasheet from the dial of the dynamometer. An Australian 2011 population-based study (Massy-Westropp, et al., 2011) noted the following average grip strength numbers for men and women across different age groups (Table 4.5):

Table 4.5: Handgrip strength reference across different age groups

Age range	Male		Female	
	Left-Hand Grip strength (kg)	Right-Hand Grip strength (kg)	Left-Hand Grip strength (kg)	Right-Hand Grip strength (kg)
20-29	44.9	46.7	27.7	29.9
30-39	46.7	46.7	28.6	30.8
40-49	44.9	46.7	27.7	28.6
50-59	42.6	44.9	25.9	27.7
60-69	37.6	39.9	22.7	23.6

Figure 4-4: Measurement of handgrip strength of a male brick kiln worker

9. **Blood Pressure (BP)**: Blood pressure is the pressure of circulating blood on the walls of blood vessels. Most of this pressure is due to work done by the heart by pumping blood through the circulatory system. Blood pressure is usually expressed in terms of the systolic pressure (maximum during one heartbeat) over diastolic pressure (minimum in between two heartbeats) and is measured in millimetres of mercury (mmHg), above the surrounding atmospheric pressure. Exercise can increase BP, but the effects are typically temporary. BP should gradually return to

normal after the activity. Physical activity raises systolic blood pressure (SBP) because aerobic activity puts additional demand on the cardiovascular system. BP was taken to assess whether the participant had high blood pressure. High blood pressure is a risk factor for chronic diseases. The participants with high BP were excluded from the study.

Figure 4-5: Measurement of blood pressure of a male brick kiln worker

Techniques of measurement

- A correctly sized blood pressure cuff was used to begin blood pressure measurement. The length of the cuff's bladder was at least equal to 80% of the circumference of the participant's upper arm.
- The cuff was wrapped around the upper arm one inch above the antecubital fossa (shown in Figure 4-5).
- The stethoscope's bell was press gently over the brachial artery just below the cuff's edge.
- The cuff inflates rapidly to 180mmHg and released air from the cuff at a moderate rate (3mm/sec).

- Korotkoff sound was listened with the stethoscope and simultaneously observed the mercury gauge. The first knocking sound (Korotkoff) was the subject's SBP. When the knocking sound disappeared, that was the DBP.

4.5 Energy Expenditure Study

The best way to measure the efficiency of a system from the Human aspect is to express the human energy (Kcal) requirement per unit item produced. With this approach, it was essential to conduct the 24-hour energy expenditure in this study.

4.5.1 K4b2 Breath by Breath Gas Analyser

Energy Expenditure (EE) is a measure of the amount of energy utilised by a person to maintain body functions, enable growth and repair, and to enable movement. The Basal Metabolic Rate (BMR) is the minimum energy requirement for a body at rest in a comfortable environment. Additional energy is required for physical activity and the greater the intensity of activity, the higher the demand for energy (Kenney, et al., 2011; Bhise, 2008; McArdle, et al., 2009)

Energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or physical movement. Daily energy expenditure is composed of three major components –

d) Resting Metabolic Rate (RMR);
e) Thermic Effect of Feeding (TEF); and
f) Thermic Effect of Activity (TEA).

Resting Metabolic Rate constitutes 60 to 75% of daily energy expenditure and is the energy associated with the maintenance of major body functions. TEA is the variable component of daily energy expenditure and constitutes 15 to 30% of 24-hour energy expenditure. The TEA component includes energy expenditure due to physical work, muscular activity, including shivering and fidgeting, as well as purposeful physical exercise (Poehlman, 1989).

The measurement of the oxygen and carbon dioxide content of expired air during physical activity is important to the assessment of energy expenditure prediction. The Oxygen exchange (VO_2) is one of the most fundamental and widely recognised measures of energy consumption as defined by two key components: the delivery of oxygen to skeletal muscle and the ability of the muscle to extract and use oxygen (McArdle, et al., 1991). In healthy individuals, physical activities require a fraction of maximal working capacity, as assessed by maximal VO_2 (known as VO_2 Max).

Oxygen Consumption (VO_2) is a measure of the volume of oxygen consumed for an activity in a given time. The level of oxygen consumed increases with the duration and intensity of activity when it peaks and plateaus at its maximum level. VO_{2max} is the maximum potential volume of oxygen that a person can consume. It is a measure of cardiovascular fitness (millimetres per kilogram of body weight per minute (ml/kg/min)) and an indicator of the efficiency in ATP generation in metabolic processes. The higher the VO_{2max}, the more efficient the metabolic processes (Wilmore, et al., 2008; Plowman & Smith, 2007; McArdle, et al., 2009).

The Cosmed K4b^2 portable metabolic analyser allows measurement of oxygen consumption outside of a laboratory setting in more typical actual field environments (specific daily life activities). Therefore, the telemetric oxygen analyser instrument, K4b^2 (Mfg. by Cosmed, Italy) was used to measure oxygen consumption during different brick making activities. The K4b2 utilises a breath-by-breath measurement of gas exchange through a rubberised facemask and a turbine for gas collection, secured by a mesh headpiece. The facemask is available in different sizes, and the headpiece is adjustable to ensure a proper fit. The system is portable and worn by the participants using a harness.

4.5.1.1 Testing Procedures

Before testing, the Cosmed K4b^2 gas analyser was warmed-up for a minimum of 20 minutes. Following the warm-up period, the O_2 and CO_2 analysers of the K4b^2 system was calibrated using reference gases of known concentrations. After that, the K4b2 system was mounted on the participant's body with a portable harness. Each participant completed the testing trial by following proper protocol (10 minutes for rest and adaptation to the equipment, 45 minutes actual brick making activity and 15 minutes recovery). Previous observation says that brick kiln worker works at a stretch near about 45 minutes and followed by a small pause/rest. Therefore, the work duration selected for 45 minutes. The participants were permitted to work their own "comfortable" speed. After completing the test, the analyser was removed, and the participant was free to move.

Figure 4-6: K4b2 gas analyser mounting procedure (in Laboratory simulation)

4.5.1.2 Calculation

From the K4b2 instrument, the HR (bpm^{-1}) and the corresponding oxygen consumption (litre/min) was noted while performing a particular job by the workers. The $K4b^2$ data were used to develop a statistical regression equation based on the straight-line equation;

$$Y = mX + C,$$

Where Y represents Oxygen Consumption (litre/min), X is HR (bpm^{-1}), m is the slope and C is the intercept. The R^2 (correlation) value was also noted. The oxygen consumed was then multiplied by 5 kcal (the energy equivalent of one-litre oxygen) to obtain the energy expenditure by the person while performing the job.

This equation was used later to determine the oxygen consumption for any heart rate during a particular job. For each task, separate average HR was derived by observing the highest and lowest heart rates during the task. Once the energy expenditure in terms of $kcal.min^{-1}$ was derived, the total energy required for the entire period to complete the job was calculated. Based on the Questionnaire and Time-motion study, the time elements for different major activities throughout the day were noted. It was divided into four major categories, actual work and pause during work, other households' activities and sleep. Thus, by using these HRs and time elements, 24-hour energy expenditure was calculated, which is required for the daily energy requirement for a person. To measure per brick energy expenditure, daily energy expenditure was divided by whole day output in terms of the number of bricks.

$$\textbf{Per brick energy expenditure} = \frac{\textbf{Daily energy expenditure}}{\textbf{Daily Output}\text{ (in terms of number of brick)}}$$

Assumption: The sleeping heart rate and the heart rate during other household-related activity were not measured due to the limitation of the study. Therefore, sleeping heart rate and other household-related work heart rate were assumed as 70 bpm^{-1} and 100 $bpm^{-1,}$ respectively.

4.5.2 Time Motion Study

4.5.2.1 The time-motion study to assist energy expenditure study

Previous observation says that the brick kiln workers can’t work for a longer duration without taking a pause. After a sufficient exhaust level of work, the workers feel fatigued on their muscle. Therefore, the workers paused in between work. The workers also are addicted to nicotine like biddi and paan, betel quid and chewing tobacco etc. This habits also tempted the worker to take a pause in between work. The brick kiln workers also get an off-hour for lunch.

Energy expenditure is calculated based on heart rate and duration (24-hour duration). The heart rates during work, pause and break (for lunch), are different. Therefore, it is necessary to measure the actual work, pause and brake time and inspired the researcher to conduct a time-motion study.

Two Sony Handicam (Model HDR-XR100E) cameras (one from the front, another from the side) were used to get the different working postures as well as the time needed to complete the jobs. The cameras were mounted on stands and were placed in such a way, that one camera captured the side view, and the other one captured the front view of the subject. After the recording, the recorded video again played in the laboratory environment, and the work duration is divided into two-time elements such as a) Actual work duration and b) Pause duration during work with the help of a properly calibrated stopwatch. The actual job was also carefully divided into repetitive cycles and time taken for a particular cycle was averaged out by noting down the frequency and time required for five repetitive cycles at a different span of the activity. From this, the average numbers of cycles per hour were determined for respective male and female workers. Beside work time, the other house-hold activity-related time and sleeping time also calculated based on observation and questionnaire techniques. For example, Bharai is an activity of transferring brick from moulding ground to inside the kiln. The Bharai activity is divided as

a) Duration (min) of brick loading,
b) Duration (min) of brick unloading,
c) Duration (min) of carrying the bricks from moulding ground to kiln and return (Onward movement and return were kept in one group, cause the bricks were carried by tractor, with the assistance of mechanisation. The physical activity level for onward and return same),
d) Duration (min) of pause in between work
e) Duration (min) of sleep
f) Duration (min) for other house-hold related activity

Based on this 24-hour time duration, the whole day energy expenditure was calculated for brick kiln workers.

4.5.2.2 The time-motion study to assist wage fixation:

The brick kiln workers get wages on a piece-rate basis. That means the workers will get wage after a specific number of bricks production. The previous study says that to fulfil target numbered brick production, the workers need to work for an extended period. According to the Factories Act, the rules regarding several working hours are as follows:

a) A worker will not be required to work more than 48 hours a week under normal circumstances.
b) A worker should not be required to work more than 9 hours a day, spread over 10.5 hours due to rest periods.
c) Workers working more than 48 hours a week or nine hours a day are entitled to be paid an overtime wage.
d) The Act further states that a worker should not be allowed to work more than ten consecutive days without a rest day.

To assist piece-rate-basis-wage fixation, the current study took the initiative Per brick time cost is calculated as follows -

$$\textbf{Per brick time cost} = \frac{\textbf{Work duration in min (including pause \& brake)}}{\textbf{Daily Output(in terms of bricks)}}$$

4.5.2.3 Determination of per brick Energy and Time cost

India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems and specific problems faced by the respective workers. More or less all Indian brick kiln industries have six types of worker, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. But the method of work is different based on social culture, geographical location, availability of raw material, availability of technology, awareness, kiln sizes, kiln output etc. To compare each work method among different brick kiln industries, the current research took the initiative to measure Per brick energy expenditure and per brick time cost by following formulae –

<u>For Energy expenditure</u> -

$$\text{Per brick energy expenditure (during work)} = \frac{\text{Work} - \text{related energy expenditure}}{\text{Daily Output (in number of brick)}}$$

The per brick energy expenditures of all sub-activities are converted in percentage (%) by the following formula –

$$Per\ Brick\ energy\ expenditure\ percentage = \frac{Specific\ group\ per\ brick\ energy\ expenditure}{Sum\ of\ all\ six\ groups\ per\ brick\ energy\ expenditure} \times 100$$

<u>For Time motion study -</u>

$$\text{Per brick time cost} = \frac{\text{Work duration in min (including pause \& brake)}}{\text{Daily Output(in terms of bricks)}}$$

The per brick time cost of all sub-activities are converted in percentage (%) by the following formula –

$$Per\ Brick\ Time\ Cost\ percentage = \frac{Specific\ group\ Per\ brick\ time\ cost}{Sum\ of\ all\ six\ groups\ per\ brick\ time\ cost} \times 100$$

4.6 Method Used to Determine Physiological Stress

4.6.1 Heart Rate

The heart rate is the number of times the heartbeats in the space of a minute. Heart Rate is a sensitive indicator of the activity level of the cardiovascular system. It is a measure of the physiological response to activity, i.e. increases with the physical workload to meet oxygen demand in active-muscles. Perhaps heart rate is the most straightforward method to measure physiological workload. For the current research, the heart rate was measured by using Polar^{TM} Heart Rate Belt (Chest strap type) and Heart Rate Monitor (shown in Figure 4-7) during work as well as rest. The Polar Heart Rate Belt (Chest strap type) is wirelessly connected to a data logger stored in a watch (Heart Rate Monitor). Before the experiment, the Polar T-61 Transmitter was placed across the participant's chest against the skin at the level of the xiphoid process. The participant wore the Heart rate monitor on the wrist. After mounting the heart rate belt, the participant asked to continue work for a whole work session, that includes sufficient cycle of actual work and pause in between work. The participants were permitted to work their own "comfortable" speed. During heart rate data collection, the participant's activity was recorded by using a Sony Handicam (Model HDR-XR100E) camera. After completing the test, the instrument was removed, and the participant was free to move. From the heart rate measurement study, resting, average working and average pause heart rates were measured and used for energy expenditure study as well as physiological stress analysis.

Resting heart rate (HR_{rest}) is a baseline measurement of the cardiovascular system.

Maximum heart rate (HR_{max}) is the maximum potential heart rate achievable and is dependent on age and physical fitness.

Following formula was used to calculate Heart Rate max (HRmax).

$$\mathbf{HRmax = 220 - Age} \text{ (Wilkins, 1995)}$$

From the resting, working & maximum heart rate, the relative cardiac cost was measured by using the following formulae.

$$\boldsymbol{Heart\ Rate\ Reserve\ (HRR) = Maximum\ Heart\ Rate - Resting\ Heart\ Rate}$$

$$\boldsymbol{Net\ Cardiac\ Cost\ (NCC) = Working\ Heart\ Rate - Resting\ Heart\ Rate}$$

$$\boldsymbol{Relative\ Cardiac\ Cost\ (RCC) = \frac{Net\ Cardiac\ Cost\ (NCC)}{Heart\ Rate\ Researve\ (HRR)} \times 100}$$

Figure 4-7: Polar belt and Heart Rate Monitor

The jobs were classified as per physiological workload (shown in Table 4.6) based on the working heart rate (bpm^{-1}). The jobs were also categorised according to Relative Cardiac Cost (RCC) (shown in Table 4.7).

Table 4.6: Classifications of Workload for Female and Male according to working HR

Classification of workload	Heart rate (bpm^{-1}) for Female	Heart rate (bpm^{-1}) for Male
Very Light	<90	<75
Light	91 – 105	75 – 100
Moderately Heavy	106 - 120	100 – 125
Heavy	121 – 135	125 – 150
Very heavy	136 – 150	150 - 175
Extremely Very Heavy	>150	>175

Source: (Varghese, et al., 1994) for Female and (Sen & Sarkar, 1973) for Male

Table 4.7: Classification of Workload as per Relative Cardiac Cost (RCC)

Relative Cardiac Cost	Intensity of work	Workload Category
0-9	Very Light	Little
10-19	Light	
20-29	A little moderate	Moderate
30-39	Moderate	
40-49	A little heavy	Vigorous
50-59	Heavy	
60-69	Intense	

Source (Kamal, et al., 1991)

4.7 Method Used to Determine Postural Stress

4.7.1 Rapid Entire Body Assessment (REBA) Method

The Rapid Entire Body Assessment (REBA) (Hignett & Mcatammey, 2000) was used to "rapidly" evaluate the risk of work-related musculoskeletal disorders (WMSDs) associated with specific job tasks. In the current research study, REBA method was applied to keep the following objectives in mind –

i. To provide a simple postural stress analysis system sensitive to musculoskeletal risks in a variety of brick kiln subtasks.

ii. To provide a scoring method for muscle activity caused by static, dynamic, rapidly changing or unstable postures in brick kiln activities.

iii. To consider coupling as a significant variable in the handling of loads.

iv. To give an action level output with an indication of urgency.
v. To provide a user-friendly assessment tool that requires minimal time, effort, and equipment.

The following criteria were used to select the posture for REBA assessment –

a) Most frequently repeated posture
b) Longest maintained posture
c) Posture requiring the most muscular activity
d) Extreme, unstable, or awkward posture

During the time-motion study, the brick kiln worker's activities were recorded by using two Sony Handicam (Model HDR-XR100E) cameras (one from the front, another from the side). The cameras were mounted on stands and were placed in such a way, that one camera captured the side view, and the other one captured the front view of the subject. From the video, multiple sequential frames were also captured, as required, for REBA assessment of the job.

A single page REBA scoresheet, shown in Figure 4-8, was used to evaluate the postural stress. Score the Group A (Trunk, Neck and Legs) postures and the Group B (Upper Arms, Lower Arms, and Wrists) postures for left and right. For each region, there is a posture scoring scale plus adjustment notes for additional considerations. Then score the Load/Force and Coupling factors. Finally, score the Activity. Find the scores from Table A for the Group A posture scores, and from Table B for the Group B posture scores. The tables, (Figure 4-8) follow the data collection sheet. Score A is the sum of the Table A score and the Load / Force score. Score B is the sum of the Table B score and the Coupling score for each hand. Score C is read from Table C, by entering it with the Score A and the Score B. The REBA score is the sum of the Score C and the Activity score. The degree of risk is found in the REBA Decision table (shown in Table 4.8).

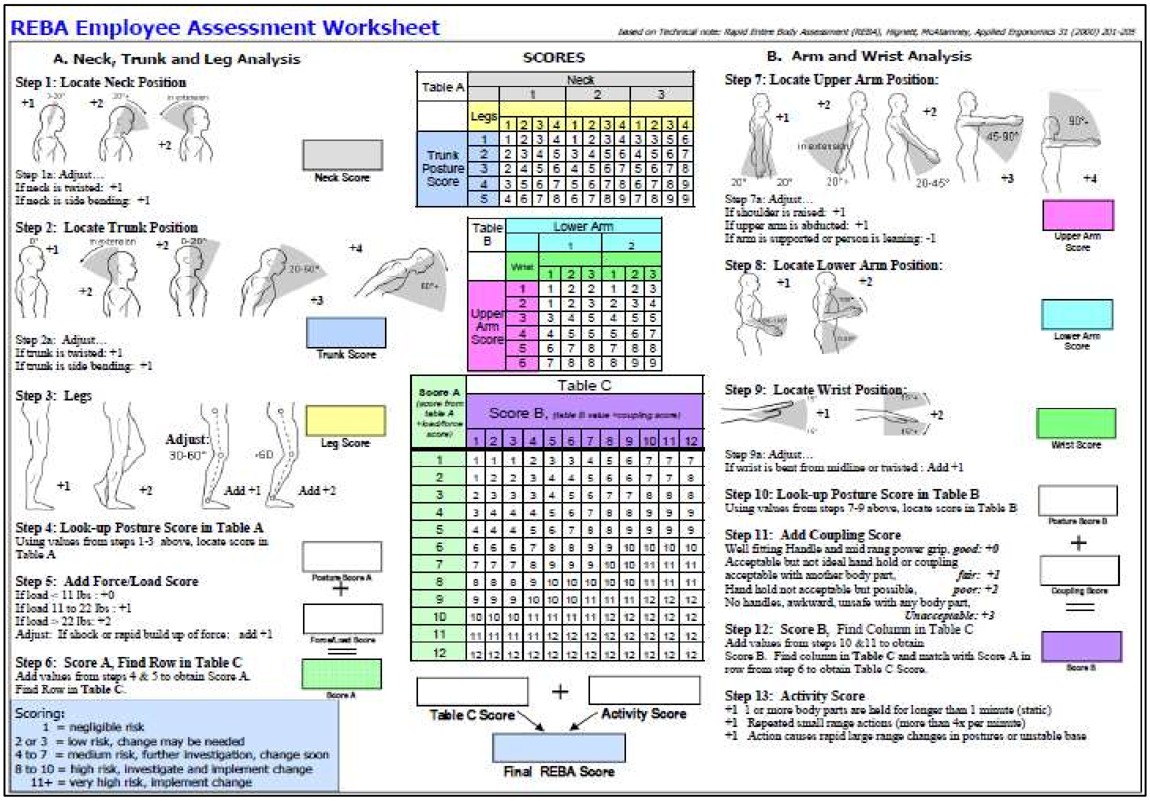


Figure 4-8: REBA assessment worksheet

Table 4.8: REBA score and action category

REBA score	Action category
1	Negligible risk, no action required
2-3	Low risk, change may be needed
4-7	Medium risk, further investigation, change soon
8-10	High risk, investigate and implement change
11+	Very high risk, implement change

4.8 The Method Used to Determine Psychological Stress

4.8.1 Perceived Stress Scale (PSS) Method

The Perceived Stress Scale (PSS) is the most widely used psychological instrument for measuring the perception of stress. It is a measure of the degree to which situations in one's life are appraised as stressful.

The Perceived Stress Scale (PSS) is a 14-item self-report measure designed to assess "the degree to which situations in one's life are appraised as stressful". Specifically, items are designed to measure the extent to which one's life is perceived as "unpredictable, uncontrollable, and overloading. The scale also includes some direct queries about current levels of experienced stress. The items are easy to understand, and the response alternatives are simple to grasp.

Moreover, the questions are general and hence are relatively free of content specific to any subpopulation group. The questions (shown in Figure 4-9) in this scale asked about the subject's feelings and thoughts.

Scoring: PSS scores are obtained by reversing responses (e.g., 0 = 4, 1 = 3, 2 = 2, 3 = 1 & 4 = 0) to the four positively stated items (items 4, 5, 7, & 8) and then summing across all scale items. A short 4 item scale can be made from questions 2, 4, 5 and 10 of the PSS 10 item scales. Based on their answers to the questions, a final score was generated, that represented the level of psychological stress (Table 4.9) (Cohen, et al., 1983).

Table 4.9: Perceived stress score and its significance

PSS Score	Significance of PSS Score
0 - 13	Low perceived stress
14 - 26	Moderate perceived stress
27 - 40	High perceived stress

PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and thoughts during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.**

Name ____ Date ___________

Age _______ Gender (*Circle*): **M F** Other ______________________________

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Figure 4-9: Perceived Stress Scale (PSS) assessment worksheet

4.9 The Method Used to Determine Environmental Stress

4.9.1 Heat Stress Measurement by WBGT Index

The commonly used heat stress indicator or indices is wet bulb globe temperature (WBGT). The WBGT index, evaluated by Yaglou and Minard, is a well-established and widely used heat stress index that is associated with human physiological reactions to heat and the limits these reactions create for work intensity and workplace heat exposure levels. Special equipment is needed to measure WBGT according to the standards (ISO, 1989). Such equipment has three thermometers measuring natural Wet Bulb Temperature (WBT), black Globe Temperature (GT), and common Dry Bulb Temperature (DBT).

4.9.1.1 Globe Thermometer

Vernon introduced the globe thermometer (shown in Figure 4-10) in 1930 as a means of assessing the combined effects of radiation, air temperature and air velocity on human comfort. It consists of a hollow copper sphere painted matt black to absorb radiant heat, with a temperature sensor at its centre. When it reaches a steady-state (after 15 minutes, approx.) the heat exchanges by convection and radiation will be in equilibrium, and the temperature recorded by the sensor will be somewhere between the air and radiant temperature. This is referred to as the globe temperature (GT) or black globe temperature and resembles the thermal conditions felt by the human body. The diameter of the standard copper sphere is 150mm.

Figure 4-10: Globe thermometer

4.9.1.2 Dry-Bulb Temperature

Dry-bulb temperature (DBT), is a measure of air temperature. It is referred to as dry-bulb temperature because the thermometer bulb is dry and so the temperature recorded does not vary with the moisture content of the air.

4.9.1.3 Wet-Bulb Temperature

Wet-bulb temperature (WBT) is the temperature recorded by a thermometer that has its bulb wrapped in cloth and moistened with distilled water. The rate of evaporation from the wet-bulb, and so the temperature it records varies depending on the humidity of the air. The higher the humidity, the lower the rate of evaporation, and so the higher the temperature recorded. Wet-bulb temperatures are the same as dry-bulb temperatures at a relative humidity of 100%. Still, otherwise, they will be lower than dry-bulb temperatures due to the cooling effect of evaporation. Wet-bulb temperature is an indicator of the temperature felt when damp skin is exposed to the air and so can be used to express a component of thermal comfort.

4.9.1.4 Sling Psychrometer

A sling psychrometer (shown in Figure 4-11) holds a wet-bulb thermometer and a dry-bulb thermometer. A dry-bulb thermometer is an ordinary thermometer, while a wet-bulb thermometer is a thermometer that has its bulb wrapped in cloth and moistened with distilled water.

Figure 4-11: Sling psychrometer (Dry bulb thermometer and wet bulb thermometer)

4.9.1.5 WBGT Index

The Wet Bulb Globe Temperature (WBGT) index is a good indicator of heat stress. To investigate the environmental stress, WBGT index value (Table 4.10) was calculated, that represented the level of environmental stress among the brick kiln workers.

$$\boldsymbol{WBGT\ Index\ (Outdoor) = 0.7 * WBT + 0.2 * GT + 0.1 * DBT}$$

$$\boldsymbol{WBGT\ Index\ (Indoor) = 0.7 * WBT + 0.3 * GT}$$

(Yaglou & Minard, 1957)

4.9.1.6 Experiment Design

Occupational heat stress and workers' perceptions of the impact of heat on their health and productivity was studied in 3 different workplaces (VS, RB and SUN Brick kiln). Data collection was conducted in two seasons, during the "hotter season" (April–June) and the "cooler season" (November–January), to estimate the impacts of occupational heat stress impacts on workers during two distinct seasons.

4.9.1.7 Procedure

a) Before using the reservoir of the psychrometer was filled with water.
b) Pulled the **psychrometer** tube clear of the body so that the body could swivel.
c) Hold the **psychrometer** tube and whirled the body two to three revolutions per second.
d) Continued whirling until the temperatures stabilise (1-2 minutes).
e) After about 1-2 minutes, stopped and quickly checked the wet-bulb temperature as well as dry-bulb temperature. (if take too long, the temperature will start to change).
f) The Globe Temperature (GT) was recorded.
g) WBGT index was calculated by using formula.

Table 4.10: The WBGT Index value and its significance

WBGT Index (^{0}C)	Significance WBGT Index	Heat Stress Category	Recommended Maximum Workload
≤25.6 – 27.7	White Zone	Category 1	Heavy
27.8 – 29.4	Green Zone	Category 2	Medium
29.5 - 31	Yellow Zone	Category 3	Moderate
31.1 – 32.1	Red Zone	Category 4	Light
≥ 32.2	Black Zone	Category 5	Very Light

Source: Japan Society of Occupational Health

Table 4.11: Recommended work-rest ratios according to WBGT Index (^{0}C) at different work intensities

Work and Rest ratio	Permissible Limits (WBGT Index) (^{0}C)			
	Light Work	Medium Work	Heavy Work	Very Heavy Work
8 Hour continuous work	31	28	27	35.5
75% work and 25% rest	31.5	29	27.5	26.6
50% work and 50% rest	32	30.5	29.5	28
25% work and 75% rest	32.5	32	31.5	31
No work at all (100% rest)	39	37	36	34

Source: American Conference of Governmental Industrial Hygienists

4.10 The Method Used to Determine Overall Stress

4.10.1 Borg 15-point RPE Scale

The Borg Rating of Perceived Exertion (RPE) scale, developed by Swedish researcher Gunnar Borg (Borg, 1982), is a tool for measuring an individual's effort and exertion, breathlessness and fatigue during physical work and so is highly relevant for occupational health and safety practice. The participants were asked to rate their exertion on the scale during the activity, combining all sensations and feelings of physical stress and fatigue. The significance of the rating score is shown in Table 4.12.

Table 4.12: Borg Rating of Perceived Exertion Scale

Rating	Perceived Exertion
6	No exertion
7-8	Extremely light
9-10	Very light
11-12	Light
13-14	Somewhat hard
15-16	Hard
17-18	Very hard
19	Extremely hard
20	Maximal exertion

4.11 Statistical Method

Various statistical measures were used to evaluate the data. Microsoft Excel software packages and the Statistical Package for Social Science (SPSS) version 17 were used for statistical analysis.

A t-test is used to determine if there is a significant difference between the means of two groups. A t-test looks at the t-statistic, the t-distribution values, and the degrees of freedom to determine the statistical significance.

In statistical modelling, regression analysis is a set of statistical processes for estimating the relationships between a dependent variable (often called the 'outcome variable') and one or more independent variables (often called 'predictors', 'covariates', or 'features'). The regression analysis is widely used for prediction and forecasting. The regression analysis can be used to infer causal relationships between the independent and dependent variables. To predict the relationship between Physiological, Postural, Psychological and Environmental stress, Rating of perceived exertion: Borg scale was used to determine overall discomfort.

4.12 Design Evaluation Method

To validate the new design, 32 Pathera workers were randomly selected from VS brick kiln, Gujarat, India. Physical characteristics (age, height and weight) of the brick kiln workers were measured by following proper protocol. The selected workers were allowed to work (brick moulding) both in the traditional method as well as the sitting-standing work method. Working heart rate and REBA score were measured for both work method (i.e. traditional method and sitting-standing method). The brick output was also recorded for 45 minutes of work duration. Previous time-motion study says that the brick kiln worker works at on stretch for 45 minutes and followed by a pause. That is the justification to consider 45 minutes of work for the evaluation study. A 10-point body part discomfort (BPD) scale was applied to identify the pain intensity difference between two work methods. A five-point rating scale (Bad, Poor, Acceptable, Good and Excellent) was applied to understand the worker perception on sitting-standing posture with compare to the traditional method. A statistical t-test was applied to determine if there is a significant difference between the means of two groups. The productivity performance percentage was also calculated.

4.13 Summary and Conclusions

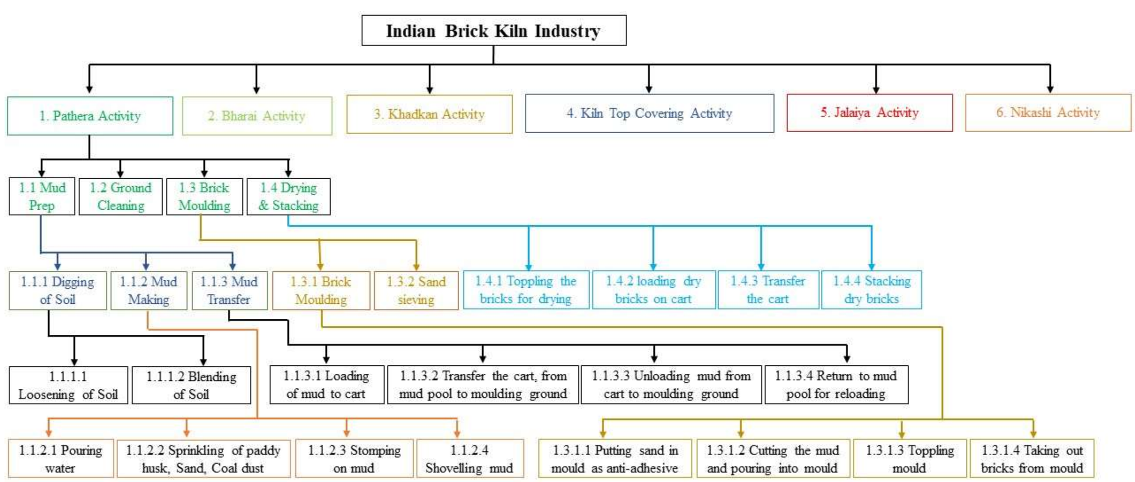
To investigate the ergonomic risk factors in the brick-making industry, three brick making industries were selected in Eastern and Western India. The subjects were chosen from studied three brick kilns having minimum two years' work experience. Physiological, Postural, Psychological, Environmental and Overall stresses were derived from working heart rate/relative cardiac cost, REBA analysis, PSS score, WBGT index and Borg's RPE scale respectively. Microsoft Excel software packages and the Statistical Package for Social Science (SPSS) version 17 were used for statistical analysis.

Chapter 5 Indian Brick Kiln Industry

In this chapter, the Indian brick making process in traditional brick making industries are highlighted. Hierarchical Task Analysis (HTA) diagrams are created to represent a variety of brick making activities. A comparative analysis of three studied brick kilns is presented here.

5.1 Introduction

In this chapter, three brick kiln industries are selected, and the brick making process is described. The brick kiln workers were observed while they carried out different brick making activities in studied brick kiln industry, India. Hierarchical Task Analysis (HTA) diagrams (Figure 5-1) is created to represent a variety of brick making activities.



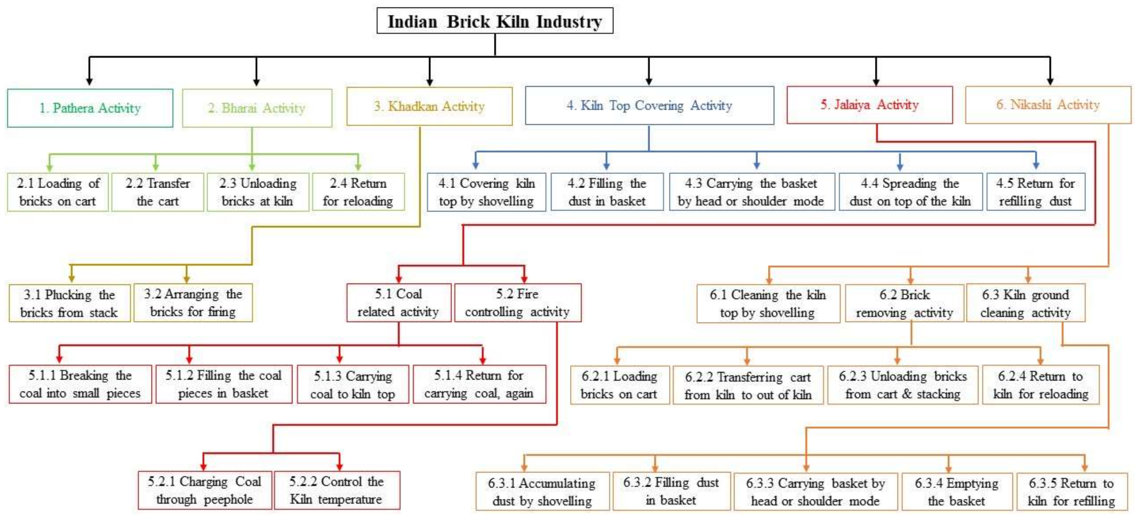


Figure 5-1: Hierarchical Task Analysis (HTA) in Indian brick kiln industry

Below three brick kilns were selected from Indo-Gangetic plains (North and East India) for the current study. Name and location of studied brick kilns are given below (Table 5.1) –

Table 5.1: Location of the selected brick kiln and the number of the subject chosen for study

Name of the Brick kiln	Location	No of Workers
VS Brick Kiln Industry (VS)	Mehasana District, Gujarat	94 (Male 57 & Female 37)
RB Brick Kiln Industry (RB)	Kheda District, Gujarat	71 (Male 42 & Female 29)
Sun Brick Kiln Industry (SUN)	Bhagalpur District, Bihar	Male 94 & No Female
Total		**259** **(Male 193 & Female 66)**

Gujarat brick kilns are the representative of North India, and Bihar brick kiln is the representative of Eastern India (Figure 5-2). In general, the brick kiln workers were free from any physical deformity and illness. The process of brick making in different kiln described briefly.

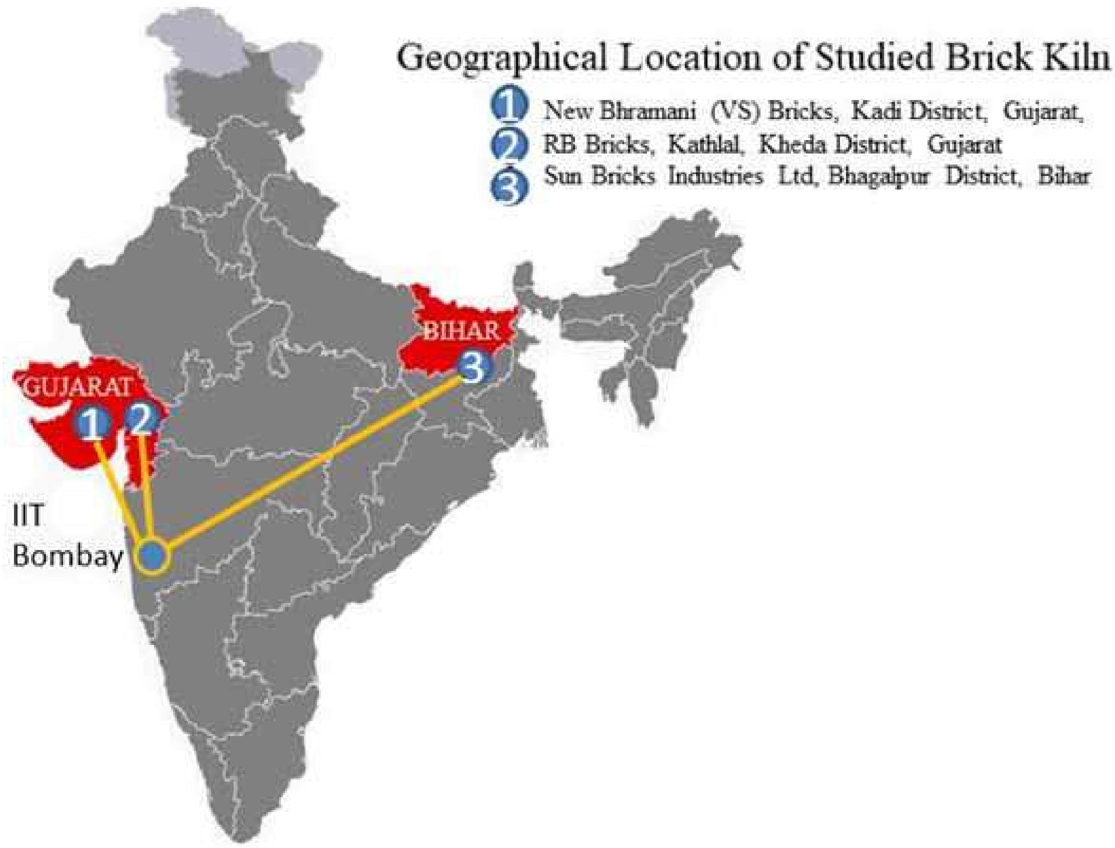


Figure 5-2: Geographical location of three studied brick kilns

5.2 VS Brick Kiln Industry, Gujarat

The VS brick kiln is situated on the bank of river Narmada Main Cannel, in Mehasana District, Gujarat (Figure 5-3). After the rainy season, the hard earth soil was dug by JCB Tractor and was kept the soil in loose condition. In VS brick kiln, there are mainly six types of workers such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi.

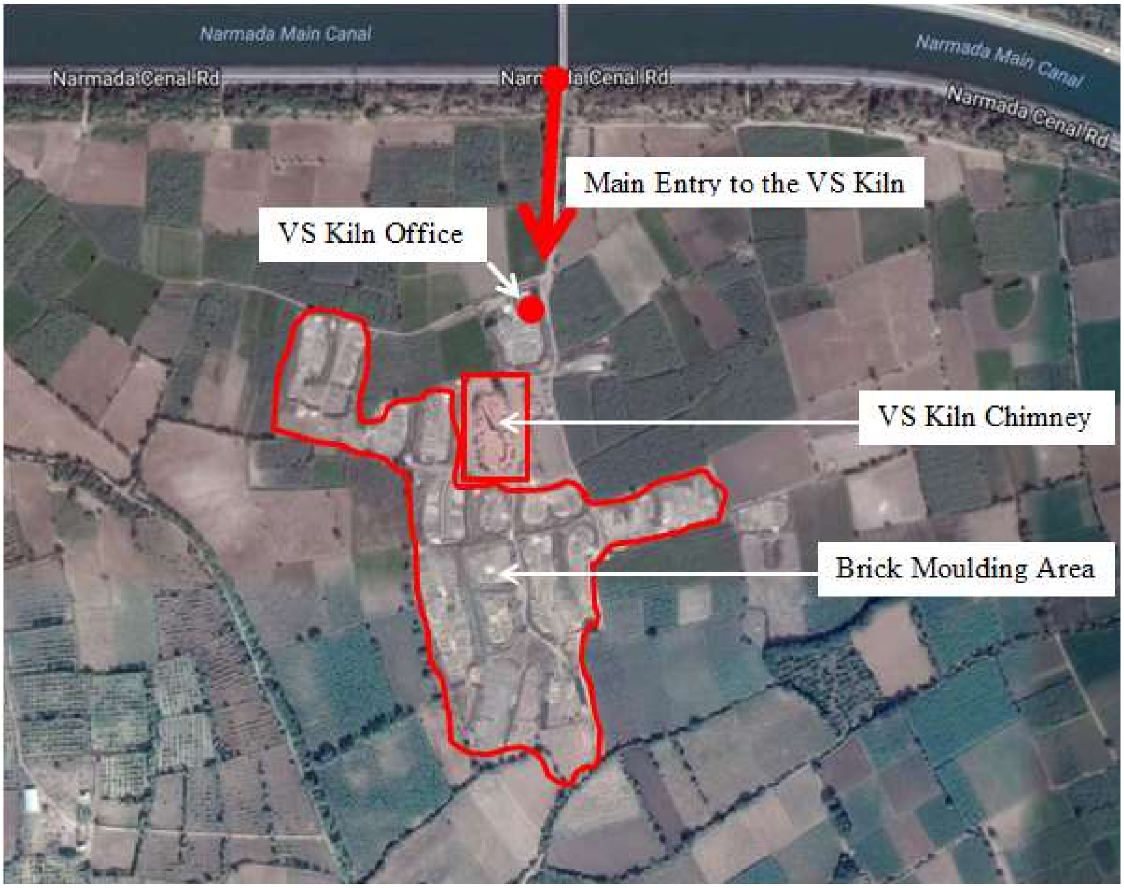


Figure 5-3: Satellite image of VS brick kiln industry, Mehsana District, Gujarat, India

5.2.1 Pathera Worker

The Pathera workers are responsible for making raw bricks from the soil by using a mould (locally known as Sancha). Based on the job assigned to the group of workers for moulding purpose, the entire activity is segmented into four significant sub-activities as given below –

5.2.1.1 Soil Preparation and Mud Making

This activity is essential for the breakdown of the larger soil lumps into smaller fragments for making it ready for the mud preparation activity. Only the male worker usually does this activity. The men typically start the activity early in the morning before Sunrise. The pre-preparation of this activity involves a loosening of the soil from the soil blocks, breaking the larger lumps into smaller lumps for easy mixing with water for dough formation. Usually, this soil preparation is done on the previous day so that the mud preparation can start early in the morning. The labourers, using a shovel initially begins with breaking down of the big blocks of clay into smaller fragments so that when introduced to water, the soil got blended uniformly as shown in Figure 5-4.


Figure 5-4: Loosening of soil in VS brick kiln industry

Use of Bull Dreiser in loosening larger soil blocks (Left), Manual loosening of soil (Right)

Based on the experience once the worker feels that the soil has turned into more beautiful grains, water is introduced at regular interval to make the mud out of clay with required water consistency so that good quality bricks can be prepared out of them (Figure 5-5). The mud maker waits for enough time until the water fills about ¾ section of the soil made.


Figure 5-5: Pouring water into the soil (Left), Sprinkling salt to the soil (Right)

Figure 5-6: Sprinkling of paddy husk (Left), Mud mixing by shovel (Right)

Figure 5-7: Stomping by feet (Left), The final mud (Right)

After that, the top layer of mud is covered with rice husk. It is mixed vigorously by shovelling and constant stomping (by feet) action, as shown in Figure 5-6 and Figure 5-7. Finally, the soft dough of clay is prepared and left for about 3 hours for tempering. It has been recorded that from a size of 5.4 (+0.70) X 3.5 (+0.55) X 0.27 (+ 0.03) meter (L X B X H), i.e. total volume of about 4.76 (+0.34) m3 of mud produced about 1534 (+163) number of bricks on an average. Once the clay is mixed very well to the required consistency, the whole mud is covered with a thick layer of rice husk so that the mud does not dry out. This entire preparation is a very time-consuming process and requires a high level of physical effort to conduct the whole activity. As the soil preparation and mud making forces frequent bending below the waist level and repetitive shovelling action, it is biomechanically highly stressful job.

5.2.1.2 Mud Transfer to Brick Moulding Site

The next step is to transfer the prepared mud to the brick moulding site after curing the clay for 3 to 3.5 hours. Both male and female workers perform this operation. Mostly both husband and wife participate together in this activity. In this, first, a little sand powder is sprinkled on the cart so that the mud doesn't stick to the cart and then with the help of a shovel the husband and wife load the cart with sufficient amount of clay as showing in Figure 5-8. The cart is then further driven to the brick moulding site and unloaded by turning for making a local stock of mud. The whole cycle is repeated till the time a long heap of mud measuring approximately 6 (+0.7) X 0.75 (+0.5) X 0.3 (+ 0.03) m (L X B X H) is achieved. Figure 5-8 below shows the sequences of the mud transfer operation.

Figure 5-8: Sequences of mud transfer activity

5.2.1.3 Brick Moulding

Brick moulding is one of the essential steps for brick making and at the same time, very time consuming and fatiguing in nature. A semi-skilled but experienced worker is required for brick moulding. The main aim of this activity is to mould of bricks from wet mud using the mould.

Figure 5-9: Sequence of the brick moulding operation

Once the heap of mud is laid on the brick moulding site, the couple sits down in a squatting posture keeping the mud heap in the middle and start moulding raw bricks by using the mould. The entire activity is conducted in the following manner (Figure 5-9):

a) The ground is cleared by using a scraper of all dust and particles to make it level sized.
b) The mould is washed with water, and then sand is sprinkled inside so that the casted raw brick comes out easily.
c) A significant section of the mud is scooped out from the mud heap using both palms.

d) It is rolled on the ground against sand layer followed by thrown into the mould.
e) The mould with the mud is lifted for a small height and dropped to the ground for impaction.
f) Excess mud is scraped out from the mould top by palm movement.
g) Sand is sprinkled on the top surface of the clay in the mould.
h) The mould with clay is taken to a few steps.
i) The mould is inverted on the preconditioned ground and left to dry in the Sun for the next three days as such.
j) This whole cycle is repeated until the entire transferred mud gets over.

In the mud preparation, the worker mixes the clay with a proportionate amount of salt, coal powder, husk and water to make the consistency of the mud appropriate for the moulding of bricks. After mixing all ingredients, the wet clay is left for about three hours for tempering, that makes the mud just optimum for moulding purpose.

5.2.1.4 Drying and Stacking

After moulding, the raw bricks are allowed to Sundry for five days. On the third or fourth day, the raw bricks are stacked to clear the ground for the next lot of moulding. By the third day, the raw bricks are strong enough for the next two days. In stacking operation, both male and female workers (couple) participate, and it is an entirely manual operation. The approximate weight of brick after Sun drying is about 3.5 kg. The process involves picking up the bricks from the brick moulding site and stack them in the nearby area by using a wheelbarrow, as shown in Figure 5-10. Then the bricks are placed in an orderly fashion on the stacking ground in the form of a mesh, as shown in the image.

Figure 5-10: Stacking of bricks after moulding

5.2.2 Bharai Worker

The brick transfer activity (locally known as Bharai) is one of the significant activities of the brick-making operations. After making the fresh/green bricks in an open field, need to burn in the kiln. The main aim of this activity is transferring the raw/green brick within kiln for proper baking. This process is semi-mechanise within the entire brick making process. The Bharai workers use a tractor for carrying the green bricks. Loading and unloading works are done by manual operation. Tractors are parked beside the stacked sundried bricks. The Bharai workers load the Sun-dried bricks on the tractor. After finishing loading activity, the tractor goes within the kiln. There are some pockets in the kiln wall. Within these pockets, the tractor can enter in the kiln. The green bricks are unloaded beside green brick storing zone. This unloading activity also is done by manual way. The job has three clear segments (Figure 5-11).

Loading from moulding site: In this activity, an open tractor is brought to the place where the dried bricks are stacked. In which the dried bricks are loaded to be further taken to the kiln for further firing. At a time, a total of 4 workers participate in this operation.

Transfer: After the tractor is loaded with roughly about 1650 bricks, it then travels to the kiln site. If there is already another tractor off-loading the dry bricks in the kiln, then the current has to wait outside till the off-loading tractor comes out as there is not enough space inside the kiln for two tractors to enter at once.

Unloading at the kiln: Once the tractor enters the kiln, the workers being off-loading the bricks in a line one over the other leaving a small space between the previous lines of off-loaded dried bricks to give enough space for the brick architect to arrange the bricks appropriately for the firing operation.

Figure 5-11: Different elements of the brick transfer activity in VS brick kiln
Loading of bricks (Left), Transfer of bricks (Middle), Unloading of bricks (Right)

5.2.3 Khadkan Worker

Sun-dried bricks are not hard enough. The Sun-dried bricks need to proper fire to make the bricks harder. The green brick has to be baked under optimal temperature as the lower temperature does not make bricks sufficiently harder and higher temperature overheats the break, which changes the shape and colour of the brick. Proper arrangement of raw bricks is required for uniform firing. Brick arrangement in the kiln is, therefore, an important step for quality output. An experienced and skilled worker is required for brick arrangement. Locally these workers are known as Khadkan. This job is done by the experienced male workers only.

In this process, raw bricks are arranged by male workers in a systematic way for fuel (coal) charging and quality firing of bricks. Knowledge of the arrangement process is acquired by watching their seniors, along with experience. These workers are the skilled workers in terms of arranging the bricks for proper firing. There is a scanty of such skilled workers in brick making activity today. The height of the kiln wall is nearly 8 feet. This demands the placement of bricks above shoulder height. Biomechanically the upper limit should be below the shoulder level. Figure 5-12 depicts different postures adopted during Khadkan activity. As the stacking of bricks during Khadkan forces frequent bending below the waist level and raising hands above the shoulder, Khadkan is biomechanically highly stressful job.

Figure 5-12: Different postures adopted while arranging the bricks in the kiln

5.2.4 The Workers Who Cover the Brick Kiln Top by Red Brick Dust

The sun-dried green bricks, made by moulder, are baked within the close chamber for making the bricks stronger. The kiln temperature needs to keep within 900^0-1100^0 centigrade. The kiln needs to cover all sides adequately to maintain the required temperature. After finishing the *Khadkan* activity, the roof of the kiln is covered by a thick layer of red brick dust. Brick dust is not conductive for heat; it prevents heat radiation. Covering of brick kiln top by red brick dust is an important step to avoid the emission of heat from the kiln. The other sides of the kiln are made by a solid wall. After arranging the bricks, the top layer of the kiln must be covered by red brick dust as a thermal insulator, as shown in Figure 5-13. The workers use a basket to carry the brick dust powder to far part from the storage area and shovel to spread the dust from the accumulated place.

Figure 5-13: Covering the top part of the brick kiln by red brick dust activity

5.2.5 Jalaiya Worker

The firing of Sun-dried bricks under controlled temperature is a very important step under the brick making activity. Locally known as 'Jalaiya' is the process by which the green bricks are strengthened, and the colour is changed from grey (dry mud) to brick red (baked brick) by baking at a constant temperature of 900^0 - 1000^0 centigrade for a specific time. The kiln is vital for this purpose and maintaining the internal kiln temperature uniformly, which is essential for optimum baking of the raw bricks. After the transfer and arranging the raw bricks in the proper way (Khadkan), experienced male workers (locally known as 'Jalaiya') are required for burning of green bricks to hard red colour bricks. The main task of Jalaiya is maintaining the fire inside the kiln, supervision of the fire temperature and accordingly determines the time to bake the bricks, charging the kiln with coal, and changing of air duct as the fire advances to next raw brick blocks inside the kiln (Figure 5-14).

Figure 5-14: Different activities performed by Jalaiya
(First-Deciding the fire temperature, Second, Breaking and loading the coal, Third, Transferring the coal, Fourth, Distributing the coal through a peephole)

Apart from these, Jalaiya worker also has to break the large chunk of coals to smaller piece for charging the kiln through "coal charging openings" or peephole on the top of the kiln.

5.2.6 Nikashi Worker

The final stage of brick production is removing the baked bricks from the kiln by using a manually drawn wheelbarrow and stacking those bricks at a distance encompassing the kiln. The work contents are divided into three primary activities;

a) Removing the top brick dust
b) Removal of red (fired) bricks
c) Cleaning the kiln

Workers for this job were mostly migrated from Rajasthan as a young couple with children. Both male and female worker is engaged in this activity. After removing the baked bricks, workers need to do the cleaning of the kiln ground for next use.

Removing the top brick dust: The first job under Nikashi activity is the removal of brick dust, from the top layer of the fired (Red) bricks (Figure 5-15). A couple of workers first go to the top of the kiln and manually by using shovel and basket (plastic/metal) they remove the top brick dust.


Figure 5-15: Removal of brick dust from kiln top

Removal of red (fired) bricks: The second operation under Nikashi is the removal of red bricks. This activity can be subdivided into four sub-activities as shown in Figure 5-16;

a) Stacking (Loading) the bricks on a cart (Wheelbarrow)
b) Transferring the bricks to a distant place by pushing the cart
c) Stacking the bricks in the pre-defined stack of bricks in an orderly fashion
d) Return to the kiln for reloading, and the process continues.

Figure 5-16: Removal of bricks from the kiln

After loading the cart with just fired red bricks in the kiln, workers take the wheelbarrow to a nearby place out of the kiln. For transferring (removal) of bricks, each worker, irrespective of gender, is assigned with a one-wheel barrow. Usually, a female worker moves about 38 while the male transfers about 50 number of bricks in each cycle. This is a very laborious task to push the cart. Apart from the wheelbarrow weight (say 15 kg) a load of 90 kg (2.8 kg X 32) for women per trip and that of 140 kg (2.8 X 50) for men gets to sink in the thick brick dust at the ground of the kiln while pushing. This causes very high resistance to push the cart. This is reflected by the very high heart rate for both the genders. The upward slope between the ground level of the brick kiln and the outside ground surface is further additive factors to increase the physiological cost. After coming out of the brick kiln workers stack the bricks in a nearby place opposite to the kiln outlet, as shown in Figure 5-16. In general, there will be six outlets from the kiln against of which red bricks are stacked. After stacking the bricks out of the kiln, the worker with empty wheelbarrow returns to the kiln for further reloading and continuing with the work cycle.

Cleaning up the kiln: The cleaning activity mostly involves the collection of all brick dust powder and dumping it to the side of the kiln. It also requires removal of broken bricks etc. as shown in Figure 5-17. The process makes the entire bed of the kiln free from any brick dust or unwanted elements. The job is performed manually by using a shovel and a basket. Almost all the couples will be engaged in this cleaning job after removal of bricks.

Figure 5-17: Kiln ground cleaning activity

The vertical height of the kiln is about 305 cm (10 feet). This makes it challenging to transfer of debris. To resolve this issue, men perform the heavy work at the ground like shovelling, lifting and transfer of debris. A woman, sitting on the top edge of the kiln, picks up the bucket and dumps the debris next to her. This debris will be reused to cover up the top of the raw bricks after Khadkan activity.

5.3 RB Brick Kiln Industry, Gujarat

The RB brick-kiln is located in the south part of Kheda District. The satellite image of RB brick kiln is shown in Figure 5-18. After the rainy season, mud was brought from somewhere else by tractor and made lots of aisle of mud on the moulding ground. During moulding activity, this mud was used as raw material. There are also six (6) types of workers in RB brick kiln industry, such as, Pathera, Bharai, Khadkan, the workers who cover the brick kiln top by red brick dust, Jalaiya and Nikashi.

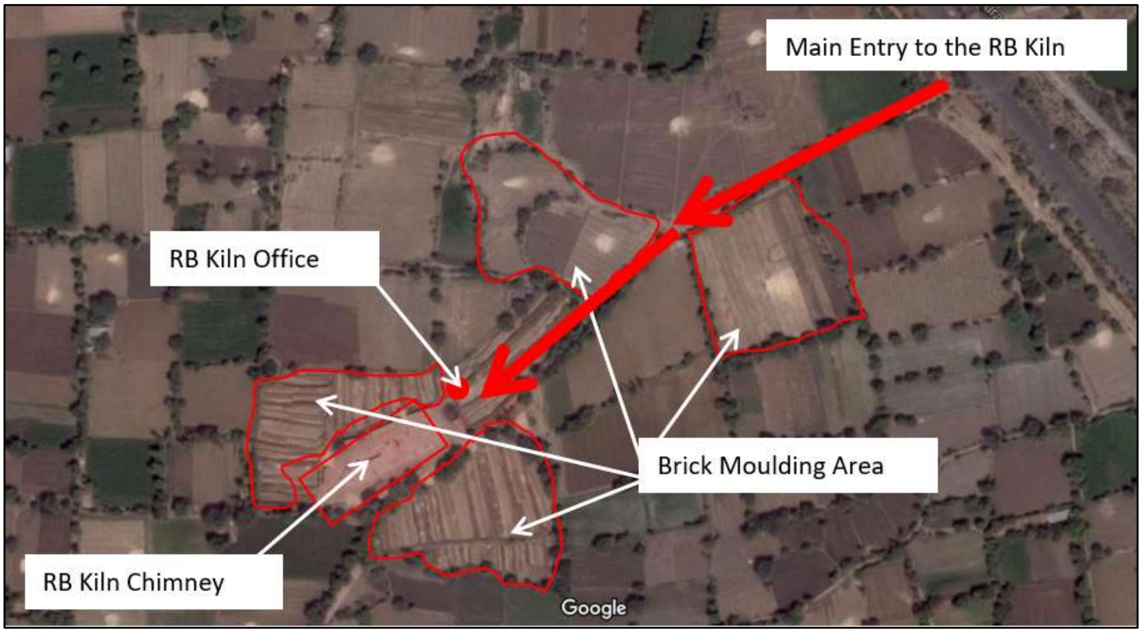


Figure 5-18: Satellite image of RB brick kiln industry, Kheda District, Gujarat, India

5.3.1 Pathera Worker

Like VS brick kiln industry, Pathera workers in RB brick kilns are responsible for mud making, brick moulding and stacking of sun-dried bricks. They make mud pool such a way; they don't need to transfer mud from mud pool to moulding ground. The brick moulding and stacking methods are quite similar, like VS brick kiln industry. Various Pathera sub-activities are shown in Figure 5-19.

Figure 5-19: Pathera activities in RB brick kiln industry, Gujarat

5.3.2 Bharai Worker

In RB brick kiln industry, Bharai activity is done by using a horse-driven cart. The Bharai worker unloads the green bricks from the horse-driven cart and handover to the Khadkan worker directly (shown in Figure 5-20). The Bharai jobs have three clear segments like Loading the bricks at moulding ground, Transfer the green bricks by horse-driven cart and Unloading the bricks from horse-driven cart and handovers to Khadkan worker.

Figure 5-20: Bharai activities in RB brick kiln Industry, Gujarat

5.3.3 Khadkan Worker

The Khadkan workers arrange bricks for uniform firing. The Khadkan (Figure 5-21) architect is a person who is a specialist in arranging the bricks in an organised manner inside the kiln keeping sizable opening within the stack of the brick to make sure that all the bricks are holistically exposed to the heat inside the kiln.

Figure 5-21: Khadkan activity in RB brick kiln industry, Gujarat, India

5.3.4 The Workers Who Cover the Brick Kiln Top by Red Brick Dust

The whole set of newly stacked bricks are then covered with a layer of brick dust powder to seal any opening on the top surface of the kiln so that the heat from the kiln does not escape out but retained inside the kiln only.

5.3.5 Jalaiya Worker

The Jalaiya man breaks the coal to smaller pieces and charges the coal through the peephole as fuel and maintain the temperature of the kiln. Once the bricks are arranged inside the kiln trench, they are put on the constant uniform high temperature of about 900^0 - 1100^0 Centigrade termed as the Jalaiya operation. The Jalaiya worker keeps a continuous watch on the heating patterns inside the kiln to make sure that bricks are exposed to sufficient high heat for a specific time (Figure 5-22).

Figure 5-22: Jalaiya activity in RB brick kiln industry, Gujarat, India
(On the left: Controlling the fire of the kiln, On the middle: breaking the coal & on the right: carrying the coal)

5.3.6 Nikashi Worker

The Nikashi is the last step of the brick making process. Male and female both types of workers are available as Nikashi activity and transfer the baked bricks by head mode. This activity includes 1) Removal and cleaning brick dust at the top surface of the kiln, 2) Removal of baked bricks from the kiln after sufficient cooling and 3) Cleaning the kiln ground, after removing the baked bricks from the kiln Figure 5-23.

Figure 5-23: Nikashi activity in RB Brick Kiln Industry

(Removing the brick dust from the top of the kiln, Loading the bricks on the head, unloading bricks from the head and Cleaning the kiln ground)

5.4 Sun Brick Kiln Industry, Bihar

The Sun Brick Kiln Industry is situated in the eastern part of India, on the bank of the River Ganges. The satellite image of SUN brick kiln industry is shown in Figure 5-24. Before brick making, raw Gangatic soil was collected from the riverside by using Bulldozer and tractor. The collected Gangatic soil was kept beside the brick-moulding area. This job was outsourced from outside.

Figure 5-24: Satellite image of SUN brick kiln industry, Bhagalpur District, Bihar, India

5.4.1 Pathera Worker

5.4.1.1 Mud Making

In SUN brick kiln industry, mud prepares in a centralised mud pool. One day before of brick moulding, the lumped soil is broken into smaller pieces by Bulldozer. River water is added as required to soften it. The day the mud is prepared, the soft clay is poured in a Churner using Bulldozer. The churner runs by a tractor using the Power take-off (PTO) shaft of the tractor.

No additives are added with mud during mud preparation. The mud making process is shown in Figure 5-25.

Figure 5-25: Mud preparation in Bihar SUN brick kiln industry, Bihar, India

5.4.1.2 Mud Transfer and Brick Moulding

After the mud preparation, the moulding-worker bring the required mud using the cart from the Mud making site to moulding area. The cart is made by iron with pneumatic wheel, which is helpful for the uneven surface like moulding ground. After that, the brick moulder makes the brick by using a mould/template made by wood. After moulding, the bricks are kept under the Sun for drying. Then the Sun-dried bricks are stacks on moulding ground for Bharai activity (Figure 5-26).

Figure 5-26: Mud transfer and moulding activity in Bihar SUN brick industry, India
(Mud Loading in Cart, Mud Transfer by Cart, Toppling of Cart/Unloading mud, Brick Moulding, Stacking the Sun-dried bricks & Ground cleaning activity)

5.4.1.3 Ground Cleaning

Before brick moulding, ground cleaning is done by the ground cleaner. For cleaning, the workers use a circular local made tool shown in Figure 5-26. In addition to ground cleaning, the workers also turn the green bricks upside down for drying.

5.4.2 Bharai Worker

The Sun-dried bricks are transferred to the kiln by using a bicycle. The Bharai worker makes an indigenously developed carrier inside the triangular frame of the bicycle in which they carry the bricks (Figure 5-27). Apart from this brick transfer workers, there are some assistants (Pushers) who push the heavily loaded bicycle near the kiln, the entrance of which has an upward slope and helps the carriers to transfer the green bricks. Raw bricks are manually off-loaded from the cycle and moved to the hand of the Khadkan workers.

Figure 5-27: Brick transfer (Bharai) activity in SUN brick kiln industry, Bihar

5.4.3 Khadkan Worker

The Khadkan architect is a person who is a specialist in arranging the bricks in an organised manner inside the kiln trench keeping sizable opening within the stack of the brick to make sure that all the bricks are holistically exposed to the heat inside the kiln (Figure 5-28).

5.4.4 The Workers Who Cover Brick Kiln Top by Red Brick Dust

The whole set of newly stacked bricks are then covered with a layer of brick powder to seal any opening on the top surface of the kiln so that the heat from the kiln does not escape out but retained inside the kiln only.

5.4.5 Jalaiya Worker

Once the bricks are placed inside the kiln, they are baked within a uniform high temperature of about 900^0 - 1100^0 Centigrade. During the Jalaiya operation, the Jalaiya worker keeps a continuous watch on the heating patterns inside the kiln to make sure that bricks are exposed to sufficient high heat for a specific time (Figure 5-28). To have one complete round of furnace firing, it takes 30 days in winter and 28 days in summer. One round need about 4200 kg (105 munds) coal which the owner gets as big lumps. Those lumps are broken in the nearby region. The chunks of coals are fed to pulverising which runs by the tractor PTO to crush the coal.

Figure 5-28: Khadkan and Jalaiya activity in SUN Brick kiln industry, Bihar, India

5.4.6 Nikashi Worker

The Nikashi workers are engaged in removing the baked red bricks. Each one carries 8 to 12 bricks by head mode for about 2-3 min walk. They dump the bricks in nearby stacks based on three different grades of bricks, Good, Medium and Bad qualities (Figure 5-29). This activity includes –

a) Removal and cleaning brick dust at the top and bottom surface of the kiln,
b) Removal of red colour fired bricks from the kiln after sufficient cooling and
c) Cleaning the kiln ground after removing the bricks.

Figure 5-29: Nikashi activity in SUN Brick kiln industry, Bihar, India

5.5 Comparative Analysis Among Three Studied Brick Kilns

Brick making is a labour-intensive industry. Manual Material Handling is the cheapest way for the unorganised sector in a developing country, like India. The strength of the workers in different studied brick kilns are given below (see Table 5.2) –

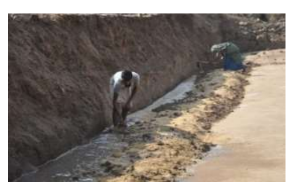
Table 5.2: Job wise distribution of the subject in studied brick kiln industry

Job Type	VS Brick Kiln (Kiln output 40,000 bricks/day)		RB Brick Kiln (Kiln output 35,000 bricks/day)		SUN Brick Kiln (Kiln output 30,000 bricks/day)	
	No of workers	Output (Bricks/day)	No of workers	Output (Bricks/day)	No of workers	Output (Bricks/day)
Pathera	27 Male 27 Female	750 (M) 550 (F)	22 Male 22 Female	1500	39	1200
Bharai	8	5000	6	6000	24	1250
Khadkan	5	8000	2	17500	5	6000

Kiln top coverer	2	20,000	1	35,000	2	15,000
Jalaiya	5	8000	4	8750	6	5833
Nikashi	10 Male 10 Female	2500 (M) 1600 (F)	7 Male 7 Female	2700 (M), 2300 (F)	15	2000
Total worker	94 (57 Male, 37 Female)		71 (42 Male, 29 Female)		94 (all Male)	

The comparison of three studied brick kilns such as VS brick kiln industry, RB brick kiln industry and SUN brick kiln industry are given below (see Table 5.3) –

Table 5.3: An insight of traditional brick making process

Brick Kiln	VS Brick Kiln Industry	RB Brick Kiln Industry	Sun Brick Kiln Industry
The layout of brick kiln			
Mud Collection		Image not available	
Pathera Activity			
Mud Making			

Mud Transfer Trolley	Single rubber wheel, Wooden 	Not Applicable	Double Pneumatic wheel, Iron, 
Trolley weight (kg)	20 (±3)	Not Applicable	50 (±5)
Transferred mud weight /Trip (kg)	120 (±10)	Not Applicable	300 (±10)
Distance covered (m)	15 (±5)	Not Applicable	46 (±15)
No of trips /Day (times)	50 (±5)		33 (±3)
Time taken /trip (min)	60 (±15)	Not Applicable	115 (±15)
Load handled /Day (kg)	7000 (± 500)	Not Applicable	11550 (± 500)
Mould Type	 Aluminium	 Metallic Plate & Wood	 Wood
Mould Weight (kg)	1 (± 0.25)	1.5 (± 0.3)	1.25 (± 0.25)
Green Brick Size (cm)	22.5 x 10.5 x7.6	22.5 x 10.5 x 7.6	24 x 12 x 8.5
Output /Day	Male 750, Female 550	1500	1200
Green Brick Weight (kg)	4 (± 0.3)	4 (± 0.3)	5.25 (± 0.4)
Load (kg) handled /Day	Male 3750, Female 2750	8250	7800

Brick making rate (Brick /min)	3 (approx.)	6 (approx.)	3 (approx.)
Bharai Activity			
Bharai Activity			
Weight of Sun-dried bricks (kg)	3 (± 0.25)	3 (± 0.25)	4.45 (± 0.30)
No of bricks transfer /trip	1650 (4950 kg)/4 person = 415 (1250 kg)	300 bricks (900 kg)	40 bricks (178kg)
No of trips	13 trips (4 workers present in every trip)	20 (± 2) trips	37 (±5) trips
Distance covered /trip (meter)	50 – 500 meters	50 – 800 meters	50 – 800 meters
Time taken/ trip (min)	52 min	27 min	13 min
Load Handled /Day (kg)	16087 kg	18000 kg	6586 kg
Nikashi Activity			
Nikashi			
Mode of work	Wheelbarrow mode	Head mode	Head mode
Red brick weight (kg)	2.5 (±0.2)	2.7 (±0.2)	3.8 (±0.3)

No of brick transfer /trip	Male: 50 (125kg), Female: 32 (80kg)	Male: 14 (38 kg), Female: 12 (32 kg)	Male: 10 (38kg)
No of trips	48 (±2)	192 (±7)	200 (±8)
Distance covered (m)	30 – 50	30 – 50	50 – 75
Load handled /Day (kg)	Male: 6000, Female: 3840	Male: 7296, Female: 6144	Male: 7600
Time taken / Trip (min)	10	2	3

Chapter 6 Results and Discussion

In this chapter, the results of the study are presented. The Physical parameter, Physiological, Postural, Psychological, Environmental and Overall stresses of the brick kiln workers are measured and presented here. From Physiological, Postural, Psychological and Environmental stress, P-P-P-E scores are derived that gives the design direction guideline for design intervention. Based on P-P-P-E Score, design interventions are carried among brick kiln workers.

6.1 Introduction

In this chapter, the results from ergonomic risk assessments carried out to evaluate occupational stress to brick kiln worker working in India, are presented. Before commencing the ergonomic risk assessment process, brick kiln workers were observed while they carried out brick making activities in different brick kiln industries, in India.

6.2 About the Selected Subjects

For physical characteristics and anthropometric study, 259 participants (193 male and 66 female), were selected from three brick kiln. As the energy expenditure and working heart rate measurement studies require a longer duration (one & half hours per participant). Therefore, for energy expenditure and working heart rate measurement study, 103 participants (84 male and 20 female) were selected. The researcher also ensured the representation from all six subgroups, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. Below Table 6.1 describes the number of the selected subject from each category. The number of participants chosen for energy expenditure study shown inside the bracket.

Table 6.1: Number of participants chosen for the research study

Gender	Type of Activity	VS Brick Kiln	RB Brick Kiln	SUN Brick Kiln	Total
Male Brick Kiln Worker (N=193)	Pathera	27 (5)	22 (5)	39 (10)	88 (20)
	Bharai	8 (5)	6 (5)	24 (5)	38 (15)
	Khadkan	5 (5)	2 (2)	5 (5)	12 (12)
	Kiln top coverer	2 (2)	1 (1)	5 (5)	8 (8)
	Jalaiya	5 (5)	4 (4)	6 (5)	15 (14)
	Nikashi	10 (5)	7 (5)	15 (5)	32 (15)
Female Brick Kiln Worker (N=66)	Pathera	27 (5)	22 (5)	NA	49 (10)
	Nikashi	10 (5)	7 (5)	NA	17 (10)
Total		**94 (37)**	**71 (31)**	**94 (35)**	**259 (103)**

6.3 Subjects Output in terms of Brick Production

VS Brick Kiln Output – 40,000/Day

RB Brick Kiln Output – 35,000/Day

SUN Brick Kiln Output – 30,000/Day

There are six types of workers in the brick kiln industry. Among them, Pathera workers can produce bricks as much as they can. But other groups output can be restricted by kiln output. Daily output (in terms of the number of bricks) of brick kiln workers are presented in Table 6.2.

Table 6.2: Subjects output in terms of number of brick production

Job Type	VS Brick Kiln (Kiln output 40,000 bricks/day)		RB Brick Kiln (Kiln output 35,000 bricks/day)		SUN Brick Kiln (Kiln output 30,000 bricks/day)	
	No of workers	Output (Bricks/day)	No of workers	Output (Bricks/day)	No of workers	Output (Bricks/day)
Pathera	27 Couple (27 Male & 27 Female)	1300*	22 Couple (22 Male & 22 Female)	1500*	39	1200*
Bharai	8	$\frac{40000}{8} = 5000$	6	$\frac{35000}{6} \approx 6000$	24	$\frac{30000}{24} = 1250$

Khadkan	5	$\frac{40000}{5} = 8000$	2	$\frac{35000}{2} = 17500$	5	$\frac{30000}{5} = 6000$
Kiln top coverer	2	$\frac{40000}{2} = 20000$	1	$\frac{35000}{1} = 35000$	5	$\frac{30000}{5} = 6000$
Jalaiya	5	$\frac{40000}{5} = 8000$	4	$\frac{35000}{4} = 8750$	6	$\frac{30000}{6} = 5000$
Nikashi	10 Couple (10 Male & 10 Female)	$\frac{40000}{10} = 4000$	7 Couple (7 Male & 7 Female)	$\frac{35000}{7} = 5000$	15	$\frac{30000}{15} = 2000$

*Pathera workers productivity doesn't depend on kiln output

6.4 Participants Male-Female Ratio

The male-female ratio of brick kiln workers is shown in Figure 6-1. Near about 40 percent of brick kiln workers are female. In the brick kiln, the workers are migrating from different parts of the country with their families. Therefore, both male and female both types of workers are there in Gujarat brick kiln. On the other side, there are no migrating workers as well as a female worker in Bihar brick kiln industry.

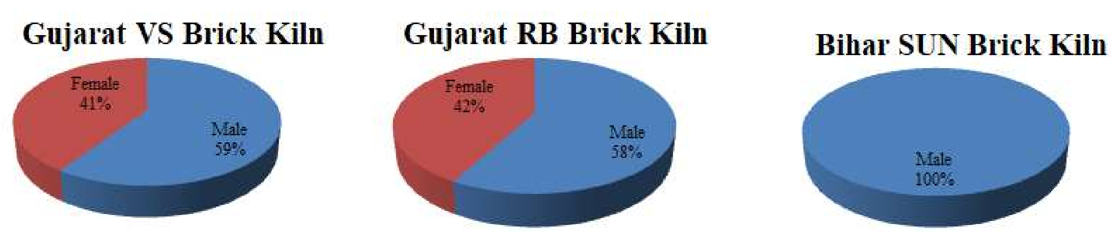


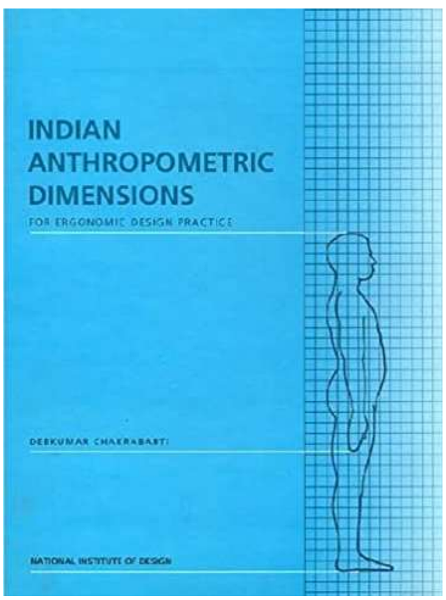
Figure 6-1: Male-Female ratio in the studied brick kiln

6.5 Studied Brick Kiln Industry – As a representative of India

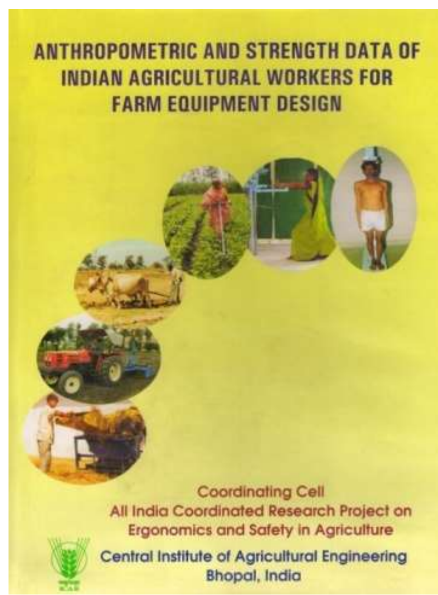
India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems faced by the respective brick kiln workers. From the three brick kiln industries, 259 participants (193 male and 66 female) were selected for the current study. Due to the vast nature of the country, it is important to check the reliability of the sampling.

Anthropometric data of a country is a vital database for design applications. It is also an important parameter in population studies. Most developed countries have invested resources over the years to develop such a database. Unfortunately, an updated and comprehensive Anthropometry of Indian Population is mostly unknown. The India-specific designs require to access the latest Indian anthropometric database, the project "SIZE INDIA" has been initiated by Automotive Research Association of India. But the Size India data are still not accessible to the common public.

There are two published Indian anthropometric data books available, one for Indian civilians and another for Agricultural Workers. There is no such anthropometric database for Indian brick kiln workers. The physical characteristics (height, weight and grip-strength) of Indian civilian, Indian agricultural worker and studied brick kiln are shown below Table 6.3.



Source:
Indian Anthropometric Dimensions for ergonomic design practice
by
Debkumar Chakrabarti, NID



Source:
Anthropometric & strength data of Indian Agricultural workers for Farm Equipment Design
by
CIAE, Bhopal, India

Table 6.3: Comparison of brick kiln anthropometric data and Indian population anthropometric data

Physical Parameters	NID Book	CIAE Bhopal	Studied Brick Kiln
Bodyweight (Mean ± SD)	57 ± 11	54.7 ± 8.7	50.3 ± 8
Height (Mean ± SD)	165 ± 7	163.3 ± 6.2	158.7 ± 7.6
Left-hand grip strength (Mean ± SD)	Not Available	34.7 ± 9.4	31.3 ± 6.6
Right-hand grip strength (Mean ± SD)	Not Available	36.7 ± 9.3	32.5 ± 6.7

As the agricultural workers also fall under unorganised workers; therefore, an unpaired t-test was conducted between two groups. The results of the t-test are shown below -

T-test for Bodyweight:

An unpaired-samples t-test was conducted to determine the difference between agricultural workers weight and brick kiln workers weight. There is a significant difference between the group, that agricultural worker group (54.7 ± 8.7) and the brick kiln worker group (50.3 ± 8) ($t=7.3717$, $p<0.05$).

T-test for Height:

An unpaired-samples t-test was conducted to determine the difference between agricultural workers weight and brick kiln workers height. There is a significant difference between the group, that agricultural worker group (163.3 ± 6.2) and the brick kiln worker group (158.7 ± 7.6) ($t=10.1317$, $p<0.05$).

T-test for Left-hand grip-strength:

An unpaired-samples t-test was conducted to determine the difference between agricultural workers weight and brick kiln workers left-hand grip-strength. There is a significant difference between the group, that agricultural worker group (34.7 ± 9.4) and the brick kiln worker group (31.3 ± 6.6) ($t=5.4809$, $p<0.05$).

T-test for Right-hand grip-strength:

An unpaired-samples t-test was conducted to determine the difference between agricultural workers weight and brick kiln workers right-hand grip-strength. There is a significant difference between the group, that agricultural worker group (36.7 ± 9.3) and the brick kiln worker group (32.5 ± 6.7) ($t=6.8230$, $p<0.05$).

From the above significance study, it can be concluded that there is a need to generate a countrywide brick kiln workers anthropometric database for Indian population.

6.6 Physical Parameters

The basic physical characteristics of studied brick kiln workers are shown in Table 6.4 (Male) and Table 6.5 (Female). The average age of different brick kiln workers is 28 years in VS kiln, 24 years in RB kiln and 37 years for male subjects and 25.6 years in VS kiln and 28.3 years in RB brick kiln for female brick kiln workers.

The brick-making activities are more strenuous job, therefore only young adult workers are engaged in the brick making activity. It was observed that the mean bodyweight of the sample population was much lower than in reference (Standard bodyweight 56 kg) to their age and height. Most of the sample population's mean blood pressure was found to be in the normal range, though the mean BMI of the sample population shows that the subjects fall in the normal category according to the WHO (2005) BMI classification, it was found that about 55.5% (for male) and 33% (for female) of the sample population was underweight according to the WHO classification.

The blood pressure of almost all of them was with the normal range. According to Waist Hip ratio classification, the brick kiln worker falls under the low health risk category. The brick kiln workers (both male and female) have slightly lower hand-grip strength according to standard, that might be due to physical stress. The hand-grip strength measurement was taken in between the work. The blood pressure of almost all of them was with the normal range.

Table 6.4: Physical characteristics of the male brick kiln workers (VS, RB and SUN Brick Kiln)

Male workers	VS Brick Kiln (n=57)		RB Brick Kiln (n= 42)		SUN Brick Kiln (n= 94)	
Variable	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Age (Year)	28 ± 5.7	20 - 45	24 ± 7.4	20 – 40	37 ± 12.7	20 - 70
Body Weight (kg)	49.1± 6.6	40 - 65	50 ± 5.6	37 – 60	54.6 ± 9.4	38 – 73.5
Height (cm)	162 ± 7.1	149 - 178	159.5 ± 5.2	149 - 171	160.4 ± 7.3	143.4 – 174
BMI	18.7 ± 2.6	15.2 - 27.2	19.5 ± 1.2	16 - 24	21.1 ± 3.1	17 – 27.5
Waist Hip Ratio	0.82 ± 0.07	0.7 – 0.9	0.86 ± 0.04	0.7 – 1	0.85 ± 0.06	0.7 – 1.2
Grip Strength (kg) (Left Hand)	32.7 ± 6.5	24 - 48	35 ± 5.1	26 - 48	29.5 ± 8.1	12 - 49
Grip Strength (kg) (Right Hand)	33.6 ± 6.2	22 - 43	35.8 ± 5.6	24 - 52	31.5 ± 8.6	11 – 52
Blood Pressure (mmHg)						
Systolic Pressure	122 ± 9.7	102 -138	113 ± 8.8	98 - 138	126 ± 17.8	95 – 178
Diastolic Pressure	83 ± 9.3	68 -108	77 ± 8.8	62 - 100	80 ± 11.6	60 – 110

Table 6.5: Physical characteristics of the female brick kiln workers (VS and RB Brick Kiln)

Female workers	VS Brick Kiln (n=37)		RB Brick Kiln (n=29)	
Variable	Mean ± SD	Range	Mean ± SD	Range
Age (Year)	25.6 ± 6.0	17 - 40	28.3 ± 7.5	20 – 50
Body Weight (kg)	46.1 ± 9.1	33.5 - 59	47.0 ± 3	42.9 – 53
Height (cm)	153 ± 6.1	141 - 163	151.5 ± 5	140.2 – 158.5
BMI	19.5 ± 3.1	13.9 – 23.8	19.5 ± 2.1	15 - 23
Waist Hip Ratio	0.85 ± 0.07	0.7 – 0.9	0.8 ± 0.04	0.7 – 0.9
Grip Strength (kg) (Left Hand)	25.25 ± 3.9	20 - 32	25.7 ± 3.8	19 – 32
Grip Strength (kg) (Right Hand)	24.38 ± 3.8	20 - 30	26.5 ± 3.9	20 - 32
Blood Pressure (mmHg)				
Systolic Pressure	119 ± 13.5	100 - 142	111.4 ± 11.1	100 – 138
Diastolic Pressure	80 ± 8.4	70 - 96	74.1 ± 7.9	60 – 90

6.7 Energy Expenditure Study

The physiological workload and energy expenditure during the job was determined by using K4b2 telemetric oxygen analyser. The actual work time, pause time (in between work), house-hold activity time and sleep time was calculated by the time-motion study. Average working and Pause heart rates were calculated by following the proper method. The relationship between oxygen consumption & heart rate (for all types of brick kiln worker) was derived from the energy expenditure study. From the derived equation, Oxygen consumption was calculated by placing the heart rate. The oxygen consumption was then multiplied by 5 kcal (the energy equivalent of one-litre oxygen) to obtain the energy expenditure rate (per minute) by the person while performing the job. Energy expenditure (Kcal) (activity wise) was then calculated by multiplying the duration of work (min).

$$Oxygen\ Consumption = m \times Heart\ rate + C$$

Where, m & C = Constant

$$Energy\ Expenditure\ rate\ (per\ minute) = Oxygen\ Consumption\ \times 5$$

$$Energy\ Expenditure\ (activity\ wise) = Energy\ Expenditure\ rate \times Duration\ of\ activity$$

$$\begin{aligned} Whole\ day\ energy\ expenditure \\ &= \Sigma\,(Brick\ kiln\ related\ energy\ expenditure + Sleep\ Energy\ Expenditure \\ &+ Other\ household\ activity\ Energy\ Expenditure) \end{aligned}$$

Whole day energy expenditure of different brick kiln workers are given below (Table 6.6 to Table 6.27) –

Table 6.6: Determination of whole day energy expenditure (Kcal) for Pathera Male workers, VS brick kiln

Pathera (Male)	Activity		HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Digging of Soil	Actual Work	135	90	4.5	405
		Pause	84	30	1.1	33
	Mud Preparation	Actual Work	134	120	4.6	552
		Pause	84	30	1.1	33
	Mud Transfer	Actual Work	142	45	4.9	220.5
		Pause	84	15	1.1	16.5
	Moulding	Actual Work	130	330	4.3	1419
		Pause	80	60	1	60
	Stacking	Actual Work	118	45	3.6	162
		Pause	84	15	1.1	16.5
House-hold Activity			100	180	2	360
Sleep			70	480	0.5	240
Total				1440		3517.5

Table 6.7: Determination of whole day energy expenditure (Kcal) for Pathera Female workers, VS brick kiln

Pathera (Female)	Activity		HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp
Brick Kiln related Activity	Mud Transfer	Actual Work	130	30	5.1	153
		Pause	80	15	1	15
	Moulding	Actual Work	126	240	4.8	1152
		Pause	80	60	1	60
	Stacking	Actual Work	118	35	4	140
		Pause	80	15	1	15
	Ground cleaning	Actual Work	100	90	2.7	243
		Pause	80	30	1	30
House-hold Activity			100	445	2.7	1201.5
Sleep			70	480	0.5	240
Total				1440		3249.5

Table 6.8: Determination of whole day energy expenditure (Kcal) for Bharai workers, VS brick kiln

Bharai	Activity	HR (bpm-1)	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Loading the bricks	122	215	4.9	1053.5
	Unloading the bricks	122	205	4.9	1004.5
	Carrying (Mechanical assistance by tractor)	94	130	1.4	182
	Pause	94	20	1.4	28
House-hold Activity		100	390	1.9	741
Sleep		70	480	0.5	240
Total			1440		3249

Table 6.9: Determination of whole day energy expenditure (Kcal) for Khadkan workers, VS brick kiln

Khadkan	Activity	HR (bpm-1)	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Khadkan activity	132	375	5.5	2062.5
	Pause	80	165	1.3	214.5
House-hold Activity		100	420	1.7	714
Sleep		70	480	0.5	240
Total			1440		3231

Table 6.10: Determination of whole day energy expenditure (Kcal) for Kiln top coverer workers, VS brick kiln

Kiln Top Coverer	Activity	HR (bpm-1)	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Covering to the top by brick dust	130	150	4.7	705
	Pause	75	60	1.3	78
House-hold Activity		100	750	2	1500
Sleep		70	480	0.5	240
Total			1440		2523

Table 6.11: Determination of whole day energy expenditure (Kcal) for Jalaiya workers, VS brick kiln

Jalaiya	Activity	HR (bpm-1)	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Fire control	112	120	3	360
	Coal breaking	137	300	5.6	1680
	Pause	85	300	1.3	390
House-hold Activity		100	240	2	480
Sleep		70	480	0.5	240
Total			1440		3150

Table 6.12: Determination of whole day energy expenditure (Kcal) for Nikashi Male workers, VS brick kiln

Nikashi, Male	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Removing of Brick Dust	137	30	5.5	165
	Loading in Cart	135	100	5.3	530
	Onward Movement	156	25	6.9	172.5
	Stacking Red Bricks	136	100	5.4	540
	Return Movement	133	25	4.9	122.5
	Cleaning the Kiln Ground	137	45	5.3	238.5
	Pause	97	140	1.9	266
House-hold Activity		100	495	2	990
Sleep		70	480	0.5	240
Total			1440		3264.5

Table 6.13: Determination of whole day energy expenditure (Kcal) for Nikashi Female workers, VS brick kiln

Nikashi, Female	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Removing of Brick Dust	137	30	5.4	162
	Loading in Cart	137	100	5.2	520
	Onward Movement	167	25	6.8	170
	Stacking Red Bricks	150	100	5.4	540
	Return Movement	133	25	4.8	120
	Cleaning the Kiln Ground	137	45	5.2	234
	Pause	93	140	1.8	252
House-hold Activity		100	495	2	990
Sleep		70	480	0.5	240
Total			1440		3228

Table 6.14: Determination of whole day energy expenditure (Kcal) for Pathera Male workers, RB brick kiln

Pathera (Male)	Activity		HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Digging of Soil	Actual Work	135	100	4.3	430
		Pause	82	30	1	30
	Mud Preparation	Actual Work	135	130	4.3	559
		Pause	82	30	1	30
	Moulding	Actual Work	132	420	4	1680
		Pause	80	120	1	120
	Stacking	Actual Work	118	45	3.8	171
		Pause	82	15	1	15
House-hold Activity			100	100	2	200
Sleep			70	450	0.5	225
Total				1440		3460

Table 6.15: Determination of whole day energy expenditure (Kcal) for Pathera Female workers, RB brick kiln

Pathera (Female)	Activity		HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Moulding	Actual Work	126	390	3.9	1521
		Pause	80	100	1	100
	Stacking	Actual Work	118	35	3.8	133
		Pause	80	15	1	15
	Ground cleaning	Actual Work	100	90	2.5	225
		Pause	80	30	1	30
House-hold Activity			100	330	2.5	825
Sleep			70	450	0.5	225
Total				1440		3074

Table 6.16: Determination of whole day energy expenditure (Kcal) for Bharai workers, RB brick kiln

Bharai	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Loading the bricks	122	205	5.1	1045.5
	Unloading the bricks	122	195	5.1	994.5
	Carrying (Horse Driven Cart)	100	120	2	240
	Pause	94	20	1.4	28
House-hold Activity		100	360	2	720
Sleep		70	540	0.5	270
Total			1440		3298

Table 6.17: Determination of whole day energy expenditure (Kcal) for Khadkan workers, RB brick kiln

Khadkan	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Khadkan activity	120	360	5.5	1980
	Pause	85	180	1.3	234
House-hold Activity		100	240	2	480
Sleep		70	660	0.5	330
Total			1440		3024

Table 6.18: Determination of whole day energy expenditure (Kcal) for Kiln top coverer workers, RB brick kiln

Kiln Top Coverer	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Covering to the top by brick dust	130	250	4.7	1175
	Pause	75	110	1.3	143
House-hold Activity		100	540	1.8	972
Sleep		70	540	0.5	270
Total			1440		2560

Table 6.19: Determination of whole day energy expenditure (Kcal) for Jalaiya workers, RB brick kiln

Jalaiya	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Fire control	112	120	3.5	420
	Coal breaking	137	330	6.1	2013
	Pause	85	270	1.3	351
House-hold Activity		100	180	2.2	396
Sleep		70	540	0.5	270
Total			1440		3450

Table 6.20: Determination of whole day energy expenditure (Kcal) for Nikashi Male workers, RB brick kiln

Nikashi, Male	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Removing of Brick Dust	135	30	5.5	165
	Loading on head	155	100	6.5	650
	Onward Movement	160	40	6.9	276
	Stacking Red Bricks	154	100	6.5	650
	Return Movement	125	25	4.9	122.5
	Cleaning the Kiln Ground	137	45	5.5	247.5
	Pause	90	140	2.1	294
House-hold Activity		100	270	2.4	648
Sleep		70	690	0.5	345
Total			1440		3398

Table 6.21: Determination of whole day energy expenditure (Kcal) for Nikashi Female workers, RB brick kiln

Nikashi, Female	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Removing of Brick Dust	130	30	5.4	162
	Loading on head	150	100	5.2	520
	Onward Movement	155	40	6.8	272
	Stacking Red Bricks	145	100	5.4	540
	Return Movement	125	25	4.8	120
	Cleaning the Kiln Ground	135	45	5.2	234
	Pause	93	140	1.9	266
House-hold Activity		100	270	2.5	675
Sleep		70	690	0.5	345
Total			1440		3134

Table 6.22: Determination of whole day energy expenditure (Kcal) for Pathera workers, SUN brick kiln

Pathera (Male)	Activity		HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Ground Cleaning	Actual Work	100	30	1.9	57
		Pause	80	10	1.3	13
	Mud Loading to Cart	Actual Work	143	30	4.6	138
		Pause	80	10	1.3	13
	Mud Transfer	Actual Work	145	30	4.6	138
		Pause	80	10	1.3	13
	Moulding	Actual Work	128	410	4.4	1804
		Pause	80	120	1.3	156
	Stacking	Actual Work	119	30	3.6	108
		Pause	80	10	1.3	13
House-hold Activity			100	270	1.9	513
Sleep			70	480	0.5	240
Total				1440		3206

Table 6.23: Determination of whole day energy expenditure (Kcal) for Bharai workers, SUN brick kiln

Bharai	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Loading the bricks	125	150	4.7	705
	Unloading the bricks	120	150	4.5	675
	Carrying (Cycle)	130	150	4.9	735
	Pause	95	150	1.6	240
House-hold Activity		100	360	2.2	792
Sleep		70	480	0.5	240
Total			1440		3387

Table 6.24: Determination of whole day energy expenditure (Kcal) for Khadkan workers, SUN brick kiln

Khadkan	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Khadkan activity	115	450	3.6	1620
	Pause	100	150	2.3	345
House-hold Activity		100	360	2.3	828
Sleep		70	480	0.5	240
Total			1440		3033

Table 6.25: Determination of whole day energy expenditure (Kcal) for Kiln top coverer workers, SUN brick kiln

Kiln Top Coverer	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Covering to the top by brick dust	128	120	3.8	456
	Removing Brick Dust	125	180	3.5	630
	Cleaning the kiln ground	130	240	4.2	1008
	Pause	75	150	1.3	195
House-hold Activity		100	270	1.8	486
Sleep		70	480	0.5	240
Total			1440		3178

Table 6.26: Determination of whole day energy expenditure (Kcal) for Jalaiya workers, SUN brick kiln

Jalaiya	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Fire control	112	120	2.9	348
	Coal Carrying	120	300	3.3	990
	Pause	85	300	1.3	390
House-hold Activity		100	240	1.8	432
Sleep		70	480	0.5	240
Total			1440		2400

Table 6.27: Determination of whole day energy expenditure (Kcal) for Nikashi workers, SUN brick kiln

Nikashi, Male	Activity	HR (bpm^{-1})	Time (Min)	Energy Exp Rate (Kcal/min)	Energy Exp (Kcal)
Brick Kiln related Activity	Loading on head	135	150	5.4	810
	Onward Movement	156	90	6.5	585
	Stacking Red Bricks	136	150	5.5	825
	Return Movement	100	90	2	180
	Pause	97	150	1.9	285
House-hold Activity		100	240	2	480
Sleep		70	570	0.5	285
Total			1440		3498

A comparative whole-day energy expenditure study (Table 6.28) has been done among three studied brick kilns. The result says that average per day per person energy expenditure among

VS and RB brick kilns is almost the same (VS-3176 and RB-3174 Kcal/Day). But average per day per person energy expenditure in SUN brick kiln (3081 Kcal/Day) is slightly lower than VS and RB brick kiln.

Energy expenditure study also says that Pathera activity is physiologically most demanding activity, and it demands 3394 Kcal energy per day per person. Nikashi (3370 Kcal) is the second physiologically demanding activity and followed by Bharai (3311 Kcal/day), Khadkan (3096 Kcal/Day), Jalaiya (3000 Kcal/day) and Kiln top coverer worker (2700 Kcal).
The study also says that Female workers demand less energy in comparison to the male worker. But it should be noted that the productivity (in terms of brick production) of female brick kiln workers also less than male brick kiln workers.

Finally, from the energy expenditure study among brick kiln workers can be concluded that the average per day energy expenditure is 3151 Kcal (range 2700 – 3394 Kcal), which is far more than 2700 Kcal. The above energy expenditure study proves that the minimum wage fixation method should be reconsidered based on 3151 Kcal/day/person. In this context, it can be mentioned that the current minimum wage fixation is made based on 2700 Kcal (Ministry of Labour & Employment, Govt of India, 1957).

Table 6.28: Comparison of whole day energy expenditure among studied brick kilns and different types of workers

Whole Day Energy Expenditure	**VS Brick Kiln (Kcal/Day)**	**RB Brick Kiln (Kcal/Day)**	**SUN Brick Kiln (Kcal/Day)**	**Average (Kcal/Day)**
Pathera Male	3517.5	3460	3206	**3394**
Pathera Female	3249.5	3074	NA	**3161**
Bharai	3249	3298	3387	**3311**
Khadkan	3231	3024	3033	**3096**
Kiln Top Coverer	2523	2560	3015	**2700**
Jalaiya	3150	3450	2400	**3000**
Nikashi Male	3264	3398	3450	**3370**
Nikashi Female	3228	3134	NA	**3181**
Average (Kcal/Day)	**3176**	**3174**	**3081**	**3151**

6.8 Time Motion Study

Two Sony Handicam (Model HDR-XR100E) cameras (one from the front, another from the side) were used to get the different working postures as well as the time needed to complete the jobs. After the recording, the recorded video again played in the laboratory environment, and the work duration is divided into two-time elements such as a) Actual work duration and b) Pause duration during work with the help of a properly calibrated stopwatch.

According to the Factories Act, a worker should not be required to work more than 9 hours a day, spread over 10.5 hours due to rest periods. But the study results say that the average working hours for Pathera workers in VS brick kiln is 780 minutes (13 hours) (Table 6.29), which is far beyond the Factories Act recommended regular working hours. The same trend is followed for RB Pathera workers (15 hours) (Table 6.30) and SUN Pathera workers (11 hours and 30 minutes) (Table 6.31) also. The other brick kiln workers (rest of Pathera workers) works spend time for work within the government approved hours limit. The firing of bricks is a continuous process (24-hour), the Jalaiya worker that work as day-night shift basis. Each shift lies on 12-hour. There are two groups of Jalaiya worker in each brick kiln industry, works 12 hours a day.

Table 6.29: Time motion study in VS brick kiln industry

VS Brick Kiln	Total Work Time (min)	Actual work Time (Min)	Pause Time (Min)	Actual work-Pause ratio
Pathera Male	780	630	150	81% - 19%
Pathera Female	515	395	120	77% - 23%
Bharai	570	420	150	74% - 26%
Khadkan	540	375	165	69% - 31%
Kiln Top Coverer	210	150	60	71% - 29%
Jalaiya	720	420	300	58% - 42%
Nikashi Male	465	325	140	70% - 30%
Nikashi Female	465	325	140	70% - 30%
Average	533	380	153	**71% - 29%**

Table 6.30: Time motion study in RB brick kiln industry

RB Brick Kiln	Total Work Time (min)	Actual work Time (Min)	Pause Time (Min)	Actual work-Pause ratio
Pathera Male	890	695	195	78% - 22%
Pathera Female	660	515	145	78% -22%
Bharai	540	400	140	74% - 26%
Khadkan	540	360	180	67% - 33%
Kiln Top Coverer	360	250	110	69% - 31%
Jalaiya	720	450	270	63% - 38%
Nikashi Male	480	340	140	71% - 29%
Nikashi Female	480	340	140	71% - 29%
Average	584	419	165	**71% - 29%**

Table 6.31: Time motion study in SUN brick kiln industry

SUN Brick Kiln	Total Work Time (min)	Actual work Time (Min)	Pause Time (Min)	Actual work-Pause ratio
Pathera Male	690	530	160	77% - 23%
Pathera Female	NA	NA	NA	NA
Bharai	600	450	150	75% - 25%
Khadkan	600	450	150	75% - 25%
Kiln Top Coverer	690	540	150	78% - 22%
Jalaiya	720	420	300	58% - 42%
Nikashi Male	630	480	150	76% - 24%
Nikashi Female	NA	NA	NA	NA
Average	655	478	177	**73% - 27%**

The average work-pause ratio in Indian brick kiln industries is 72:28, means the brick kiln worker works for 72 minutes and takes 28 minutes brake.

There are no such published data about ideal work and pause ratio in Indian brick kiln industry, but there is a magic number (52-17) for maximum productivity for VDT (Video Display Terminal) workers. This magic number says that 52 minutes of work sprint followed by 17 minutes of recuperation (i.e. 75% work – 25% recuperation) is an ideal ratio for maximum productivity. The brick kiln workers also follow the same work-rest ratio (shown in Table 6.32).

Table 6.32: Average work pause ratio in VS brick kiln, RB brick kiln and SUN brick kiln industries

Time-motion study	Total Work Time (Min)	Actual work Time (Min)	Pause Time (Min)	Actual work-Pause ratio
VS Brick Kiln	533	380	153	71% - 29%
RB Brick Kiln	584	419	165	71% - 29%
SUN Brick Kiln	655	478	177	73% - 27%
Average	**590**	**425**	**165**	**72% - 28%**

Brick kiln workers get their daily wage on the piece-rate system basis. On average, there fifty-three (53%) percent Pathera worker in a brick kiln industry. The Pathera workers get minimum wages on the production of 1000 bricks per day and paying as a family unit. Generally, Pathera workers are migratory workers, migrate from far (even from another state) to work in the brick industry with their family. The couple (husband and wife) works together in the brick kiln industry by forming one unit. The results say that to make 1000 bricks, VS Pathera worker takes 990 minutes, which is 360 minutes more than government-recommended work time (Table 6.33).

The RB Pathera worker also takes 400 minutes extra. As per calculation, the Pathera worker can make 624 bricks within 10.5 hours of work duration. Therefore, the piece-rate basis minimum wage system should be lies on 624 bricks per day per person (Table 6.33).

In this context, it can be noted that SUN Pathera worker takes 560 minutes to make 1000 bricks due to the use of mechanisation. In SUN brick kiln industry, mud is prepared by the mechanised way in a centralised mud pool (Table 6.33).

Table 6.33: Comparison between Brick kiln Pathera work hours and government recommended work hours

Brick Kiln	Productivity (In Bricks)	Work Time (Min)		Total Time (Min)	Per Brick Time (Min)	Time requirement for 1000 bricks (Min)	Using Extra Time (Min)*
		Male	Female				
VS Pathera	1300	780	515	1295	0.99	990	(990-630) =360
RB Pathera	1500	890	660	1550	1.03	1030	(1030-630) =400
SUN Pathera	1200	690	NA	690	0.56	560	(560-630) = -70

*According to the Factories Act, a worker should not be required to work more than 9 hours a day, spread over 10.5 hours (630 minutes) due to rest periods.

6.9 Determination of Per Brick Energy and Time Cost

India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems and specific problems faced by the respective workers. More or less all Indian brick kiln industries have six types of worker, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. But the method of work is different based on social culture, geographical location, availability of raw material, availability of technology, awareness, kiln sizes, kiln output etc. To compare each work method among different brick kiln industries, the current research took the initiative to measure Per brick energy expenditure and per brick time cost by following formulae –

<u>For per brick time cost –</u>

$$\text{Per brick time cost} = \frac{\text{Work duration in min (including pause \& brake)}}{\text{Daily Output(in terms of bricks)}}$$

The per brick time cost of all sub-activities are converted in percentage (%) by the following formula –

$$Per\ Brick\ Time\ Cost\ percentage = \frac{Specific\ group\ Per\ brick\ time\ cost}{Sum\ of\ all\ six\ groups\ per\ brick\ time\ cost} \times 100$$

For per brick energy expenditure -

$$\text{Per brick energy expenditure (during work)} = \frac{\text{Work} - \text{related energy expenditure}}{\text{Daily Output (in number of brick)}}$$

The per brick energy expenditures of all sub-activities are converted in percentage (%) by the following formula –

$$Per\ Brick\ energy\ expenditure\ percentage = \frac{Specific\ group\ per\ brick\ energy\ expenditure}{Sum\ of\ all\ six\ groups\ per\ brick\ energy\ expenditure} \times 100$$

Table 6.34: Determination of per brick time cost and human energy expenditure in VS brick kiln Industry

VS Brick Kiln	Total Work Time (Min)	Work-related Energy Expenditure	Productivity (in Bricks)	Per Brick Time Cost (Min)	Per Brick Energy Expenditure (Kcal)
Pathera Male	780	2917.5	1300	0.99	3.64
Pathera Female	515	1808			
Bharai	570	2268	5000	0.11	0.45
Khadkan	540	2277	8000	0.07	0.28
Kiln Top Coverer	210	783	20000	0.01	0.04
Jalaiya	720	2430	8000	0.09	0.3
Nikashi Male	465	2034.5	4000	0.23	1
Nikashi Female	465	1998			

Table 6.35: Determination of per brick time cost and human energy expenditure in RB brick kiln Industry

RB Brick Kiln	Total Work Time (Min)	Work-related Energy Expenditure	Productivity (in Bricks)	Per Brick Time Cost (Min)	Per Brick Energy Expenditure (Kcal)
Pathera Male	890	3035	1500	1.03	3.37
Pathera Female	660	2024			
Bharai	540	2308	6000	0.09	0.38
Khadkan	540	2214	17500	0.03	0.13
Kiln Top Coverer	360	1318	35000	0.01	0.04
Jalaiya	720	2784	8750	0.08	0.32
Nikashi Male	480	2405	5000	0.19	0.9
Nikashi Female	480	2114			

Table 6.36: Determination of per brick time cost and human energy expenditure in SUN brick kiln Industry

SUN Brick Kiln	Total Work Time (Min)	Work-related Energy Expenditure	Productivity (in Bricks)	Per Brick Time Cost (Min)	Per Brick Energy Expenditure (Kcal)
Pathera	690	2453	1200	0.56	2.04
Bharai	600	2355	1250	0.48	1.88
Khadkan	600	1965	6000	0.1	0.33
Kiln Top Coverer	690	2289	6000	0.12	0.38
Jalaiya	720	1728	5000	0.14	0.35
Nikashi Male	630	2685	2000	0.32	1.34

The comparative analysis says that to make one single brick, VS (Table 6.34) and RB (Table 6.35) brick kiln Pathera workers take 0.99 minutes (or 59 seconds) and 1.03 minutes (or 63 seconds). But SUN (Table 6.36) brick kiln Pathera workers take only 0.56 minutes (or 34 seconds), which is almost half of the other two brick kiln. The reason behind less time requirement in SUN brick kiln industry is the use of mechanisation. The mud is prepared by mud making mechanisation system (locally known as 'Kolu') (Figure 6-2). Similar results also found for per brick energy expenditure study. The sun brick kiln Pathera workers use 2.04 Kcal human energy to make one single brick, which is less than the per brick energy expenditure by VS (3.64 Kcal) and RB (3.37 Kcal) Pathera workers. There is another interesting fact among VS and RB Pathera activity. In RB brick kiln industry, the Pathera worker makes mud in such a way (Figure 6-3); they don't need to transfer the mud from mud pool to moulding ground. By this technique, the RB brick kiln Pathera workers are eliminating the mud transfer activity by mud pool design concept and reduce per brick human energy expenditure during Pathera activity (brick moulding).

Figure 6-2: Mud mixing technique in SUN brick kiln industry, Bihar, India

Figure 6-3: Mud pool concept in RB brick kiln industry and VS brick kiln Industry

Bharai activity is another perfect example of the use of an assistive method, and technology can reduce human energy load as well as work time. VS, RB and SUN Bharai workers take 0.11 minute (7 seconds), 0.09 minutes (5 seconds) and 0.48 minutes (29 seconds) respectively, to transfer one single brick from moulding ground to inside the kiln. The SUN Bharai workers utilise higher human energy (1.88 Kcal) than rest two brick industry (VS-0.45 Kcal and RB-0.38 Kcal) to transfer one brick from moulding ground to inside the kiln. The reason behind time cost and energy expenditure discrepancy among different Bharai workers is assistive technology. In VS brick kiln worker use a tractor for transfer activity, and the RB brick kiln workers use a horse-driven cart for brick transfer. On the other side, SUN brick kiln worker use a bicycle, and they push the brick-loaded cycle manually towards the kiln from moulding ground (Figure 6-4). Therefore, the use of mechanisation or assistive support can reduce time requirement and human energy expenditure.

Figure 6-4: Bharai activity in the different studied brick kiln (Tractor Bharai, Horse driven Cart, Cycle Bharai)

The Khadkan work process, Kiln top covering work process and Jalaiya work process are similar in all three brick kilns. There are also minimal discrepancies with reference time requirement and energy consumption those are –

In VS brick kiln industry, Khadkan activity is not dependent on Bharai activity. Here, Bharai worker stacks the green brick on the kiln-ground but in RB and SUN brick kiln, the bricks are handed over from hand to hand from Bharai worker to Khadkan worker. This hand-to-hand brick transfer reduces the unnecessary frequent bending below the waist level (Figure 6-5).

Figure 6-5: Khadkan's work method in the different studied brick kiln (Khadkan Bending in VS, Hand to hand transfer in RB and SUN)

SUN kiln top coverer worker takes higher time and expenses more energy due to task allotment. In VS and RB brick kiln industry, the worker only covers the top of the kiln by red brick dust or rubbish. But in SUN brick kiln industry, the worker also does some extra activity like removing brick dust from the kiln top before Nikashi activity and cleaning the kiln ground after Nikashi activity.

Breaking the coal into smaller pieces is one important activity in all brick kiln industry. In SUN brick kiln industry, coal breaking process is done by the assistance of mechanical tools, jaw-crusher. But in the other two brick kilns, coals are broken into smaller pieces by manually with the help of a hammer.

In the brick manufacturing process, Nikashi is the last activity, where the red-bricks are transferred from the inside of a kiln to outside and stacks somewhere else for marketing. In VS brick kiln industry, the Nikashi worker uses a single-wheel-barrow. Usually, a female worker transfers about 32 while the male transfers about 50 number of bricks in each cycle. Apart from the wheel-barrow weight (say 15 kg) a load of 90 kg (2.8 kg X 32) for women per trip and that of 140 kg (2.8 X 50) for men gets to sink in the thick brick dust at the ground of the kiln while pushing. This causes very high resistance to push the cart. But in RB and SUN brick kiln industry, the bricks are removed from the kiln by head mode. The SUN brick kiln Nikashi workers use higher energy and take higher time due to different work terrain. The SUN brick kiln worker makes a temporary staircase to come out from the kiln trench with loaded bricks (Figure 6-6).

Figure 6-6: Different types of Nikashi activity in the studied brick kiln

Table 6.37: Per-brick time cost in three different studied brick kiln industry

Per Brick Time Cost	VS Brick Kiln		RB Brick Kiln		Sun Brick Kiln	
	Actual Value (Min)	Percentage Value (%)	Actual Value (Min)	Percentage Value (%)	Actual Value (Min)	Percentage Value (%)
Pathera	0.99	66%	1.03	72%	0.56	32.60%
Bharai	0.11	7.30%	0.09	6.30%	0.48	27.90%
Khadkan	0.07	4.50%	0.03	2.10%	0.1	5.80%
Kiln top coverer	0.01	0.70%	0.01	0.70%	0.12	7%
Jalaiya	0.09	6%	0.08	5.60%	0.14	8.10%
Nikashi	0.23	15.30%	0.19	13.30%	0.32	18.60%
Total	**1.5**		**1.43**		**1.72**	

Table 6.38: Per-brick energy expenditure cost in three different studied brick kiln industry

Per Brick Energy Cost	VS Brick Kiln		RB Brick Kiln		Sun Brick Kiln	
	Actual Value (Kcal)	Percentage Value (%)	Actual Value (Kcal)	Percentage Value (%)	Actual Value (Kcal)	Percentage Value (%)
Pathera	3.64	63.70%	3.37	65.60%	2.04	32.30%
Bharai	0.45	7.90%	0.38	7.40%	1.88	29.70%
Khadkan	0.28	4.90%	0.13	2.50%	0.33	5.20%
Kiln top coverer	0.04	0.70%	0.04	0.80%	0.38	6%
Jalaiya	0.3	5.30%	0.32	6.20%	0.35	5.50%
Nikashi	1	17.50%	0.9	17.50%	1.34	21.30%
Total	**5.71**		**5.14**		**6.32**	

The current study also took the initiative to measure the time cost of different brick kiln related activity for a single brick in the studied brick kilns. There are 66% of the time contribution from Pathera worker to make a single brick in VS brick kiln industry and followed by Nikashi (15%), Bharai (7%), Jalaiya (6%), Khadkan (5%) and Kiln top coverer worker (1%) (Figure 6-7).

But, in RB brick kiln industry, there are 72% of the time contribution from Pathera worker to make a single brick and followed by Nikashi (13%), Bharai (6%), Jalaiya (6%), Khadkan (2%) and Kiln top coverer worker (1%) (Figure 6-7).

But, in SUN brick kiln industry, there are 32% of the time contribution from Pathera worker to make a single brick and followed by Bharai (28%), Nikashi (19%), Jalaiya (8%), Kiln top coverer worker (7%) Khadkan (6%) (Figure 6-7).

There is a leaner relationship between time cost and energy expenditure. The percentage of energy expenditure of different brick kiln related activity for single brick in the studied brick kiln also following the same trend (Figure 6-8).

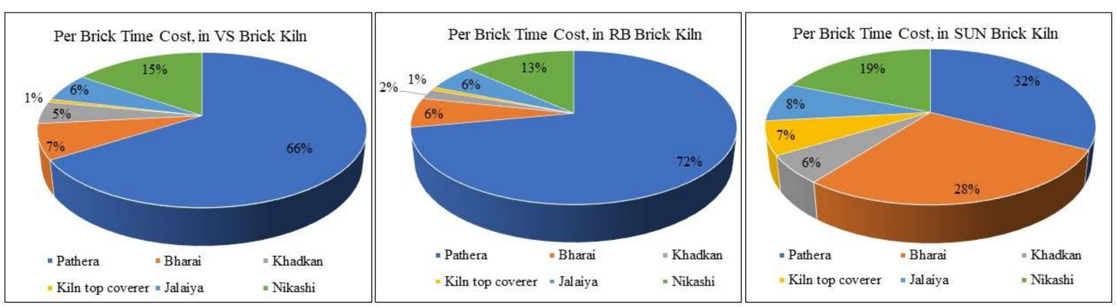


Figure 6-7: Percentage of time cost of different brick kiln related activity for single brick in the studied brick kiln

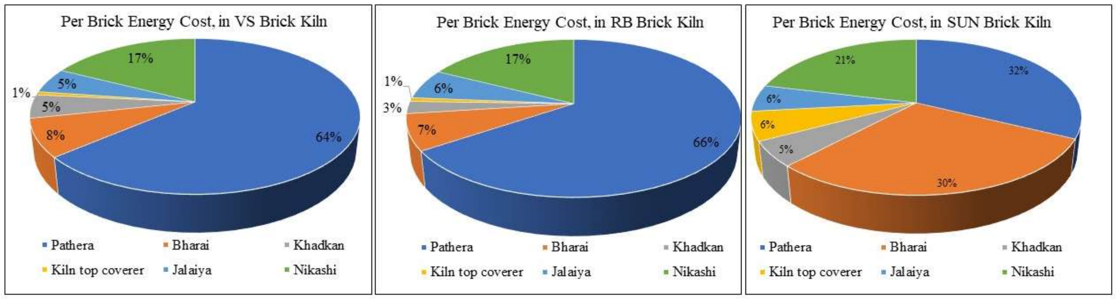


Figure 6-8: Percentage of energy expenditure of different brick kiln related activity for single brick in the studied brick kiln

6.10 Quantification of Physiological Stress among Brick kiln worker

In this section, the brick kiln worker's **physiological response** was measured in terms of their **working heart rate and relative cardiac cost** for each brick making activity. Working heart rate for all brick kiln related sub-activities were measured by using polar heart rate belt and monitor in three studied brick kilns. For the workload analysis study, the higher working heart rate value among the three studied brick kilns was selected for each work category. According to Sen et al., (1973) (for Male worker) and Varghese et al., (1994) (for Female worker), brick making activities are classified as light to extremely very heavy category.

The Net Cardiac Cost (NCC) was also calculated from working heart rate and resting heart rate by the following formula. The brick kiln worker has started their work in the early morning; therefore, it was difficult to measure the exact resting heart rate. The study assumed the resting heart rate of the brick kiln workers is 75 bpm^{-1}. The brick kiln activities also again classified according to Relative Cardiac Cost (RCC).

Working heart rate – Measured during activity

Resting heart rate (HR_{rest}) - 75 bpm^{-1} (assumed).

$$\mathbf{HRmax = 220 - Age} \text{ (Wilkins, 1995)}$$

$$\boldsymbol{Heart\ Rate\ Reserve\ (HRR) = Maximum\ Heart\ Rate - Resting\ Heart\ Rate}$$

$$\boldsymbol{Net\ Cardiac\ Cost\ (NCC) = Working\ Heart\ Rate - Resting\ Heart\ Rate}$$

$$\boldsymbol{Relative\ Cardiac\ Cost\ (RCC) = \frac{Net\ Cardiac\ Cost\ (NCC)}{Heart\ Rate\ Researve\ (HRR)} \times 100}$$

Pathera Worker

Digging Soil: In the process of brick moulding, the digging Soil is the first step. In VS & RB brick kiln, the earth soil was dug by male Pathera worker. It was observed that the mean working heart rate was 135 b.min^{-1}. As per Sen et al., Digging of soil falls under the heavy category. As per RCC, the digging of soil activity falls under the vigorous (heavy) category (Table 6.39).

Mud Making: In the process of brick moulding, the mud making is the fundamental and important operation for appropriate amalgamation of clay, salt, charcoal powder, water and rice husk which would then be used for the moulding of raw bricks. From Table 6.39, it was observed that the mean heart rates took a steep rise as the worker proceeded from resting to the shovelling activity during soil preparation and mud preparation. It was observed that the working heart rate was 135 b.min^{-1} and classified as heavy category. As per RCC, mud making falls under the vigorous (heavy) category.

Mud Transfer: From the Table 6.39, it can be observed that the heart rate took a steep rise when the men proceeded from resting to the shovelling activity for transferring the mud on to the cart followed by pushing it by using his core strength and inverting the cart at the moulding site. For mud-transferring activity, it was observed that the mean working heart rate was 142 b.min^{-1} during work. A similar steep rise was observed for the women, too while performing the shovelling activity as it was seen that mean working heart rate was 130 b.min-1 during work. Based on work-related heart rate, mud transfer job for the men and women both should be classified under heavy job. As per RCC classification, mud transfer is a vigorous job (Table 6.40).

Moulding: Moulding is a semi-skilled operation and requires long hours of work to give the required output. As per workload classification, moulding also falls under the heavy category (Table 6.39 and Table 6.40).

Stacking: From the table, it can be observed that the mean heart rate while performing the stacking activity was found to be 118 b.min-1 for men and women. Based on workload classifications, Stacking falls under the moderately heavy category for men and women (Table 6.39 and Table 6.40).

Ground Cleaning: Female workers did the ground cleaning activity in VS and RB brick kiln industry and male workers in SUN brick kiln industry. As per workload classification, ground cleaning activity falls under the light category for both men (SUN brick kiln) (Table 6.39) and women (VS & RB brick kiln) (Table 6.40).

Mud loading to the cart: In SUN brick kiln industry, mud making activity was done by mechanical assistance. After mixing, the mud was loaded to cart. As per workload classification, mud loading to cart activity falls under the heavy category (Table 6.39).

Table 6.39: Workload classification of Pathera male worker in studied brick kiln industries

Pathera Male Worker	HR (bpm^{-1})				Workload Classification (according to Working HR)	RCC				Workload Category (Intensity of work)
	VS	RB	SUN	Max		VS	RB	SUN	Max	
Digging of Soil	135	135	NA	135	Heavy	53	53	NA	53	Vigorous (Heavy)
Mud Preparation	134	135	NA	135	Heavy	52	53	NA	53	Vigorous (Heavy)
Mud Transfer	142	NA	145	145	Heavy	59	NA	64	64	Vigorous (Intense)
Moulding	130	135	128	135	Heavy	49	53	48	53	Vigorous (Heavy)
Stacking	118	118	119	119	Moderately Heavy	38	38	40	40	Vigorous (A little heavy)
Ground cleaning (SUN)	NA	NA	100	100	Light	NA	NA	23	23	Moderate (A little moderate)
Mud Loading to Cart (SUN)	NA	NA	143	143	Heavy	NA	NA	62	62	Vigorous (Intense)

Table 6.40: Workload classification of Pathera female worker in studied brick kiln industries

Pathera Female Worker	HR (bpm^{-1})					HR (bpm^{-1})				
	VS	RB	SUN	Max	Workload Category	VS	RB	SUN	Max	Workload Category
Mud Transfer	130	NA	NA	130	Heavy	49	NA	NA	49	Vigorous (A little heavy)
Moulding	126	126	NA	126	Heavy	44	46	NA	46	Vigorous (A little heavy)
Stacking	118	118	NA	118	Moderately Heavy	37	39	NA	39	Moderate (Moderate)
Ground cleaning	100	100	NA	100	Light	22	22	NA	22	Moderate (A little moderate)

Bharai

For Bharai worker, it was observed that the working heart rate 125 $b.min^{-1}$ during loading, unloading bricks and 130 $b.min^{-1}$ during carrying (in SUN brick kiln). Considering the working heart rate, Bharai activity falls under the moderately heavy to heavy category. As per the RCC workload classification, Bharai (pushing the bicycle) falls under vigorous activity (Table 6.41).

Table 6.41: Workload classification of Bharai worker in studied brick kiln industries

Bharai Worker	HR (bpm^{-1})				Workload Classification (according to Working HR)	RCC				Workload Category (Intensity of work)
	VS	RB	SUN	Max		VS	RB	SUN	Max	
Loading the bricks	122	122	125	125	Moderately Heavy	43	41	45	45	Vigorous (A little heavy)
Unloading the bricks	122	122	120	122	Moderately Heavy	43	41	41	43	Vigorous (A little heavy)
Carrying tractor (VS)/Horse Driven Cart (RB)/Cycle (SUN)	94	100	130	130	Heavy	17	22	50	50	Vigorous (Heavy)

Khadkan

For Khadkan worker, it was observed that the working heart rate 132 $b.min^{-1}$. Considering the working heart rate, it can be said that Khadkan activity falls physiologically under the heavy workload (Table 6.42).

Kiln top coverer

For the kiln top covering worker, it was observed that the mean working heart rate 125 to 130 b.min^{-1} during work. Considering the average working heart rate, this activity falls physiologically under moderately heavy to heavy category (Table 6.42).

Table 6.42: Workload classification of Khadkan and Kiln top coverer worker in studied brick kiln industries

Khadkan & Kiln Top Coverer Worker	HR (bpm^{-1})				Workload Classification (according to Working HR)	RCC				Workload Category (Intensity of work)
	VS	RB	SUN	Max		VS	RB	SUN	Max	
Khadkan										
Khadkan activity	132	120	115	132	Heavy	45	27	39	45	Vigorous (A little heavy)
Kiln Top Coverer										
Covering to the top by brick dust	130	130	128	130	Heavy	48	49	50	50	Vigorous (Heavy)
Removing Brick Dust (SUN)	NA	NA	125	125	Moderately Heavy	NA	NA	47	47	Vigorous (A little heavy)
Cleaning the kiln ground (SUN)	NA	NA	130	130	Heavy	NA	NA	51	51	Vigorous (Heavy)

Jalaiya is one crucial step in brick making activity. The Jalaiya worker controls the fire in the brick kiln industry. The Jalaiya worker also breaks the coal into smaller pieces and charge the coal through the peephole from the top of the kiln. In SUN brick kiln industry, coal breaking process is done by the assistance of mechanical tools, jaw-crusher. But in the other two brick kilns, coals are broken into smaller pieces by manually with the help of a hammer. As per workload classification, Fire control falls under the moderately heavy category. Coal breaking is a very heavy and laborious activity. It was observed that the working heart rate 137 b.min^{-1} during coal breaking activity, and as per workload classification, coal breaking activity falls under the heavy category (Table 6.43).

Table 6.43: Workload classification of Jalaiya worker in studied brick kiln industries

Jalaiya Worker	HR (bpm^{-1})				Workload Classification (according to Working HR)	RCC				Workload Category (Intensity of work)
	VS	RB	SUN	Max		VS	RB	SUN	Max	
Fire control	112	112	112	112	Moderately Heavy	34	39	36	39	Moderate (Moderate)
Coal breaking, carrying (For SUN, Only Carrying)	137	137	120	137	Heavy	57	53	43	57	Vigorous (Heavy)

In the brick manufacturing process, Nikashi is the last activity, where the red-bricks are transferred from the inside of a kiln to outside and stacks somewhere else for marketing. In VS brick kiln industry, the Nikashi worker uses a single-wheel-barrow. As per workload classification, Nikashi activities fall under the heavy to the very heavy category for both male and female workers (Table 6.44 and Table 6.45).

Table 6.44: Workload classification of Nikashi male worker in studied brick kiln industries

Nikashi Male Worker	HR (bpm^{-1})				Workload Classification (according to Working HR)	RCC				Workload Category (Intensity of work)
	VS	RB	SUN	Max		VS	RB	SUN	Max	
Removing of Brick Dust	137	135	NA	137	Heavy	55	52	NA	55	Vigorous (Heavy)
Loading in Cart (VS)/Head (RB & SUN)	135	155	135	155	Very Heavy	54	70	56	70	Vigorous (Intense)
Onward Movement	156	160	156	160	Very Heavy	74	74	75	75	Vigorous (Intense)
Stacking Red Bricks	136	154	136	154	Very Heavy	55	69	57	69	Vigorous (Intense)
Return Movement	133	125	100	133	Heavy	53	50	23	53	Vigorous (Heavy)
Cleaning the Kiln Ground	137	137	NA	137	Heavy	55	54	NA	55	Vigorous (Heavy)

Table 6.45: Workload classification of Nikashi female worker in studied brick kiln industries

Nikashi Female Worker	HR (bpm^{-1})					HR (bpm^{-1})				
	VS	RB	SUN	Max	Workload Category	VS	RB	SUN	Max	Workload Category
Removing of Brick Dust	137	130	NA	137	Very Heavy	55	48	NA	55	Vigorous (Heavy)
Loading in Cart (VS)/Head (RB & SUN)	137	150	NA	150	Very Heavy	55	48	NA	55	Vigorous (Heavy)
Onward Movement	167	155	NA	167	Extremely Very Heavy	81	70	NA	81	Vigorous (Intense)
Stacking Red Bricks	150	145	NA	150	Very Heavy	66	61	NA	66	Vigorous (Intense)
Return Movement	133	125	NA	133	Heavy	51	44	NA	51	Vigorous (Heavy)
Cleaning the Kiln Ground	137	135	NA	137	Very Heavy	55	53	NA	55	Vigorous (Heavy)

6.11 Quantification of Biomechanical / Postural Stress among Brick kiln worker

Almost for all the brick-making activities, the workers are compelled to take sustained forward trunk bending at the waist region (Lumbaro-sacral), that causes musculoskeletal disorder among them. Severe sustained back bending and musculoskeletal stress impose on the hip, knee and ankle joints in association with repetitive muscle force development in thigh, calf and foot muscles lead to biomechanical/postural stress. During entire brick making activities, the workers have to maintain sustained awkward posture and repetitiveness throughout work as the whole period. Therefore, biomechanically such work is highly detrimental in terms of neuro-muscular activity with possible lead towards spinal cord injury.

Pathera

Whether it is soil preparation or mud making, a high degree of sustained forward trunk bending in the waist region (Lumbaro-sacral) is the route of the cause of slipped disk phenomenon, backache and back pain. The study results also indicate the severe sustained back bending and musculoskeletal stress imposed on the hip, knee and ankle joints in association with repetitive muscle force development in thigh, calf and foot muscles during stomping during mud making. The workers have reported that after mud preparation, they become exhausted and need rest at least for half an hour to feel fresh. Apart from high physiological demand, mud transfer also demands good muscle strength. This causes an impact on the musculoskeletal system, especially on the wrist, arm, shoulder and back. Different safety gadgets like wrist band abdominal guard etc. can be introduced to prevent musculoskeletal disorders (MSD). The Pathera workers work in sustained squatting posture with repetitive nature throughout the entire brick-moulding work period. They work continuously minimum for 45 minutes to one hour. Loss of sensation in the lower leg during operation, fatigue in calf, thigh, and ankle are other associated features. Severe back, shoulder, arm pain are prevalent disorders as reported by all the workers.

The Pathera workers used to handle about 6 kg load per moulding operation, which included 1.34 kg weight for Aluminium mould plus 5.5 kg of mud. Each hand use to share about 3.0 kg with a frequency of 3.0 bricks per minute by male and 2.2 bricks per minute by female workers. Thus, a male and a female worker handle 18 and 13.2 kg, respectively per minute. The number of bricks produced per head per day ranges from 600 to 800. This leads to a minimum of 3750 kg of cumulative load handling by both hands a day which is practically beyond human limit. As the handling of mould is done by hand, palm and fingers, such heavy load handling during turning the mould likely to cause severe musculoskeletal stresses on the thumb, other fingers and wrist. The upper arm muscles, especially biceps, also get heavily loaded for lifting and holding operation of the mould with mud (Table 6.47).

It was observed that in every stage of brick moulding REBA score was ten (10) or more than that (Table 6.46). The REBA analysis also suggested for an immediate change of posture. Changes in tool design are immediately recommended. Based on posture evaluation scores from direct observations it was clear that adoption of sustained squatting posture and moulding the bricks by forwarding bending, for hours after hours throughout the day, under high thermal load condition in the field is very detrimental for the workforce. The sustained high degree of bending posture is the most detrimental posture observed during the raw bricks stacking activity. Though small, but handing dry raw bricks, average weight 3.0 kg per brick, in sustained repetitive manner causes a cumulative load of 2250 kg (3 kg X 750 bricks) just for this transfer job. Human anatomy is not designed for such heavy manual load handling (Table 6.47).

Bharai

Arrangement of bricks during Bharai activity demands highly repetitive below waist bending work for the loading and unloading of the brick activity. Therefore, biomechanically such work is highly detrimental in terms of neuro-muscular activity with possible lead towards spinal cord injury (Table 6.46 and Table 6.47).

Khadkan

The total output of VS brick kiln industry is 40,000 bricks per day. There was 5 number of Khadkan workers engaged in this work. Every single worker arranged near about 8,000 bricks per day. To arrange the bricks, they had to adopt bending posture very frequently of approximately 1333 times a day, considering two breaks are being handled per bending and number of bends will be 1/3 number of the total number of bricks (For VS Brick kiln). This repetitive bending posture creates a severe musculoskeletal problem, especially in the lower back, neck, hip and knee joints as reported by the workers. The entire process of brick arrangement was divided into certain components for postural assessment. Different standardised methods were applied to assessing the risk factors associated with this job. REBA score was ten (10) or more than 10, indicating corrective action, and further assessment is immediately required. Based on posture evaluation scores and from direct observations, it was clear that such high-frequency repetitive bending posture for hours after hours throughout the day, and days after days, is highly detrimental for the workforce. Shifting of load in high frequency is the next imperative cause of the musculoskeletal disorder. Considering the average weight of each sun-dried raw brick is of 3 kg, which is handled for shifting 8,000 bricks a day causes a cumulative load handling of 24,000 kg per day. This high volume of load handling days after days leads to localised musculoskeletal disorders/injuries as evident from the high degree of body ache/body pain discomfort rating of the workers (Table 6.46 and Table 6.47).

Kiln top coverer

To cover the bricks with red brick dust, the Kiln-top-coverer need to adopt a bending posture very frequently. This repetitive bending posture creates musculoskeletal problems, especially in the neck, lower back, hip and knee joints. The entire process of brick kiln covering was assessed based on work posture. Based on postural evaluation scores and from direct observations, it was clear that such sustained bending posture is highly detrimental for the workforce by causing MSD in the lumbero-sacral, shoulder and hip joints. The environmental heat stress will be the added factor for further exaggeration of the problem. Changes in work posture and associated with the redesign of tools need immediate attention. Shovelling of load in high frequency is the second cause of the musculoskeletal disorder. This volume of load handling days after days leads to localised musculoskeletal disorders/ injuries as evident from the body ache/body pain discomfort rating of the workers (Table 6.46 and Table 6.47).

Nikashi

Manual handling of load by using a cart/head is one of the significant biomechanical issues for nikashi activity. The high physiological demand, as recorded in this study, coupled with the body ache/body pain report expressed by the workers, leads towards a strong possibility of WMSDs. Apart from backache, back pain, shoulder pain, pain in thigh and calf are also prominent in this operation. Generation of high pushing force as against the ground condition may be the reason for that.

Frequent bending coupled with twisting trunk also leads to severe back pain, and if this work posture allows being continued, it will lead to severe spinal cord injury. In this case, workers follow the same work posture, which might be another cause of backache, back pain. Frequent load handling during brick stacking is further additive factors related to localised MSD. The REBA method also suggests for immediate intervention based on ergonomics principle (Table 6.46 and Table 6.47).

Table 6.46: Postural analysis among brick kiln workers in studied brick kilns

Brick kiln	**REBA Analysis**	**Pathera**			**Bharai**	**Khadkan**	**Jalaiya**	**Nikashi**
		Mud Preparation	Mud Transfer	Moulding				
VS Brick Kiln	REBA Score	10	8	12	10	10	10	8
	REBA Action Category	High risk, investigate and implement change	High risk, investigate and implement change	Very high risk, implement change	High risk, investigate and implement change	High risk, investigate and implement change	High risk, investigate and implement change	High risk, investigate and implement change
RB Brick Kiln	REBA Score	10	NA	12	10	10	10	9
	REBA Action Category	High risk, investigate and implement change	NA	Very high risk, implement change	High risk, investigate and implement change	High risk, investigate and implement change	High risk, investigate and implement change	High risk, investigate and implement change
SUN Brick Kiln	REBA Score	2	9	12	10	10	7	9
	REBA Action Category	Low risk, change may be needed	High risk, investigate and implement change	Very high risk, implement change	High risk, investigate and implement change	High risk, investigate and implement change	Medium risk, further investigation, change soon	High risk, investigate and implement change

The brick kiln workers need to handle high-intensity load every day. From the MMH viewpoint, the workers dealt with a high level of repetitive load, shown in Table 6.47, which is higher than recommended NIOSH guideline (RWL-51 lb/23 kg).

Table 6.47: Load handled during various brick kiln activities

Activity	Brick Kiln	Tool Weight (kg) (a)	Mud or Brick Weight (kg) (b)	Total Weight (kg), (a+b)	No of Trip /Output	Load Handled (kg)
Mud Transfer	VS	20	120	140	50 trips	7000
	RB	-	-	-	-	-
	SUN	50	300	350	33 trips	11500
Moulding	VS	1	4	5	Male: 750, Female: 550	Male: 3750. Female:2750
	RB	1.5	4	5.5	1500	Male: 8250, Female 6000
	SUN	1.25	5.25	6.5	1200	7800
Stacking	VS	-	3	3	Male: 750, Female: 550	Male: 2250, Female 1650
	RB	-	3	3	Male: 1500, Female 1500	Male: 4500. Female 4500
	SUN	-	4.45	4.45	1200	5340
Bharai	VS	-	3	415	13 trips	16185
	RB	-	3	300	20 trips	18000
	SUN	-	4.45	40	37 trips	6586
Khadkan	VS	-	3	8000	-	24000
	RB	-	3	17500	-	51000
	SUN	-	4.45	6000	-	26700
Nikashi	VS	20	Male: 125, Female: 80	Male: 145, Female100	48 trips	Male: 6960, Female 4800
	RB	-	Male: 37.8, Female:32.4	Male: 37.8, Female 32.4	192 trips	Male: 7257. Female 6221
	SUN		3.8	10	200 trips	7600

6.12 Quantification of Psychological Stress among Brick kiln worker

Psychological well-being has a severe impact on the overall well-being and is linked to physical health and happiness of the employees. There are many factors directly or indirectly associated with overall psychological wellbeing of the employees, such as occupational stress, self-esteem, work-life balance and mental health. Increased workloads, long work hours, overtime, hostile work environments etc. are the causes of stressful working conditions. The psychosocial stress & strain were due to long working hours, lower wages, job uncertainty, repetitive work, job-dissatisfaction. Repetitive work at the brick kiln might be responsible for anxiety, frustration, job-dissatisfaction, job-uncertainty among the brick kiln workers. Brick kiln workers don’t have any fixed monthly salary (Except Jalaiya and Khadkan Worker). They get wages on a piece-rate basis. Moulding workers get wages on the number of bricks they made per day (excluding defective bricks). Bharai and Nikashi workers get wages based on numbers of bricks they transfer. Everyday brick kiln workers have to achieve the target to get the minimum amount of wages. This uncertainty creates high psychological stress among brick kiln workers. Perceived Stress Scale (PSS) was applied to measure psychological stress among the brick kiln workers. Table 6.48 shows that Pathera and Nikashi are medium-level psychologically stressful job. Bharai, Khadkan and Jalaiya are lower-level stressful job. Khadkan and Jalaiya have fixed monthly wages; this might be the reason for lower psychological stress.

Table 6.48: Psychological stress score of different job in the studied brick kilns

Activity	PSS, VS Brick kiln	PSS, RB Brick kiln	PSS, SUN Brick kiln	Overall PSS
Pathera	16	16	16	16
Bharai	13	12	13	13
Khadkan	9	10	8	9
Jalaiya	9	10	8	9
Nikashi	16	16	16	16

6.13 Quantification of Environmental Stress among Brick kiln worker

In summer seasons, the brick kiln workers are affected by working environments hotter than that with which human physiological mechanisms can cope. The Wet Bulb Globe Temperature (WBGT) assess the proportion of a working hour during which a worker can sustain work and the proportion of that same working hour that (s)he needs to rest to cool the body down and maintain core body temperature below 38°C. Using this proportion, a 'work capacity' estimate was calculated for selected heat exposure levels and work intensity levels.

If cooling via sweating and convection (via contact with cooler air and air movement) is not sufficient, the metabolic heat generation needs to be reduced to avoid heat strain and heat stroke. This creates limits to the extent to which physical activity and work output can be maintained without rest periods. When physical activity is high in a hot working environment, the worker is at risk of increased core body temperature (above 38^{0}C), diminished physical work capacity, decreased mental task ability, increased accident risk and eventually heat exhaustion or heat stroke. Symptomatic exhaustion and clinical diseases, particularly kidney disease, can be the result of excessive dehydration. When body temperature exceeds 39^{0C}, acute heat disorders (heat stroke) may occur, and above 40.6^{0}C life-threatening 'severe hyperpyrexia' starts to happen.

Indian traditional brick kiln industries are established under the open sky. Therefore, kiln workers are doing their work under environmentally stressful conditions. During the winter season, the workers are suffered in negative heat stress; on another side, during the summer, they are sustained in positive heat stress. The WBGT index was measured by using a standardised formula (Table 6.49). The Jalaiya workers, who control the kiln temperature, fall under a vulnerable situation, especially during the summer season. Inside the kiln, the temperature lies near about 900^{0}C to 1100^{0}C and on the top of the kiln, Globe temperature remains near 55^{0}C to 65^{0}C. During the summer season, the WBGT Index falls between 21.7^{0}C to 30.4^{0}C. The WBGT Index in top of the kiln is 47.4^{0}C. Most of the brick kiln activities fall under heavy workload category. As per work-rest recommendation, in the summer season, brick kiln activity needs 50% work and 50% rest (Table 6.50). As the WBGT Index is very high (47.4^{0}C) for Jalaiya worker, therefore, no job is recommended during that high temperature.

Table 6.49: Environmental stress (WBGT index) in Gujarat & Bihar during winter & summer season

Season	Measurement time	WBT (^{0}C)	DBT (^{0}C)	GT (^{0}C)	WBGT Index (^{0}C)
Winter Season	Morning	15.2	18.2	22	16.8
	Noon	18	22	24	19.6
	Afternoon	18.5	22	22	19.5
Summer Season	Morning	20	25	26	21.7
	Late Morning	23.5	33	37	27.2
	Noon	24	37.5	43	29.2
	Afternoon	26	38	42	30.4
	Evening	24	38.5	42	29
Top of the kiln	Noon	45	49	55	47.4

Table 6.50: Work-Rest Recommendation according to environmental stress

Worker	Highest WBGT Index	Heat Stress Category	Workload Category (according to HR)	Recommendation
Pathera	30.4	Category 3/Yellow Zone	Heavy	50% work and 50% rest
Bharai	30.4	Category 3/Yellow Zone	Heavy	50% work and 50% rest
Khadkan	30.4	Category 3/Yellow Zone	Heavy	50% work and 50% rest
Kiln top coverer	30.4	Category 3/Yellow Zone	Heavy	50% work and 50% rest
Jalaiya	47.4	Category 5/Black Zone	Heavy	No work at all (100% rest)
Nikashi	30.4	Category 3/Yellow Zone	Very Heavy	50% work and 50% rest

6.14 Development of P-P-P-E method

The results **recommended for ergonomic design interventions** to make the work more ergonomic. The brick kiln workers are exposed to physiological, postural, psychological and environmental stresses simultaneously, due to their nature of work. Therefore, it is important to identify the most severe pain, where design intervention can be focused on. The current study is taking the initiative to combine the **P**hysiological, **P**ostural, **P**sychological and **E**nvironmental stress. The combined method, **P-P-P-E method** (first letter of all four-individual stresses) will give the design direction in the Indian context. RCC, REBA, PSS & WBGT index methods were selected for the above purpose.

In statistical modelling, regression analysis is a set of statistical processes for estimating the relationships between a dependent variable (often called the 'outcome variable') and one or more independent variables (often called 'predictors', 'covariates', or 'features'). The regression analysis is widely used for prediction and forecasting. The regression analysis can be used to infer causal relationships between the independent and dependent variables. To predict the relationship between Physiological, Postural, Psychological and Environmental stress, Rating of perceived exertion: Borg scale is used to determine overall discomfort.

6.14.1 Overall Discomfort

The Borg's Rated Perceived Exertion (RPE) method was applied among the brick kiln workers to understand the overall stress. The results are shown in Table 6.51.

Table 6.51: Overall discomfort among the brick kiln workers

Activity	RPE, VS Brick kiln	RPE, RB Brick kiln	RPE, SUN Brick kiln	Maximum
Pathera	18	19	15	19
Bharai	14	15	17	17
Khadkan	11	13	11	13
Jalaiya	10	11	10	11
Nikashi	16	17	18	18

6.14.2 Design Direction Guideline – P-P-P-E Method

The results **recommended for ergonomic design interventions** to make the work more ergonomic. The brick kiln workers are exposed to physiological, postural, psychological and environmental stresses simultaneously, due to their nature of work. Therefore, it is important to identify the most severe pain, where design intervention can be focused on. To develop a combined method, one method selected from each category, i.e. Physiological, Postural, Psychological and Environmental stress analysis, keeping in mind that the application of method chosen should be straightforward, effortless and applied by locally available instruments. The accepted methods should be used by designers, engineers or industry management (novice/non-expert in ergonomics). The current study is taking the initiative to combine the **P**hysiological, **P**ostural, **P**sychological and **E**nvironmental stress. The combined method, **P-P-P-E method** (first letter of all four-individual stresses) will give the design direction in the Indian context. RCC, REBA, PSS & WBGT index methods were selected for the above purpose.

6.14.3 Calculation of Standardisation Factors

Standardised scores are more suitable measures than raw scores as they allow the researcher to be compared with other scores. Generally, tests are standardised so that the average, standardised score automatically comes out as 100, irrespective of the difficulty of the test. As standardised scores are transformed into a standard scale, they enable meaningful comparisons between scores from other standardised tests. Standardised scores from most tests cover the same range. The lower limit and upper limit of the scores are different for above-said methods. Therefore, the standardisation factor was calculated (Table 6.52) from the upper and lower limit.

Table 6.52: Calculation of standardisation factor

Method Name	Lower limit	Upper limit	Difference	Standardisation factor
RCC	1	100	100	100/100 = 1
REBA	1	12	12	100/12 = 8.3
PSS	0	40	41	100/41=2.44
WBGT Index	1	45	45	100/45=2.22

6.14.4 Standardisation of Scores

Standardisation of RCC, REBA, PSS and WBGT scores was done by multiplying the standardisation factors with the raw scores (Table 6.53).

Table 6.53: Standardization of scores

Brick Kiln	RCC	REBA	PSS	WBGT Index	Standardised RCC	Standardised REBA	Standardised PSS	Standardised WBGT Index
Mud Prep.	53	10	16	30.4	53	83	39	67
Mud Transfer	64	9	16	30.4	64	75	39	67
Moulding	53	12	16	30.4	53	100	39	67
Bharai	50	10	13	30.4	50	83	32	67
Khadkan	45	10	9	30.4	45	83	22	67
Jalaiya	39	10	9	47.4	39	83	22	100
Nikashi	81	9	16	30.4	81	75	39	67

6.14.5 Calculation of Weightage Factor on Overall Stress Feeling

To understand the proportionate values of different stress, on overall stress, a statistical regression analysis was performed by using SPSS statistical software. RCC, REBA, PSS and

WBGT index were used as independent scores, and the overall stress (Borg's score) was considered as the dependent score. From the regression equation, the weightage factors of physiological, postural, psychological and environmental stresses were determined. The derived regression equation is shown below –

RPE = -4.568 + 0.082*RCC + 1.032*REBA + 0.022*PSS + 0.157*WBGT index

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WBGT, REBA, RCC, ...[b]	.	Enter

a. Dependent Variable: RPE

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991[a]	.983	.982	.213

a. Predictors: (Constant), WBGT, REBA, RCC, PSS

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	173.852	4	43.463	960.192	.000[b]
	Residual	3.033	67	.045		
	Total	176.885	71			

a. Dependent Variable: RPE

b. Predictors: (Constant), WBGT, REBA, RCC, PSS

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-4.568	.337		-13.570	.000
	RCC	.082	.002	.833	36.614	.000
	REBA	1.032	.027	.821	38.342	.000
	PSS	.022	.009	.059	2.389	.020
	WBGT	.157	.003	.976	47.955	.000

a. Dependent Variable: RPE

From standardised coefficients value, the weightage factors measured by the following methods.

For RCC, standardized coefficients = 0.833

For REBA, standardized coefficients = 0.821

For PSS, standardized coefficients = 0.059

For WBGT index, standardized coefficients = 0.976

Therefore, Weightage factor, RCC

= standardized coefficients of RCC/ (summation all 4 standardized coefficients)

= 0.833/ (0.833+0.821+0.059+0.976)

= 0.833/2.689

= 0.3

Same way,

Weightage factor, REBA = 0.3

Weightage factor, PSS = 0.1

Weightage factor, WBGT index = 0.3

6.14.6 Determination of P-P-P-E score

Physiological stress component, Postural stress component, Psychological stress component and Environmental stress component were calculated by multiplying P-P-P-E weightage factor (Table 6.54).

Table 6.54: Calculation of P-P-P-E score

Brick Kiln	Standardised RCC	Standardised REBA	Standardised PSS	Standardised WBGT	PPPE – RCC score	PPPE – REBA score	PPPE – PSS score	PPPE – WBGT score
Mud Prep.	53	83	39	67	15.9	24.9	4	20
Mud Transfer	64	75	39	67	19.2	22.5	4	20
Moulding	53	100	39	67	15.9	30	4	20
Bharai	50	83	32	67	15	24.9	3.2	20
Khadkan	45	83	22	67	13.5	24.9	2.2	20
Jalaiya	39	83	22	100	11.7	24.9	2.2	30
Nikashi	81	75	39	67	24.3	22.5	3.9	20

From the P-P-P-E score, the brick-making jobs were prioritised according to stress. As per P-P-P-E score (shown in Table 6.55), Brick moulding (Pathera) and Jalaiya are the most strenuous job. The Pathera workers are suffering unbearable postural stress, and P-P-P-E score suggests for design intervention to improve the posture. As per P-P-P-E score, the Jalaiya workers are suffering under high environmental heat stress, when they work on the top of the kiln and P-P-P-E score suggests designing the personal protection equipment to reduce thermal stress.

Table 6.55: Prioritisation of the brick-making activities as per P-P-P-E score and design direction guidelines

PPPE Score	Physiological component	Postural component	Psychological component	Environmental component	Highest PPPE Score	Rank
Mud Prep.	15.9	**24.9**	4	20	24.9 (Postural)	2
Mud Transfer	19.2	**22.5**	4	20	22.5 (Postural)	3
Moulding	15.9	**30**	4	20	30 (Postural)	**1**
Bharai	15	**24.9**	3.2	20	24.9 (Postural)	2
Khadkan	13.5	**24.9**	2.2	20	24.9 (Postural)	2
Jalaiya	11.7	24.9	2.2	**30**	30 (Environment)	**1**
Nikashi	**24.3**	22.5	3.9	20	24.3 (Physiological)	4

P-P-P-E Score Sheet

Evaluator Name: ……………………, Name of the Unorganised Sector: ………………………………, Address: ……………………………………………………, Date: ……………………………………

Activity Name	Raw Score				Standardised Score = (Raw Score * Standardised factor)				PPPE Score = (Standardised Score * PPPE weightage factor)				Highest PPPE Score	Most dominating stress
	RCC	REBA	PSS	WBGT Index	RCC	REBA	PSS	WBGT Index	RCC	REBA	PSS	WBGT Index		
					=(Raw score*1)	=(Raw score*8.3)	=(Raw score*2.44)	=(Raw score*2.22)	=(Standardised score*0.3)	=(Standardised score*0.3)	=(Standardised score*0.1)	=(Standardised score*0.3)		
1 ………														
2 ………														
3 ………														
4 ………														
5 ………														
6 ………														
7 ………														

PPE Score: Design Intervention Direction	
Higher Physiological Stress: 20 – 30 = High physiological stress 10 – 20 = Medium physiological stress 0 – 10 = Low physiological Stress	Introduce mechanised design intervention
Higher Postural Stress: 20 – 30 = High postural stress 10 – 20 = Medium postural stress 0 – 10 = Low postural Stress	Concentrate on Hand tool design and improve posture
Higher Psychological Stress: 20 – 30 = High psychological stress 10 – 20 = Medium psychological stress 0 – 10 = Low psychological Stress	Job rotation, Training, Improve the relation between work and worker
Higher Environmental Stress: 20 – 30 = High environmental stress 10 – 20 = Medium environmental stress 0 – 10 = Low environmental Stress	Environmental stress-specific design intervention to reduce environmental stress

Figure 6-9: Sample PPPE score sheet

6.14.7 Validity and Reliability of P-P-P-E Method

The P-P-P-E scores are derived from standard popular ergonomic methods. Standardisation and weightage factors calculation are done by using standard statistical methods. Therefore, the reliability of the PPPE method is acceptable.

6.15 Recommendations or Design Intervention Guideline from P-P-P-E Method

The results of P-P-P-E method says that Brick moulding (Pathera worker) and Temperature control (Jalaiya worker) are two stress dominating activity. Both the activity scored 30 out of 30 in terms of P-P-P-E scores. Considering the Indian context below are suggested design intervention (from Table 1.2: The dominating stress and suggested design intervention, Chapter 1: Introduction) for brick moulding and temperature control activity.

Brick moulding - Change the posture towards neutral posture. Generally, posture is adopted due to tools. Therefore, redesign the tools that help to adopt an ergonomic posture.

Temperature control - Make the environment ergonomically good. Reduce environmental stress by using personal protective equipment (PPE).

6.16 Design Intervention

As per PPPE score, Moulding (Pathera) and brick-firing (Jalaiya) are more strenuous job. PPPE score also suggests the possible design intervention to reduce the postural stress (for Pathera workers) and environmental stress (for Jalaiya workers).

6.16.1 Design Intervention on Brick Moulding Activity

Before forwarding for design intervention for brick moulding activity, the brick-moulding process and problem among brick moulding activity are highlighted below.

6.16.1.1 Description of Moulding Activity

Moulding is an essential part of brick making process, which includes six sub-processes like, 1.making a sizable portion of mud (a good mixture of clay, water, coal dust, rice husk and salt) for the mould, 2.rolled in the sand and thrown to the mould, 3.excess mud is discarded, and sand is spread above the mould, 4.the mould with mud is taken to the site, and 5.the mould is turned upside down by the help of fingers of both hand so that the soften brick comes out of the mould and 6.the mould is again used for a new brick making (Figure 6-10).

6.16.1.2 Problem Identification

For casting bricks, a MOULD is essential. The mould used by the workers is a hollow rectangular cube made of aluminium, steel or wood with weighing 1kg to 1.5 kg as shown in Figure 6-11. Moulding is a repetitive and continuous work performed in awkward squatting posture in which a load of around 6 kg (mud plus mould) is handled each time by finger and wrist of both hands with a frequency of 3 bricks per minute. This leads to a total load handling equivalent to 18 kg per minute at a stretch for a minimum half-hour to forty-five minutes. A person in average makes 1000 bricks a day, depending on the kiln size. Taking it on the minimum side, a worker handles minimum 6000 kg of cumulative load by both hands a day. In every brick making cycle, they use the thumb for generating the force, and remaining fingers as a pivot to topple the mould so that the brick comes easily, as shown in Figure 6-10.

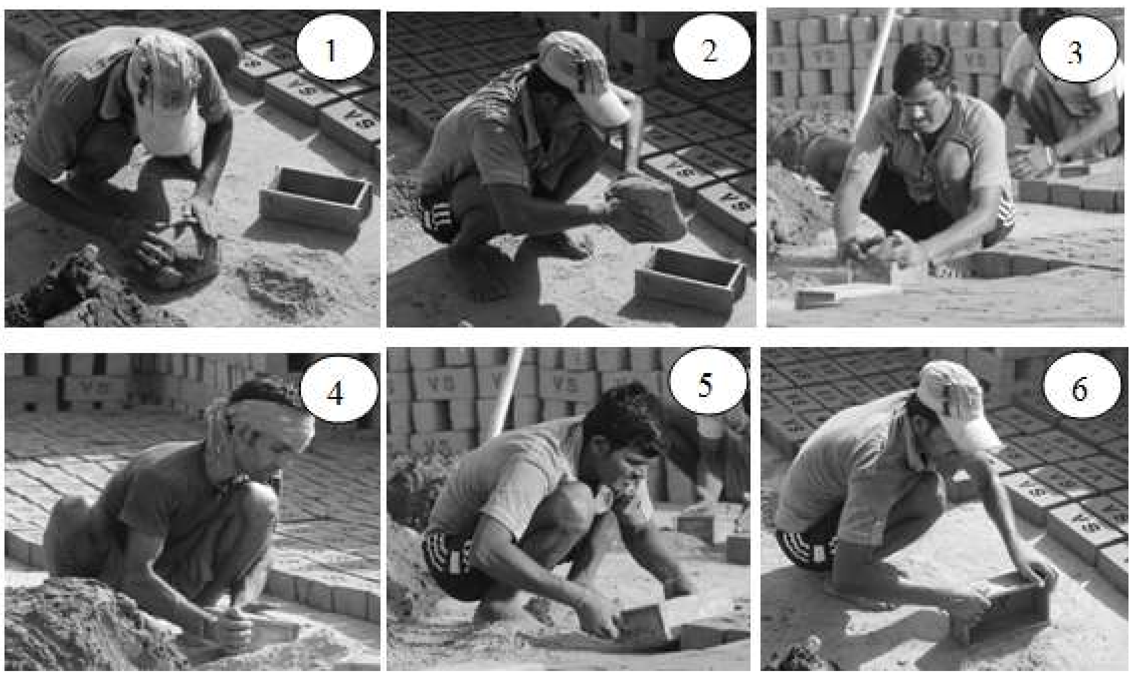


Figure 6-10: Steps of brick moulding

Figure 6-11: Different types of brick-moulding tool

6.16.1.3 Joint Angle Study

During moulding, a high range of wrist movement at the rate of three movements per minute is seen among the brick-moulding workers as depicted in Figure 6-12. This unnatural degree of wrist bending ($32.78^{o} \pm 12.84^{o}$), as shown in Table 6.56, mostly consists of ulnar deviation, which in turn causes more adverse Musculoskeletal-disorder (MSD) effect on worker's health, especially at wrist joint movement.

Table 6.56: Deviation of the wrist during moulding activity of different workers

Parameters	**Deviation Angle**						
Type of Deviation	Radial Deviation (N=3)			Ulnar Deviation (N=3)			Average Deviation (Mean ± SD**)**
Deviation Angle	25^{0}	27^{0}	36^{0}	24^{0}	20^{0}	27^{0}	$32^{0} \pm 13^{0}$

Figure 6-12: Degree of wrist bending during moulding activity of different workers

This long-time awkward squatting posture makes a serious injury in workers spinal cord. At the time of interaction with the workers, they were complaining about lower back pain along with thigh, calf and ankle. The centre of gravity (CG) was shifted to backward from his/her normal posture due to squatting posture. Sometimes they feel numbness due to continuous stress in muscle.

6.16.1.4 Recommendation from P-P-P-E Method

The results of P-P-P-E method says that Brick moulding (Pathera worker) is pastorally a stressful activity, and recommended to change the working posture towards to neutral posture. The current study took the initiative to improve the posture at the local level (i.e. wrist posture) as well as in system-level (whole-body posture).

Posture: Posture is the position in which a human holds his/her body upright against the forces of gravity while standing or sitting. Good posture is the correct alignment of body parts supported by the right amount of muscle tension against gravity. The good posture is a position where the least strain is placed on supporting muscles and ligaments during weight-bearing activities.

Neutral posture: The posture when the joints are not bent, and the spine is aligned and not twisted. Working in neutral postures is always preferable than to work in twisting or squatting the back or bending the wrists.

The neutral posture supports the natural curves of the spine and maintains the body in good alignment. This position will give the biochemical advantages to do certain things along with work or long sitting time. The stress on the musculoskeletal system can be reduced. In the 1980s, NASA developed the Man-System Integration Standards (MSIS), a set of guidelines for neutral body posture, based on anthropometry and biomechanics (shown in Figure 6-13) (NASA, 1980 (retrieved 2015)).

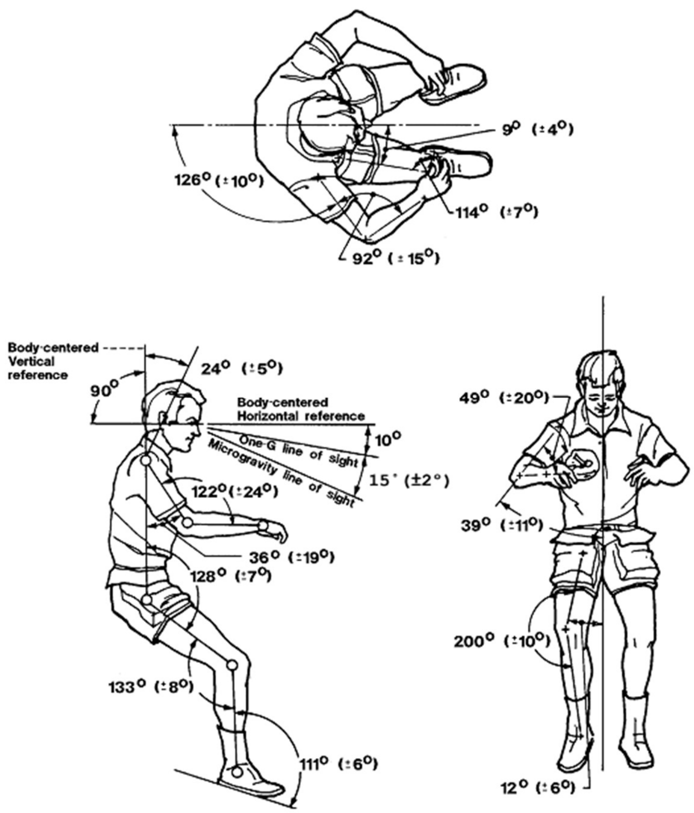


Figure 6-13: An averaged neutral body position as defined in Man-System Integration Standards (MSIS), NASA

Sitting-Standing Posture Concept: A sit/stand workstation allows users to easily alternate between working from a seated position to a standing position. Brick moulding is a prolonged activity, which needs a long time to fulfil the target. Therefore sitting-standing posture (Figure 6-14) is the best solution to improve the posture of brick moulding workers.

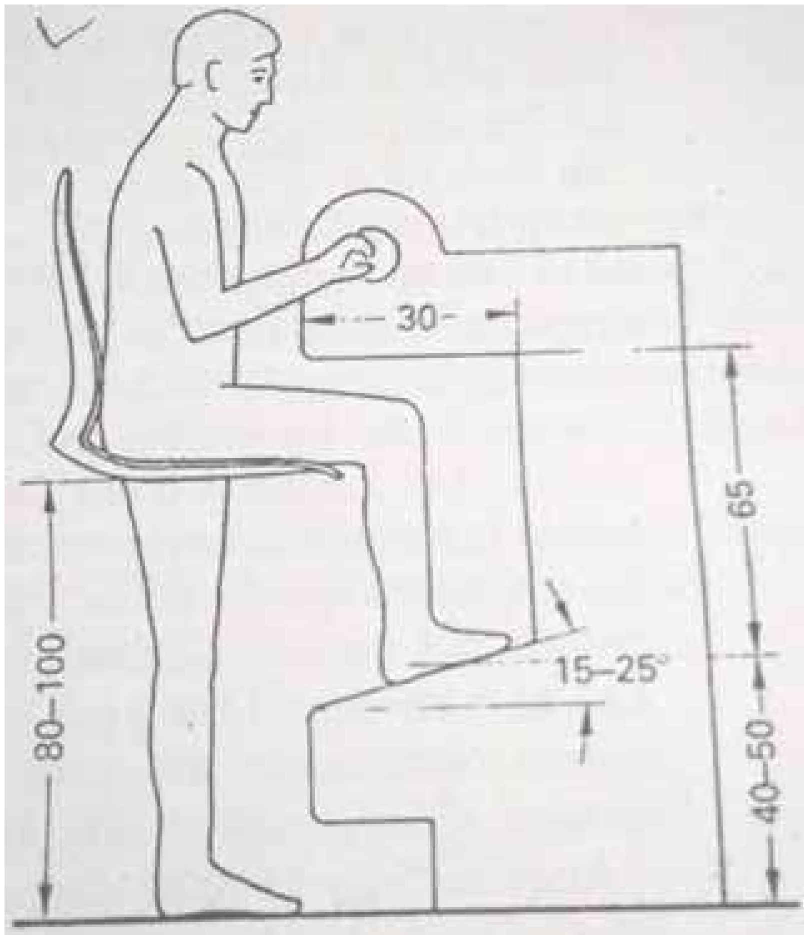


Figure 6-14: Sitting-Standing posture concept

6.16.1.5 Design Intervention: Mould Design

Based on anthropometric data, different conceptual models of the mould were developed by using solid works CAD software. The CAD drawing was then converted to a full-scale prototype for stimulation study. The new concept was designed and fabricated with proper gripping for moulding activity. The new mould design will increase productivity by delaying postural fatigue (Figure 6-15).

Figure 6-15: Prototype & Solidworks (3D) model with additional grip and high fillet and Actual field testing of prototype

6.16.1.6 Design Intervention: Moulding Workstation Design

The worker handled more than 6kg load at every time with a squatting posture. They are feeling more pain in lower back, thigh, hip, calf and ankle due to awkward posture. Current study says that the workers need to change their posture. Ergonomically this is a comfortable working posture in which our joints are naturally aligned. Working with the body in a neutral position reduces stress and strain on the muscle, tendons, and skeletal system and reduces the risk of developing a musculoskeletal disorder (MSD). The **sitting-standing posture** will be the best way to overcome the postural stress.

6.16.1.7 Design Intervention: Pallet Concept

Concept: The pallet concept consists of 9 brick mould with 3X3 distribution. The mould should be able to make nine (9) bricks in a batch, directly on the pallet provided underneath. The pallets are supplied by co-worker through the roller bed situated underneath the feed table. The mould is placed once the pallet is secured at the moulding area and mud is dragged over the mould by the people associated with the moulding activity. The mud is also supplied by a co-worker, whose duty is to load the mud from ground to the table. The mould is sprayed with water and one by one each mould is filled by hands. Once every mould is filled and evened a roller, or a stamping plate is used to stamp the logo on the bricks. After stamping the roller is taken away and the mould is lifted by pulley action, and the tray is slid towards the trolley loading area where a person is ready to shift the pallet on the trolley and take it away for drying.

Material: The mechanisms serve as the key element in lifting the mould upwards to mould bricks on the table by use of gravitational force. The mould is open-ended so that its easier for the person to fill the mould and de-mould the brick on the tray directly.

Mechanism: The type of mechanisms which can be used based on the type of load-bearing capacity, load output, the motion of the load, continuous or intermittent motion. This type of mechanism can be used for actuating the mould up and down by using foot since leg has more muscles compared to the hands and even body weight can be applied to push the pedal downs it makes it a lot easier for the person to operate the machine and gives more freedom to its hands so that he can perform other works simultaneously. The lever type mechanism is more suitable since it doesn't slack, unlike the wire mechanisms and has zero slip chances. The mechanism consists of bar linkages which are pivoted at amid point which acts as a lever for both mould and the foot pedal. The linkage also has an air piston to slow down the downward action to avoid accidents by rapid travel of the links. When the pedal is pressed, the mould is lifted upwards via links and when the pedal is released the mould comes back to the original position.

The whole setup is supposed to sit inside a pit, which gives an excellent working height (standing elbow height) to the people moulding bricks as well as to the person bringing the mud and transferring the bricks. The number of people involved in this is **five (5)**, as shown in the illustration, **two (2)** people are engaged with the moulding work, whereas the **third person** is loading the trays for laying the bricks. **Two (2)** additional workers are required to transfer the mud and the bricks to the machine.

CAD Model: The cad model shows the various components in the brick moulding workstation. The machine consists of two-level, of which the upper level has the mud loading bay on which the mud is loaded by a hand-pushed cart since the whole setup is supposed to be used in a pit the lower lever is for transferring loading trays (shown in Figure 6-16).

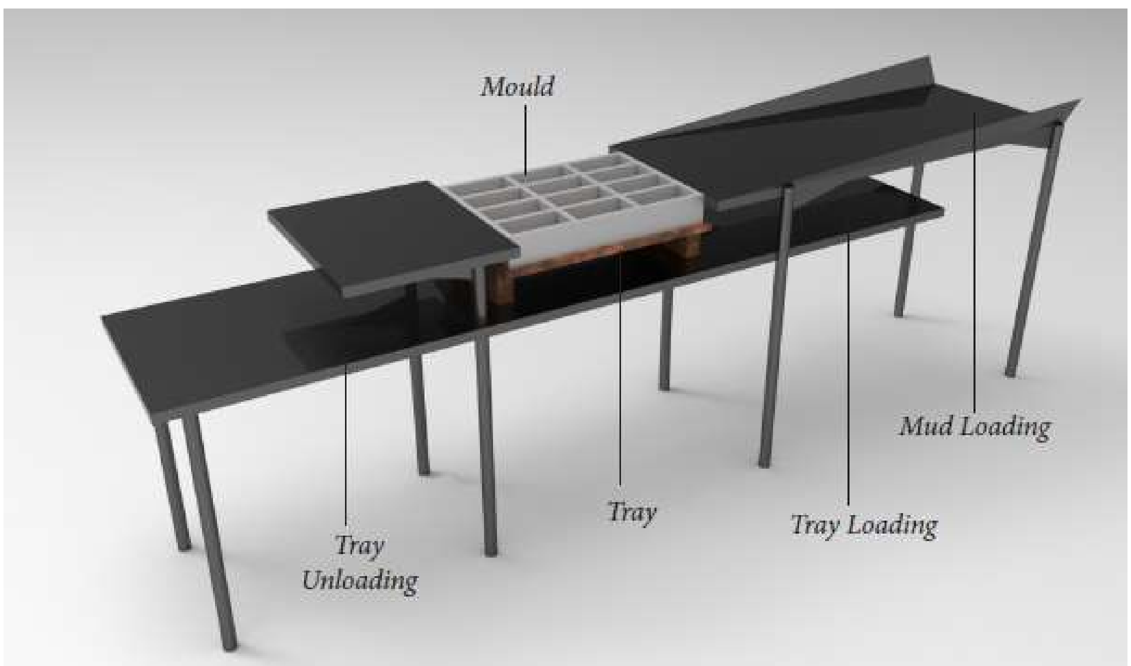


Figure 6-16: Concept model of the brick moulding machine

The brick moulding machine (shown in Figure 6-17 and Figure 6-18) is one of the main components of the whole workstation, which is installed in between the mud transfer bay and brick transfer bay. The mechanical linkages provide better and effortless brick moulding by use of foot muscular power and body weight. When the foot pedal is pressed, the mould is lifted by levers. An external drum is provided for embossing logo on the bricks. The single foot pedal is provided to give more control on to the person operating the machine and providing the freedom to the other person in opposite to carry out other tasks such as transfer of tray etc. A secondary guide is provided as a support to avoid cantilever bending of the mould.

Figure 6-17: Concept model of the brick moulding machine

Figure 6-18: Concept model of the brick moulding machine

Embossment Pin: The Drum type Logo embossment drum (shown in Figure 6-19) is provided for embossing logo directly on the brick by rolling the pin on the brick. The rolling pin concept inspires the Idea. The Logos are made up of Silicon which avoids sticking it to the mud of the brick. The cross-section of the logo is in tapered shape so that the mud is not removed from the brick with embossing and the logo easily comes out once the embossing is done without damaging the brick. A raised triangular guide provides a path to the pin so that the pin doesn't slip away from the position and the logo is embossed directly on the centre of the brick. An arrow is provided to mark the starting point.

Figure 6-19: Proposed embossment pin for brick-moulding machine

6.16.1.8 Anthropometric dimension for brick moulding machine

The application of anthropometry is an essential part of the design process. The main objective for ergonomists is to improve consumer's lives by increasing their comfort when using products. When ergonomics is incorporated into industrial machinery and tooling it can increase efficiency, productivity and reduce errors and accidents. At the time of design intervention, following anthropometric dimensions (Table 6.57) were used.

Table 6.57: Different relevant anthropometric dimensions for the proposed brick moulding machine

Measurement of Machine	Anthropometric Dimensions	Measurement percentile has taken for design
Height of the Brick moulding machine	Standing elbow height	5^{th} percentile – 95^{th} percentile (the machine will go inside a pit; therefore, surface height can be adjustable)
The breadth of Brick moulding machine	Arm length	5^{th} percentile

6.16.1.9 Concept Validation Study

Before the design intervention, one prototype testing study was carried out to validate the setting standing posture. A rig was made by using the slotted angle to uplift the working plain towards the elbow level of the brick-moulding worker. A wooden plank was used as a brick moulding pallet. During the validation of the sitting-standing concept, the brick moulding workers were asked to do brick moulding activity in the traditional method, i.e. with squatting posture as well as sitting-standing posture (Figure 6-20 and Figure 6-21).

Figure 6-20: Sitting-standing workstation & testing of the Pallet Concept

Figure 6-21: Sitting-standing workstation & testing of the Pallet Concept

6.16.1.9.1 Design Validation Study Methodology

During concept validation study, 32 brick moulding workers were selected randomly, and they were allowed to do the brick moulding in the traditional way as well as sitting standing method for 40 minutes each. The work duration was considered for 40 minutes because the brick-moulding worker does the moulding activity at a stretch in average for 40 minutes in the traditional method. After 40 minutes, the worker takes a small pause/rest.

6.16.1.9.2 Design Validation Study Results

The average age, weight and height of selected workers were 30 years, 52.1 kg and 162 mm. Resting HR of the workers was considered as 75 bpm^{-1}. Due to the sitting-standing posture, the working heart rate was decreased from 126 bpm^{-1} to 111 bpm^{-1}. Even the output (the number of brick production), was also increased from 120 to 155 bricks/40 minutes (Table 6.58).

Table 6.58: Results of the concept validation study

Concept Validation Study	Physical Characteristics (N=32)	
Age	30 ± 6	
Weight	52.1± 6.6	
Height	162 ± 7.1	
	Traditional Method	**Sitting Standing Method**
Resting HR	75 bpm^{-1}	75 bpm^{-1}
Working HR	126 ±5.45	111 ± 4.18
No of bricks moulded /40 minutes	120 ± 15 / 40 minutes	155 ± 12 / 40 minutes
REBA Score	12	7
REBA Action Category	Very high risk, implement change	Medium risk, further investigation, change soon

6.16.1.9.3 Body Part Discomfort Study

Body Part Discomfort (BPD) Scale also applied and asked the Pathera worker to rate the intensity of pain on different body parts for existing and new workstation. The graphical representation BPD pain intensity is shown in Figure 6-22. The result says that there is a significant difference in lower back pain. The BPD analysis justifies the goodness of the newly design workstation.

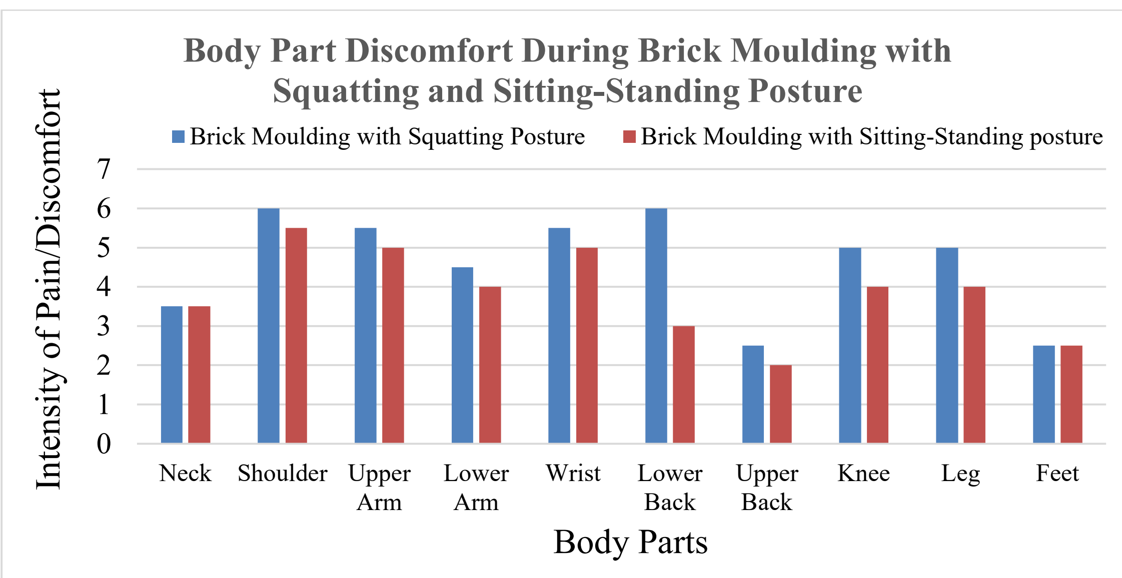


Figure 6-22: Body part discomfort during moulding with squatting and sitting-standing posture

6.16.1.9.4 Five-point rating scale

A five-point rating scale was applied to understand the worker perception of the newly designed workstation. The sensitivity of sitting-standing posture was also measured by using a five-point ordinal scale (Bad, Poor, Acceptable, Good and Excellent). Out of 32 participants, 20 participants said that sitting-standing posture is good with compare to existing traditional brick moulding method (Figure 6-23).

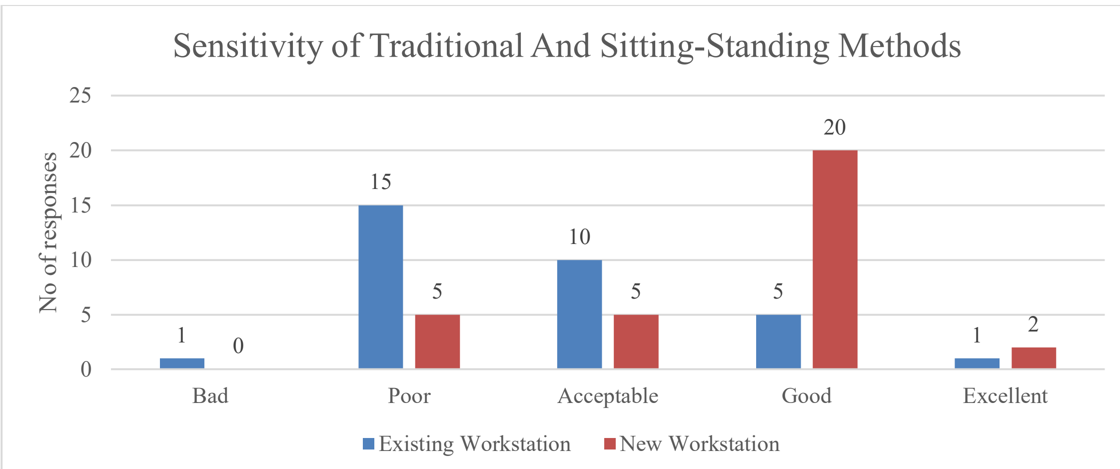


Figure 6-23: Sensitivity of traditional and sitting standing method

6.16.1.9.5 Statistical Analysis

A t-test is used to determine if there is a significant difference between the means of two groups, traditional brick moulding method and sitting-standing brick moulding method.

The T-test between Brick Output (Traditional method vs Sitting standing method):

A paired-samples t-test was conducted to determine the difference between traditional method brick output and sitting-standing method brick output. There is a significant difference between the groups, the traditional method brick output (120 ± 15) and the sitting-standing method brick output (155 ± 12) ($t=10.3069$, $p<0.05$).

The T-test between Working Heart rate (Traditional method vs Sitting standing method):

A paired-samples t-test was conducted to determine the difference between traditional method brick output and sitting-standing method working heart rate. There is a significant difference between the groups, the traditional method working heart rate (126 ± 5.45) and the sitting-standing method working heart rate (111 ± 4.18) ($t=11.5305$, $p<0.05$).

6.16.1.10 Productivity analysis

In terms of bricks

Number of Brick moulded traditionally = 126 bricks

Number of brick moulded sitting-standing posture = 155 bricks

Productivity Increases = (155 – 126) bricks = 29 bricks

Percentage of productivity increases in terms of brick = (29 /126) *100 = **23%**

Hence, it can be said that productivity increases by **23%**.

In terms of working heart rate

Average Age of worker = 30 years

Heart Rate Max = 220 – Age = 220 – 30 = 190 bpm^{-1}

Resting Heart Rate = 75 bpm^{-1}

Heart Rate Reserve (HRR) = (190 – 75) = 115 bpm^{-1}

Working Heart Rate for traditional method = 126 bpm^{-1}

Net Cardiac Cost (NCC) for traditional method = (Working HR – Resting HR)

= (126 -75) = 51

Relative Cardiac Cost (RCC) for traditional method = (NCC/HRR) *100

= (51/115) *100 = 44%

Working Heart Rate for Sitting-standing method = 111 bpm^{-1}

Net Cardiac Cost (NCC) for sitting-standing method = (Working HR – Resting HR)

= (111 -75) = 36

Relative Cardiac Cost (RCC) for traditional method = (NCC/HRR) *100

= (36/115) *100 = 31%

Hence, it can be said that the workload has decreased by (44 – 31) % = **13%**.

In terms of postural stress:

REBA analysis says that sitting posture is better posture than traditional squatting posture.

6.16.2 Face Mask Design for Jalaiya Worker

6.16.2.1 Description of Jalaiya Activity

The firing of Sun-dried bricks under controlled temperature is a very important step under the brick making activity. Locally known as 'Jalaiya' is the process by which the green bricks are strengthened, and the colour is changed from grey (dry mud) to brick red (baked brick) by baking at a constant temperature of 900^0 - 1000^0 centigrade for a specific time. The kiln is vital for this purpose and maintaining the internal kiln temperature uniformly, which is essential for optimum baking of the raw bricks. After the transfer and arranging the raw bricks in the proper way (Khadkan), experienced male workers (locally known as 'Jalaiya') are required for burning of green bricks to hard red colour bricks. The main task of Jalaiya is maintaining the fire inside the kiln, supervision of the fire temperature and accordingly determines the time to bake the bricks, charging the kiln with coal (Figure 6-24), through the peephole (Figure 6-25).

Figure 6-24: Coal charging through the peephole

Figure 6-25: Peephole, on the top of the brick kiln

6.16.2.2 Problems in Jalaiya Activity

The workers have exposure to both the radiant heat from the kiln and the general ambient heat load, especially during the hot summer months. Inside the Kiln, the temperature varied between 900^0C – 1100^0C. During summer, the Corrective Effective Temperature (CET) was 30.5^0C, and the Wet Bulb Globe Temp (WBGT) Index was 30.4^0C in the entire kiln area. The radiant (Globe) temperature was near about 42^0C on the top of the kiln. The workers were wearing uncovered wooden sandals along with cotton-based T-Shirts and trousers which were not sufficient to protect them from the radiation heat. Human's face and neck regions are very sensitive to temperature exposure. During the questioner's survey, the Jalaiya workers answered the questions, and the workers mentioned the following problems:

a) The workers indicated that they felt very hot while working.
b) The workers pointed out that while looking into the peepholes to check the colour of the bricks, the air coming out is very hot, and it hits their face, which is quite hot and is uncomfortable.
c) The workers also mentioned that they could not look at the brick closely through the peepholes as it would be very hot.
d) The workers pointed out that the kiln top was so warm that they could not wear normal shoes which would conduct heat. So, they made wooden sandals which provide them with enough thermal insulation, but it is not very comfortable to wear.

6.16.2.3 Recommendation from P-P-P-E Method

The results of P-P-P-E method said that Coal charging through the peephole (Jalaiya worker) is environmentally a stressful activity, and recommended to reduce environmental stress by designing personal protective equipment (PPE).

6.16.2.4 Design Intervention

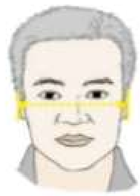
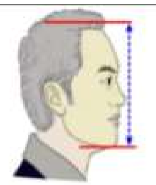
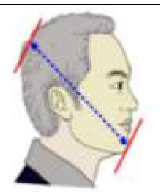
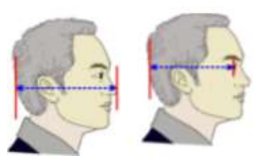
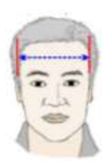
The main problem stressed by the Jalaiya workers was that of heat stress. The environment where they have to work is hot, and they do not use any equipment to protect against the heat. The idea was to design equipment to protect the workers from heat.

The main principle behind designing the equipment was that of insulation against heat from the environment. So, design intervention is required to insulate the worker without disturbing their natural work process. The human face is the most heat sensitive area among the whole body. Therefore, headgear was essential to keep the workers safe from heat stress. Based on the above observation, **seven** conceptual models of face neck mask were developed. All conceptual models have some advantage and some disadvantage also. Out of seven conceptual models, one model was selected based on the worker's literacy level, sustainability, production cost and comfort. All the conceptual models had compared with each other. The parameters used to evaluate the models were usability, sustainability, ease of use, cost and body comfort and scored on a scale of 10. As per the evaluation study, basic frame retractable front face cover was the most appropriate model. But the problem with the design was that it was not retractable, and the workers could not just move the visor up to talk to their fellow workers or spit tobacco which was very important to the natural way of work of the brick kiln workers. This result from the evaluation was because the natural way of work of the workers was not factored in. So, the basic frame with a retractable frontal face cover design was chosen for the final design.

6.16.2.5 Anthropometric dimension

The application of anthropometry is an essential part of the design process. The main objective for ergonomists is to improve consumer's lives by increasing their comfort when using products. When ergonomics is incorporated into industrial machinery and tooling it can increase efficiency, productivity and reduce errors and accidents. At the time of design intervention, following anthropometric dimensions (Table 6.59) were used.

Table 6.59: Different relevant anthropometric dimensions for the proposed headgear

Headgear dimensions	**Body Dimensions**	**Image of the dimension**	**Measurement percentile has taken for design**
Headgear visor width	Head breadth		95^{th} percentile
Headgear visor height	Menton to top of the head		95^{th} percentile
Headgear diameter	Diametric menton to back of the head		95^{th} percentile
Headgear circumference	Head Circumference		5^{th} percentile to 95^{th} percentile (adjustable)
Headgear length	Pronasale to the eye (The value of Pronasale to back of the head minus (-) the value of Eye to back of the head		95^{th} percentile
The width of the front of the headgear mesh	Face Breadth		95^{th} percentile

The design that was made as the final product consists of a harness which covers the head both around and over it, and they can be adjusted easily to fit the head of the worker. The frame attached to the side of the harness just above the ear. The visor was attached to the frame and remained in front of the face. The visor was attached with a link which makes the visor retractable. There were two pre-set positions of the visor. One was the using position when the visor is in front of the face. There was a stop which prevents the link from sliding down due to gravity which makes the visor stay in place. There was also a rest position when the visor was retracted over the head, and another stop prevents the link from sliding down due to gravity behind the head. This ensured that the visor stays in place on top of the head while in the rest position. Based on the above observations, a conceptual model of face-neck mask was developed through CAD modelling, which was then converted to a full-scale prototype for simulation study (Figure 6-26).

Figure 6-26: Newly designed headgear for brick kiln (Jalaiya) worker (Front & side view)

6.16.2.6 Design Validation

For the simulation of the visor, a study was conducted in the laboratory. Two temperature sensors were placed on both sides of the sample visor, made by SS mesh. An electrical heater that produces radiant heat was used as an artificial heat source. The result said that a barrier of the SS mesh could reduce 30% radiant heat (Figure 6-27).

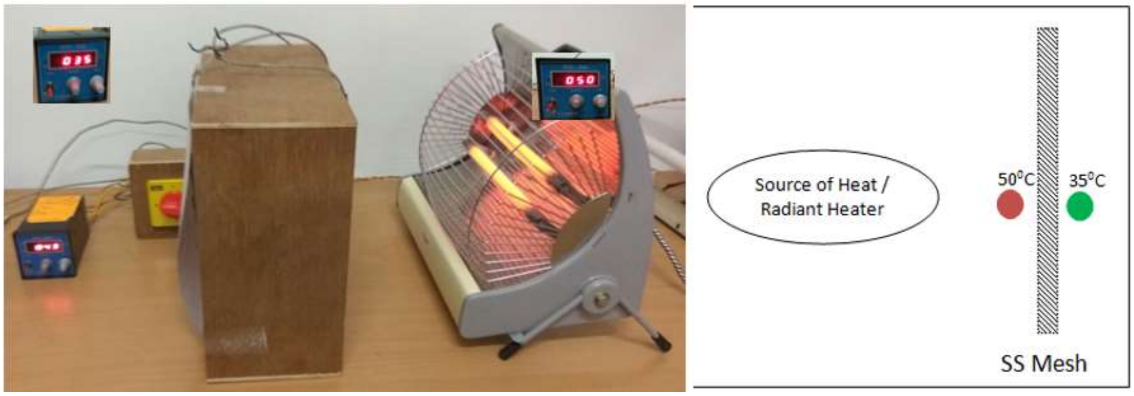


Figure 6-27: Testing of SS mesh as a temperature barrier

(Temperature 50^{0}C Inner side and Temperature 35^{0}C Outer side)

From the above simulation study, it can be concluded that the newly designed headgear will protect the Jalaiya workers from radiant heat. The helmet will be cheap, maintenance-free and durable and will not hamper the normal activities and air circulation of the workers.

6.16.2.7 Productivity Analysis

The following formula calculated the productivity of the headgear.

Radiant heat at source = 50^{0}C

Radiant heat towards the opposite of heat source = 35^{0}C

Reduced radiant temperature = (50 -35)^{0}C = 15^{0}C

Percentage of reduced radiant temperature

= (Reduced radiant temperature/ Radiant heat at the source) *100 %

= (15/50) *100 %

= 30%

From the above study, it can be concluded that newly designed headgear can reduce the radiant temperature by 30%.

Chapter 7 Conclusions

There are six types of workers in traditional Indian brick making industry, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. Male and female both types of workers are available in Indian brick kiln (Gender ratio: 60% male and 40% female). The output of the studied brick kilns are as follows –
VS Brick Kiln Output – 40,000/Day
RB Brick Kiln Output – 35,000/Day
SUN Brick Kiln Output – 30,000/Day
The Pathera workers output does not depend on brick kiln output. But other workers output depends on kiln output. The output for the brick kiln workers (except Pathera) was calculated from kiln output divided by the number of workers.

India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems faced by the respective brick kiln workers. From the three brick kiln industries, 259 participants (193 male and 66 female) were selected for the current study. Due to the vast nature of the country, the reliability of the sampling was calculated by t-test. The results say that there is a significant difference between Indian anthropometric data and brick kiln workers anthropometric data. It concludes with a need for nationwide brick kiln workers anthropometric data.

The average weight and height of the brick kiln workers are 50.3 (± 8) kg and 158.7 (± 7.6) cm, respectively. The average grip strengths of brick kiln workers are 31.3 (± 6.6) kg and 32.5 (± 6.7) kg for left hand and right hand, respectively.

A comparative whole-day energy expenditure study has been done among three studied brick kilns. The result says that average per day per person energy expenditure among VS and RB brick kilns is almost the same (VS-3176 and RB-3174 Kcal/Day). But average per day per person energy expenditure in SUN brick kiln (3081 Kcal/Day) is slightly lower than VS and RB brick kiln.

Energy expenditure study also says that Pathera activity is physiologically most demanding activity, and it demands 3394 Kcal energy per day per person. Nikashi (3370 Kcal) is the second physiologically demanding activity and followed by Bharai (3311 Kcal/day), Khadkan (3096 Kcal/Day), Jalaiya (3000 Kcal/day) and Kiln top coverer worker (2700 Kcal).

The study also says that Female workers demand less energy in comparison to the male worker. But it should be noted that the productivity (in terms of brick production) of female brick kiln workers also less than male brick kiln workers.

Finally, from the energy expenditure study among brick kiln workers can be concluded that the average per day energy expenditure is 3151 Kcal (range 2700 – 3394 Kcal), which is far more than 2700 Kcal. The above energy expenditure study proves that the minimum wage fixation method should be reconsidered based on 3151 Kcal/day/person. In this context, it can be mentioned that the current minimum wage fixation is made based on 2700 Kcal (Ministry of Labour & Employment, Govt of India, 1957).

According to the Factories Act, a worker should not be required to work more than 9 hours a day, spread over 10.5 hours due to rest periods. But the study results say that the average working hours for Pathera workers in VS brick kiln is 780 minutes (13 hours), which is far beyond the Factories Act recommended regular working hours. The same trend is followed for RB Pathera workers (15 hours) and SUN Pathera workers (11 hours and 30 minutes) also. The other brick kiln workers (rest of Pathera workers) works spend time for work within the government approved hours limit. The firing of bricks is a continuous process (24-hour), the Jalaiya worker that work as day-night shift basis. Each shift lies on 12-hour. There are two groups of Jalaiya worker in each brick kiln industry, works 12 hours a day.

The average work-pause ratio in Indian brick kiln industries is 72:28, means the brick kiln worker works for 72 minutes and takes 28 minutes brake. There are no such published data about ideal work and pause ratio in Indian brick kiln industry, but there is a magic figure (52-17) for maximum productivity for VDT (Video Display Terminal) workers. This magic figure says that 52 minutes of work sprint followed by 17 minutes of recuperation (i.e. 75% work – 25% recuperation) is an ideal ratio for maximum productivity. The brick kiln workers also follow the same work-rest ratio.

Brick kiln workers get their daily wage on the piece-rate system basis. On average, there fifty-three (53%) percent Pathera worker in a brick kiln industry. The Pathera workers get minimum wages on the production of 1000 bricks per day and paying as a family unit. Generally, Pathera workers are migratory workers, migrate from far (even from another state) to work in the brick industry with their family. The couple (husband and wife) works together in the brick kiln industry by forming one unit. The results say that to make 1000 bricks, VS Pathera worker takes 990 minutes, which is 360 minutes more than government-recommended work time.

The RB Pathera worker also takes 400 minutes extra. As per calculation, the Pathera worker can make 624 bricks within 10.5 hours of work duration. Therefore, the piece-rate basis minimum wage system should be lies on 624 bricks per day per person.

In this context, it can be noted that SUN Pathera worker takes 560 minutes to make 1000 bricks due to the use of mechanisation. In SUN brick kiln industry, mud is prepared by the mechanised way in a centralised mud pool.

India is a vast diversified country; almost all the regions/states have brick kiln industries with specific processes and specific problems and specific problems faced by the respective workers. More or less all Indian brick kiln industries have six types of worker, such as Pathera, Bharai, Khadkan, Kiln top coverer, Jalaiya and Nikashi. But the method of work is different based on social culture, geographical location, availability of raw material, availability of technology, awareness, kiln sizes, kiln output etc. To compare each work method among different brick kiln industries, the current research took the initiative to measure Per brick energy expenditure and per brick time cost.

The comparative analysis says that to make one single brick, VS and RB brick kiln Pathera workers take 0.99 minutes (or 59 seconds) and 1.03 minutes (or 63 seconds). But SUN brick kiln Pathera workers take only 0.56 minutes (or 34 seconds), which is almost half of the other two brick kiln. The reason behind less time requirement in SUN brick kiln industry is the use of mechanisation. The mud is prepared by mud making mechanisation system (locally known as 'Kolu').

The sun brick kiln Pathera workers use 2.04 Kcal human energy to make one single brick, which is less than the per brick energy expenditure by VS (3.64 Kcal) and RB (3.37 Kcal) Pathera workers. There is another interesting fact among VS and RB Pathera activity. In RB brick kiln industry, the Pathera worker makes mud in such a way; they don't need to transfer the mud from mud pool to moulding ground. By this technique, the RB brick kiln Pathera workers are eliminating the mud transfer activity by mud pool design concept and reduce per brick human energy expenditure during Pathera activity (brick moulding).

Bharai activity is another perfect example of the use of an assistive method, and technology can reduce human energy load as well as work time. VS, RB and SUN Bharai workers take 0.11 minute (7 seconds), 0.09 minutes (5 seconds) and 0.48 minutes (29 seconds) respectively, to transfer one single brick from moulding ground to inside the kiln. The SUN Bharai workers utilise higher human energy (1.88 Kcal) than rest two brick industry (VS-0.45 Kcal and RB-0.38 Kcal) to transfer one brick from moulding ground to inside the kiln. The reason behind time cost and energy expenditure discrepancy among different Bharai workers is assistive technology. In VS brick kiln worker use a tractor for transfer activity, and the RB brick kiln workers use a horse-driven cart for brick transfer. On the other side, SUN brick kiln worker uses a bicycle, and they push the brick-loaded cycle manually towards the kiln from moulding ground. Therefore, the use of mechanisation or assistive support can reduce time requirement and human energy expenditure.

The Khadkan work process, Kiln top covering work process and Jalaiya work process are similar in all three brick kilns. There are also minimal discrepancies with reference time requirement and energy consumption. In VS brick kiln industry, Khadkan activity is not dependent on Bharai activity. Here, Bharai worker stacks the green brick on the kiln-ground but in RB and SUN brick kiln, the bricks are handed over from hand to hand from Bharai worker to Khadkan worker. This hand-to-hand brick transfer reduces the unnecessary frequent bending below the waist level.

In VS brick kiln industry, the Nikashi worker uses a single-wheel-barrow. Usually, a female worker transfers about 32 while the male transfers about 50 number of bricks in each cycle. Apart from the wheel-barrow weight (say 15 kg) a load of 90 kg (2.8 kg X 32) for women per trip and that of 140 kg (2.8 X 50) for men gets to sink in the thick brick dust at the ground of the kiln while pushing. This causes very high resistance to push the cart. But in RB and SUN brick kiln industry, the bricks are removed from the kiln by head mode. The SUN brick kiln Nikashi workers use higher energy and take higher time due to different work terrain. The SUN brick kiln worker makes a temporary staircase to come out from the kiln trench with loaded bricks.

The current study also took the initiative to measure the time cost of different brick kiln related activity for a single brick in the studied brick kilns. There are 66% of the time contribution from Pathera worker to make a single brick in VS brick kiln industry and followed by Nikashi (15%), Bharai (7%), Jalaiya (6%), Khadkan (5%) and Kiln top coverer worker (1%). But, in RB brick kiln industry, there are 72% of the time contribution from Pathera worker to make a single brick and followed by Nikashi (13%), Bharai (6%), Jalaiya (6%), Khadkan (2%) and Kiln top coverer worker (1%). But, in SUN brick kiln industry, there are 32% of the time contribution from Pathera worker to make a single brick and followed by Bharai (28%), Nikashi (19%), Jalaiya (8%), Kiln top coverer worker (7%) Khadkan (6%). There is a leaner relationship between time cost and energy expenditure. The percentage of energy expenditure of different brick kiln related activity for single brick in the studied brick kiln also following the same trend.

To understand the physiological stress among the brick kiln workers, real-time heart rate, during work was measured by using proper methods. The worker has started their work in the early morning; therefore, it was difficult to measure the exact resting heart rate. The study assumed the resting heart rate of the brick kiln workers is 75 bpm^{-1}. Pre-work, work and recovery heart rate were measured during the study. As per workload classification in Gujarat, Digging, Mud preparation, Mud transfer, Coal breaking, and Nikashi activities are falling under the heavy category. On the other hand, in Bihar, Mud transfer, Bharai and Nikashi are falling under the heavy category, as per workload classification. Relative cardiac cost also shows similar results.

Almost for all the brick-making activities, the workers are compelled to take sustained forward trunk bending at the waist region (Lumbaro-sacral), that causes musculoskeletal disorder among them. Severe sustained back bending and musculoskeletal stress impose on the hip, knee and ankle joints in association with repetitive muscle force development in thigh, calf and foot muscles lead to biomechanical/postural stress. During entire brick making activities, the workers have to maintain sustained awkward posture and repetitiveness throughout the entire work period. Therefore, biomechanically such work is highly detrimental in terms of neuro-muscular activity with possible lead towards spinal cord injury. As per posture analysis study, moulding is maximising strenuous job and have highest REBA score, that suggest ‘very high risk, implement change'. This might be due to excessive load handling with continuous squatting posture.

The brick kiln workers need to handle high-intensity load every day. From the MMH viewpoint, the workers dealt with a high level of repetitive load, which is higher than recommended NIOSH guideline (RWL-51 lb/23 kg).

To understand the psychological stress, perceived stress scale was applied among brick kiln workers. As per PSS score, Pathera and Nikashi activities are psychologically more strenuous job. Uncertainty of wage, lower-wage system, extended long time hours is the main reason for psychological stress. Khadkan and Jalaiya had fixed wages; this might be the reason of low psychological stress.

To understand the environmental stress, the WBGT index method was applied. Being a topical country, Indian brick kiln worker is suffering under heat stress. During the summer, it becomes more horrible. Environmentally, Jalaiya is a more difficult job due to kiln temperature. Inside the kiln, the temperature is 900^0 – 1100^0 centigrade and in the top of the kiln, the radiant temperature is 65^0 centigrade. The high radiant temperature makes the Jalaiya's situation more adverse.

The results recommended for ergonomic design interventions to make the work more ergonomic. The brick kiln workers are exposed to physiological, postural, psychological and environmental stresses simultaneously, due to their nature of work. Therefore, it is important to identify the most severe pain, where design intervention can be focused on. The current study took an initiative to combine the Physiological, Postural, Psychological and Environmental stress. The combined method, P-P-P-E method (first letter of all four-individual stresses) will give the design direction in the Indian context. Standardised scores are more suitable measures than raw scores as they allow the researcher to be compared with other scores. Generally, tests are standardised so that the average, standardised score automatically comes out as 100, irrespective of the difficulty of the test. The standardisation factor was calculated from the upper and lower limit. Standardisation of RCC, REBA, PSS and WBGT scores was done by multiplying the standardisation factors with the raw scores. To understand the proportionate values of different stress, on overall stress, a statistical regression analysis was performed by using SPSS statistical software. RCC, REBA, PSS and WBGT index were used as independent scores, and the overall stress (Borg's score) was considered as the dependent score. From the regression equation, the weightage factors of physiological, postural, psychological and environmental stresses were determined. The derived regression equation is shown below –

RPE = -4.568 + 0.082*RCC + 1.032*REBA + 0.022*PSS + 0.157*WBGT index

Physiological stress component, Postural stress component, Psychological stress component and Environmental stress component were calculated by multiplying P-P-P-E weightage factor. From the P-P-P-E score, the brick-making jobs were prioritised according to stress. As per P-P-P-E score Brick moulding (Pathera) and Jalaiya are the most strenuous job. The Pathera workers are suffering unbearable postural stress, and P-P-P-E score suggests for design intervention to improve the posture. As per P-P-P-E score, the Jalaiya workers are suffering under high environmental heat stress, when they work on the top of the kiln and P-P-P-E score suggests designing the personal protection equipment to reduce thermal stress. The P-P-P-E scores are derived from standard popular ergonomic methods. Standardisation and weightage factors calculation are done by using standard statistical methods. Therefore, the reliability of the PPPE method is acceptable.

As per P-P-P-E method, Brick moulding and Jalaiya activities are selected for design intervention. P-P-P-E method suggests that design intervention should be carried out among brick moulding workers to reduce the postural stress and on Jalaiya worker to reduce the environmental stress.

The results of P-P-P-E method says that Brick moulding (Pathera worker) is pastorally a stressful activity, and recommended to change the working posture towards to neutral posture. The current study took the initiative to improve the posture at the local level (i.e. wrist posture) as well as in system-level (whole-body posture). To reduce the postural stress, the brick moulding process is changed from a squatting posture to sitting-standing posture. A validation study says that new design intervention reduces the postural stress, working heart rate and increases productivity. Newly design brick making tools resolved the two major problem areas of workers (Squatting posture and Excess physiological stress on fingers due to repetitive turning of mould). To validate the design, a validation study was conducted among 32 brick moulding workers. The results say that new design can increase productivity by 23% (in terms of bricks) and decrease the physiological workload by 13%. The REBA analysis says that sitting posture is better posture than traditional squatting posture.

A design intervention also carried out on Jalaiya worker. The facial region of the Jalaiya workers are exposed to radiant heat; therefore, a face mask was designed to save the workers from high heat stress. Due to unavailability of brickfield, the facemask was validated in a laboratory situation. A radiant heater was used as a source of high temperature, and two temperature sensors were used on both side of the facemask. The validation study proved that; face mask can reduce the heat exposure 50^0 centigrade 35^0 centigrade. The newly designed mask will protect the Jalaiya workers from radiant heat. The mask will be cheap, maintenance-free and durable and will not hamper the normal activities and air circulation of the workers. The lab simulation study concludes that the newly designed headgear can reduce the radiant temperature by 30%.

The study also identified the limitation and future scope of the current research. The P-P-P-E method was developed in brick making environment. It needs to validate the sensitivity of P-P-P-E method in other unorganised sectors. WBGT index is considered as a representative of environmental stress in the brick kiln. It might be different in other unorganised sector depending on available environmental stress.

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Appendix

Appendix A: Anthro Datasheet

Anthropometric Study Data Sheet

Sl No ……………….,   Date. ……/………/2016

Name: ………………….……………., Age: ………, Sex: Male/Female, Occupation: ………………

Body Weight: ………………..... Kg, Height:....………. Cm, Illiac Height: ………….……….... Cm

Sitting Height: …..………….Cm, Bicondyle Femur: ………………. Cm, Wrist Breadth: ……..…....…… Cm

Max Calf Circumference: ………..Cm, Upper Arm Circumference: ……... Cm, Total Arm Length: …......... Cm

Bi-Acromial Dia: ………… Cm, Transverse Chest: ……..….. Cm, Antero-Posterior Chest:…………...… Cm

Bi-illocristal Dia: ….…..... Cm, Head length:……………..…. Cm, Head Breadth: ………..…….. Cm

Bizygomatic Diameter: ……….….. Cm, Morphological Face Height (Nasion-gnathion): ………………… Cm

Nose Height: …………………………..……. Cm, Nose Breadth:….……………………………….. Cm

Hand Breadth: …..……..…… Cm, Max Hand Breadth:…….……….. Cm, Fist Height:……..…….. Cm

Palm Length: ………………..Cm, Max Grip Circumference: ……………………………..….….. Cm

Max Grip Strength (Left Hand): …………………..Kg/N, Max Grip Strength (Right Hand): ……………..Kg/N

Waist Circumference: ……………………………… Cm, Hip Circumference: ……………………..……… Cm

Skinfolds:

Biceps: …......… mm, Triceps: ………..…… mm, Subscapular:………..…... mm, Supra-Iliac: ……………mm

Blood Pressure: ……………………………………………………..……………...……….……….. mmHg

K4b2 ID :

Clock Time:

Experiment Start Time: Exercise Start Time : Recovery Start Time:

Appendix B: Anthropometric Dimensions

Some anthropometric dimensions (Table 7.1) also collected to know the nutritional status of workers. This data also helped for work station assessment of brick kiln workers. It also used during prototype making during design intervention step.

Table 7.1: Anthropometric data of male and female brick kiln workers

Anthropometric Data of Brick Kiln worker	Male Worker (N=195)		Female Worker (N=68)	
	Mean ± SD	Range	Mean ± SD	Range
Iliac Height (cm)	92.86 ± 4.8	84.6-103.6	91.71 ± 5.75	78.5-101.4
Sitting height (cm)	81.99 ± 3.21	74.8-89.2	76.39 ± 2.76	70-80.6
Bicondylar femur (cm)	8.6 ± 0.32	8-9.1	8.19 ± 0.5	7.7-9.6
Wrist breadth (cm)	5.44 ± 0.25	05-06	4.69 ± 0.35	4.1-5.1
Max. calf circumference (relaxed) (cm)	29.56 ± 1.71	26-33	27.57 ± 1.85	22.1-30
Upper arm circumference (relaxed) (cm)	23.39 ± 1.76	20-27	22.34 ± 1.24	19.4-24.5
Total arm length (cm)	80.86 ± 3.2	73.3-87.4	79.37 ± 5.5	74.8-83.5
Bi-acromial diameter (cm)	31.24 ± 2.21	25.6-35.1	29.46 ± 1.95	26.4-34
Transverse chest (cm)	25.78 ± 1.52	22.1-28.1	26.03 ± 7.87	22.1-55.2
Antero-posterior chest (cm)	19.87 ± 1.4	17.6-23.3	19.71 ± 1.13	18-21.6
Bi-iliocristal diameter (cm)	25.17 ± 1.73	22.8-31.8	25.3 ± 1.22	23.1-26.7
Head length (cm)	17.97 ± 1.02	14.5-19.5	17.91 ± 0.92	15.6-18.9
Head breadth (cm)	14.23 ± 0.92	13-18.4	14.21 ± 0.88	12.6-16.3
Bizygomatic diameter (cm)	11.56 ± 0.71	10.2-13	11.07 ± 0.57	10.2-12.3
Morphological face height (nasion-gnathion) (cm)	10.76 ± 0.8	8.4-12.7	10.08 ± 0.46	9.3-11.2
Nose height (cm)	1.87 ± 0.29	1.4-2.8	1.85 ± 0.31	1.5-2.1
Nose breadth (cm)	3.4 ± 0.24	2.8-3.8	3.29 ± 0.5	2.2-4.5

Hand Breadth (cm)	8.04 ± 0.41	7.3-9.1	7.36 ± 0.38	6.5-8
Maximum Hand Breadth (cm)	9.91 ± 0.76	8.5-11.9	8.56 ± 0.49	7.5-10.5
Fist Height (cm)	6.22 ± 0.27	5.5 – 7.5	5.96 ± 0.35	5.1-7.2
Palm length (cm)	17.59 ± 0.75	16.1 -20.4	16.44 ± 0.48	15-17.9
Max grip circumference (cm)	4.88 ± 0.33	4.2 – 5.3	4.2 ± 0.3	3.8-4.9

Appendix C: Nutritional Status of Brick Kiln Workers

One of the basic needs of a human is good nutrition which forms the key towards leading a healthy life. From the very early stages of life, a proper diet is important from the viewpoint of proper growth and development. Malnutrition is a basic public health concern of many of the developing nations. The study was conducted on a total number of 16 males and 12 females between the age ranges of 20 to 37 years engaged in brick making operations in the state of Ahmedabad. In general, the workers were free from any kind of physical deformity and illness. The lack of sufficient calorie intake for both the population groups as evident from the calorie adequacy ratio was one of the contributing factors for the sample population being underweight. Carbohydrates were the major source of energy for both the sample population. The protein intake of the sample population was found to be adequate for both the vegetarians and non-vegetarian population samples. The non-vegetarian population was found to have an overall better nutrition status in comparison to the vegetarian population irrespective of their gender. Fat intake was found to be high in the entire population sample. High fat consumption contributes to a major calorie intake among the brick kiln workers making it easier for them to do the heavy activity and it also reduces the bulk of food that should be eaten in the form of cereals. Percentage of calorie consumption of different food groups of Non-vegetarian & vegetarian, Male-Female workers are shown below –

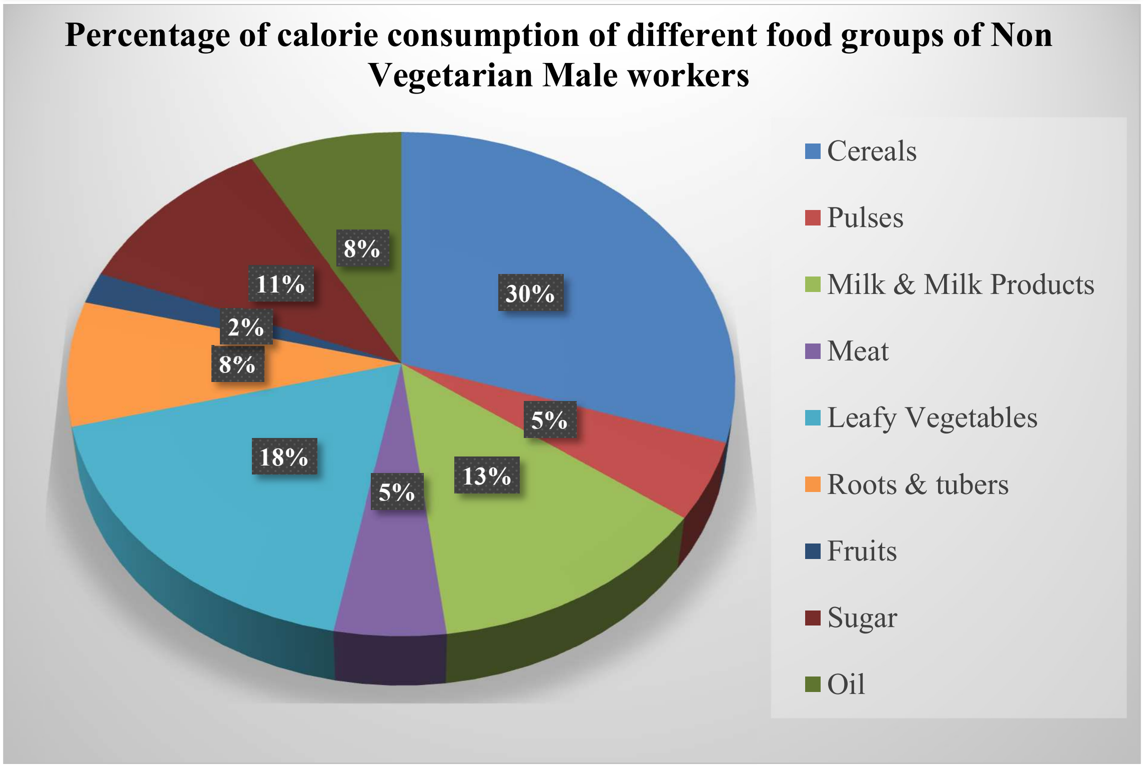


Figure 7-1: Percentage of calorie consumption of different food groups of non-vegetarian male workers

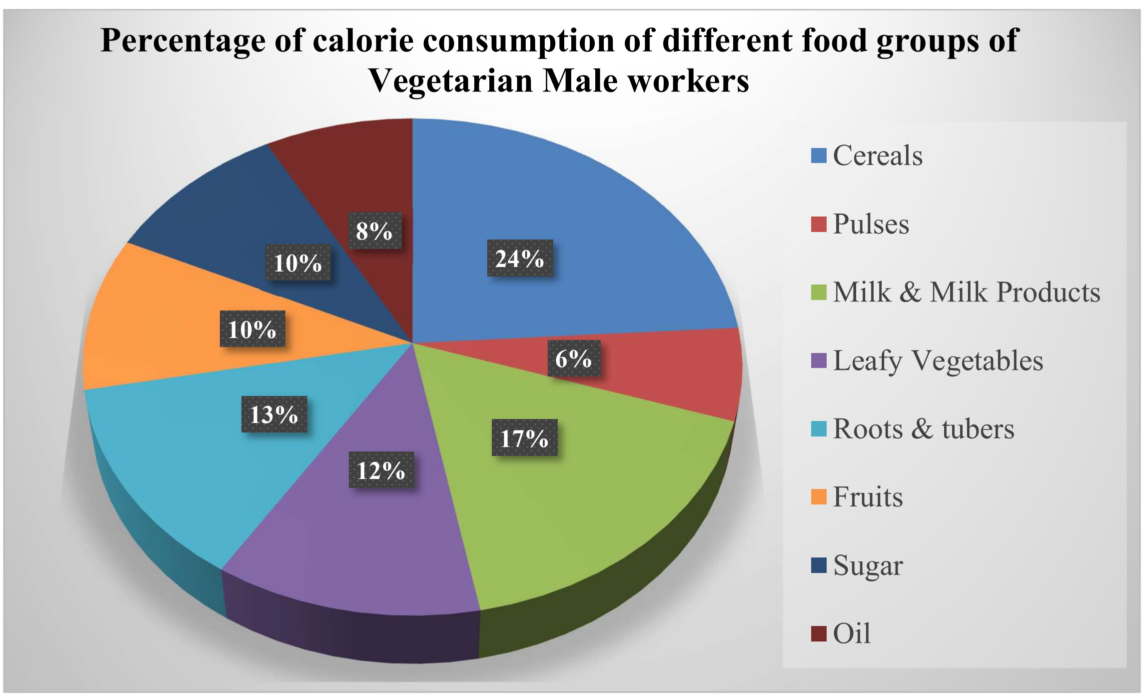


Figure 7-2: Percentage of calorie consumption of different food groups of vegetarian male workers

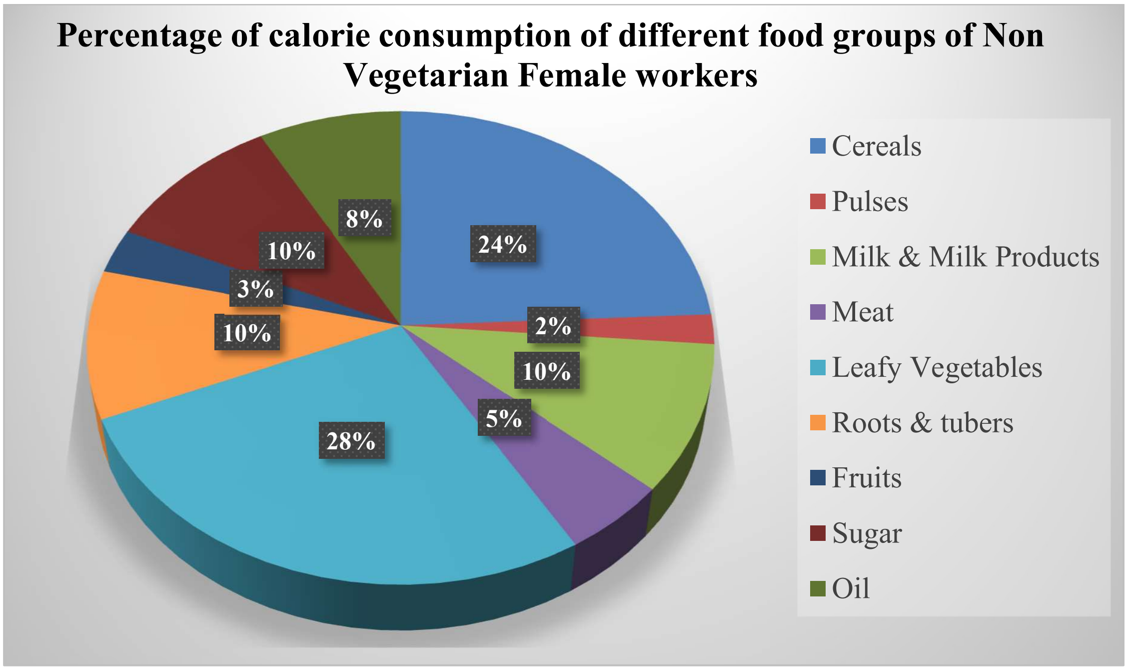


Figure 7-3: Percentage of calorie consumption of different food groups of non-vegetarian female workers

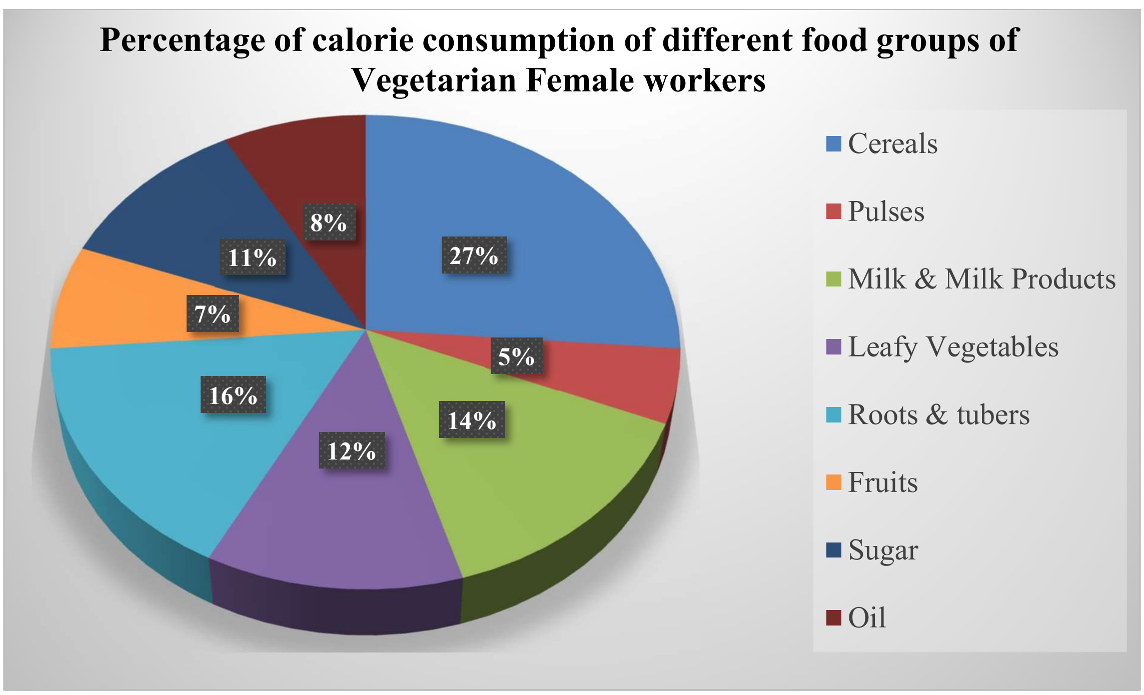


Figure 7-4: Percentage of calorie consumption of different food groups of vegetarian female workers

Appendix D: Body Part Discomfort Analysis of Brick Kiln Workers

This study took the initiative to compare the body part discomfort among three brick kilns for each activity. This result shows that Lower Back, Neck, Shoulder, Knee, Leg and wrists are most prone to discomfort due to manual material handling, repetitive bending and awkward posture, in Figure 7-5 to Figure 7-11.

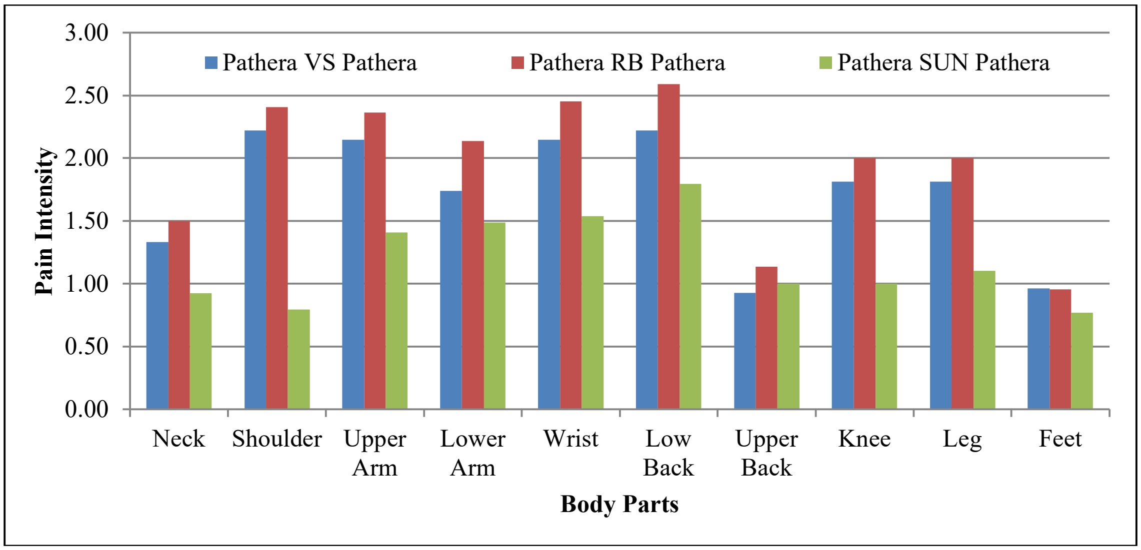


Figure 7-5: Compare between three studied brick kilns with reference to body part discomfort for Pathera male workers

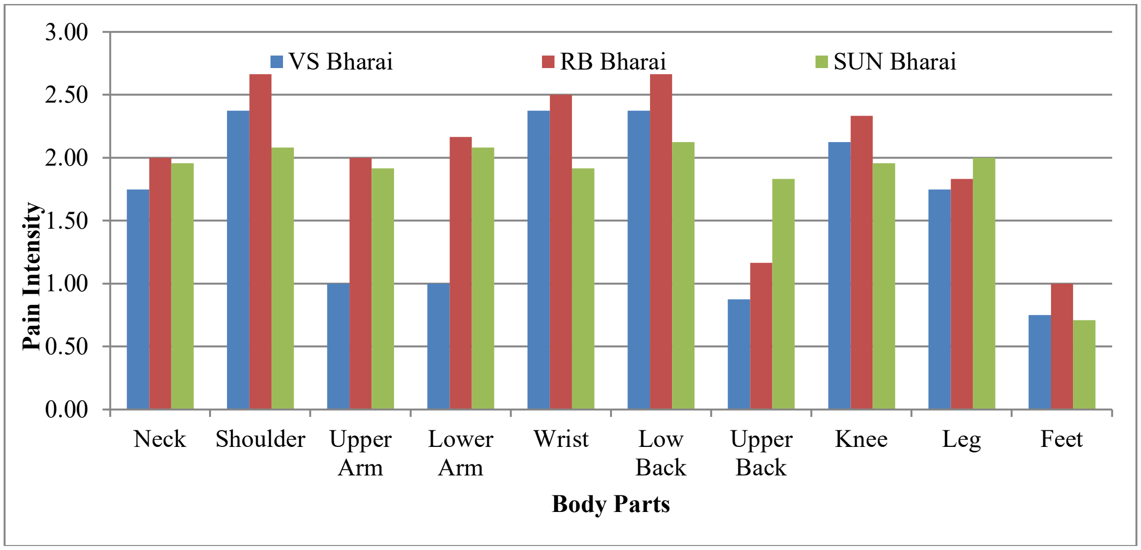


Figure 7-6: Compare between three studied brick kilns with reference to body part discomfort for Bharai workers

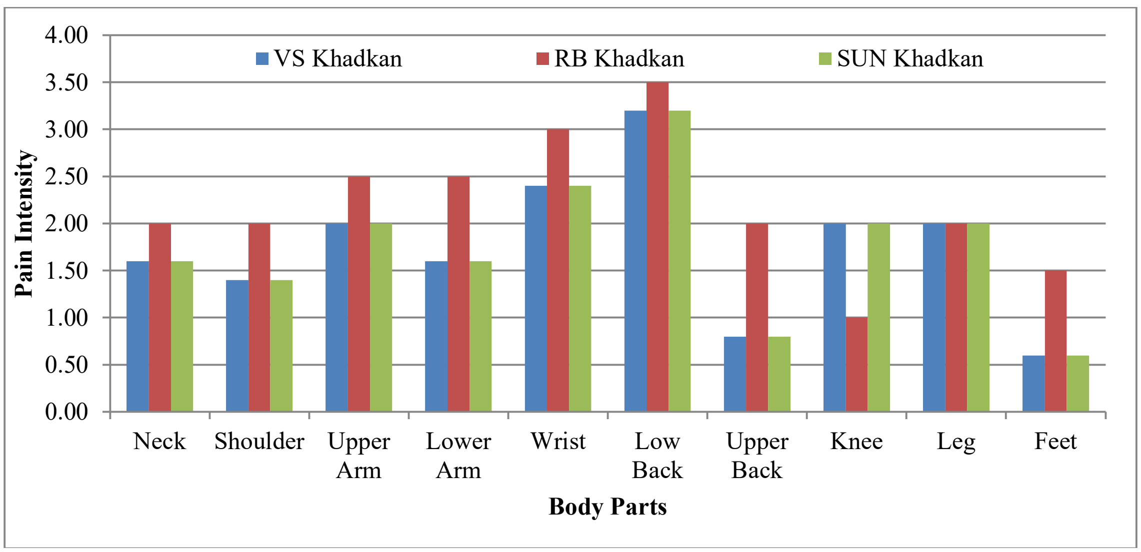


Figure 7-7: Compare between three studied brick kilns with reference to body part discomfort for Khadkan workers

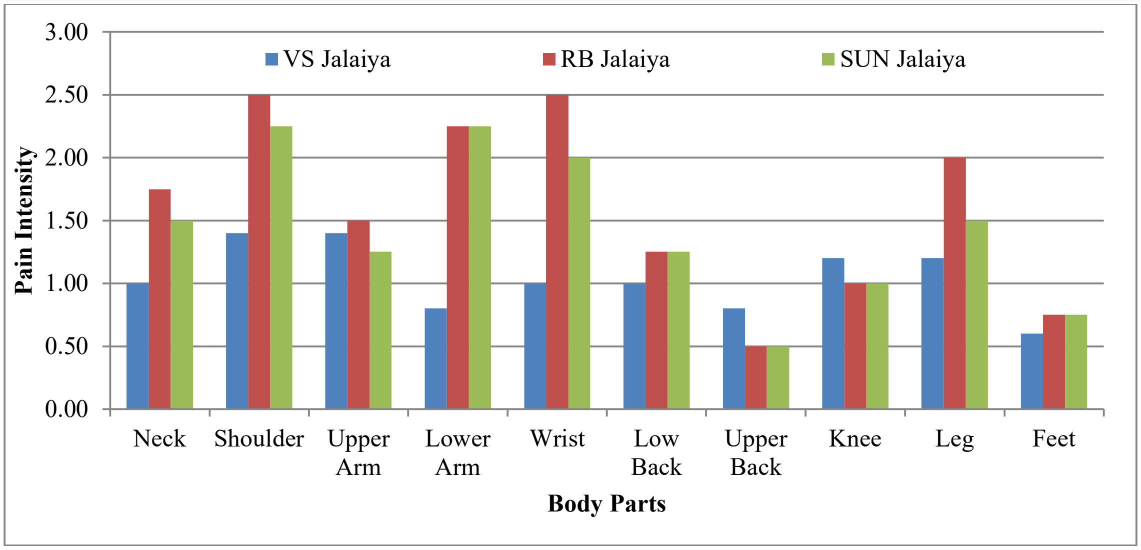


Figure 7-8: Compare between three studied brick kilns with reference to body part discomfort for Jalaiya workers

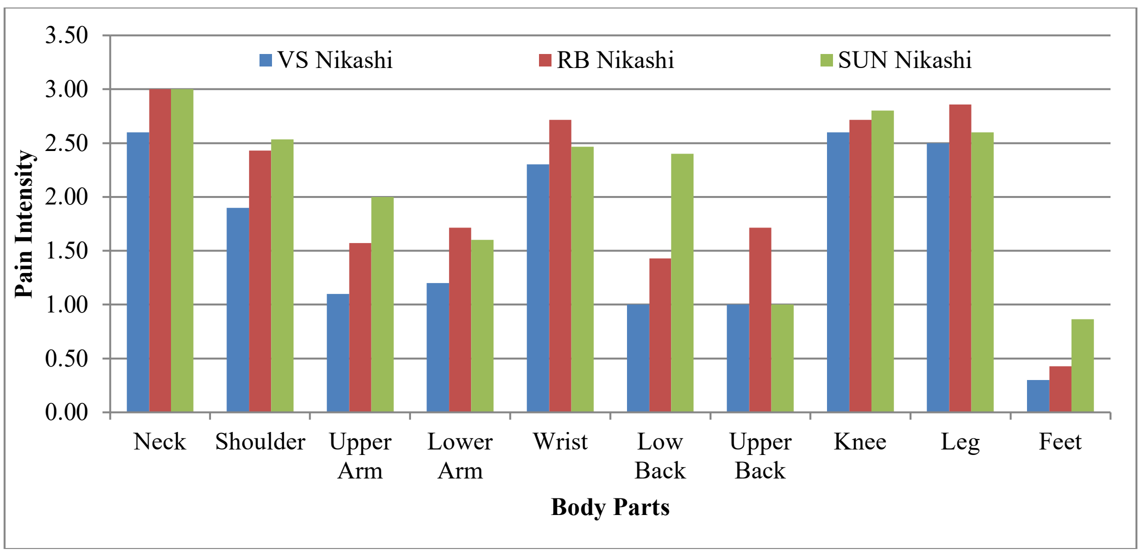


Figure 7-9: Compare between three studied brick kilns with reference to body part discomfort for Nikashi male workers

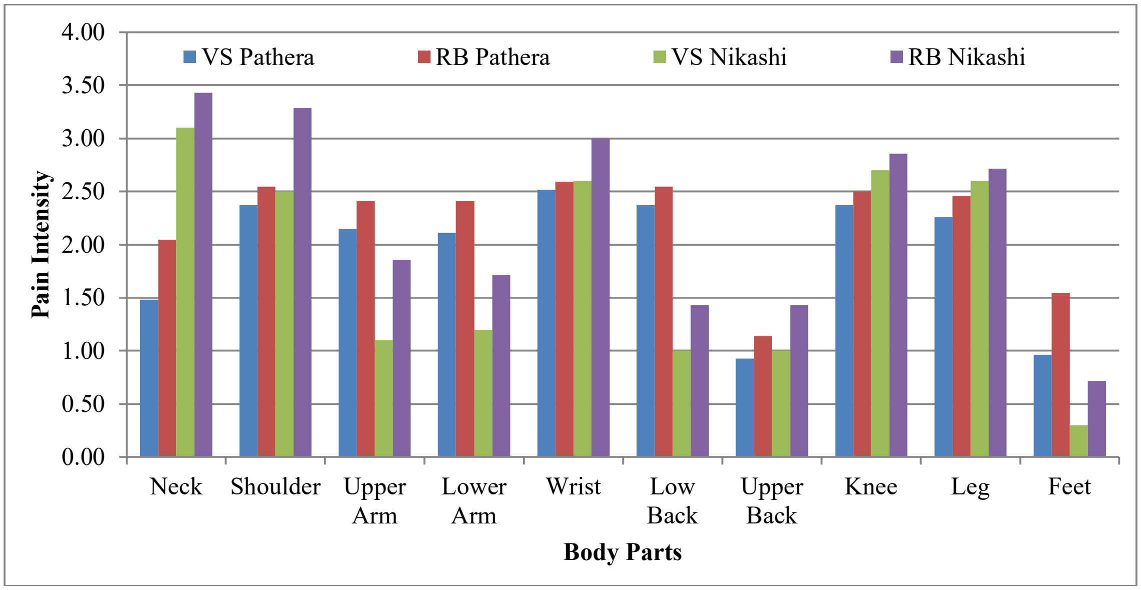


Figure 7-10: Compare between three studied brick kiln with reference to body part discomfort for Pathera and Nikashi female workers

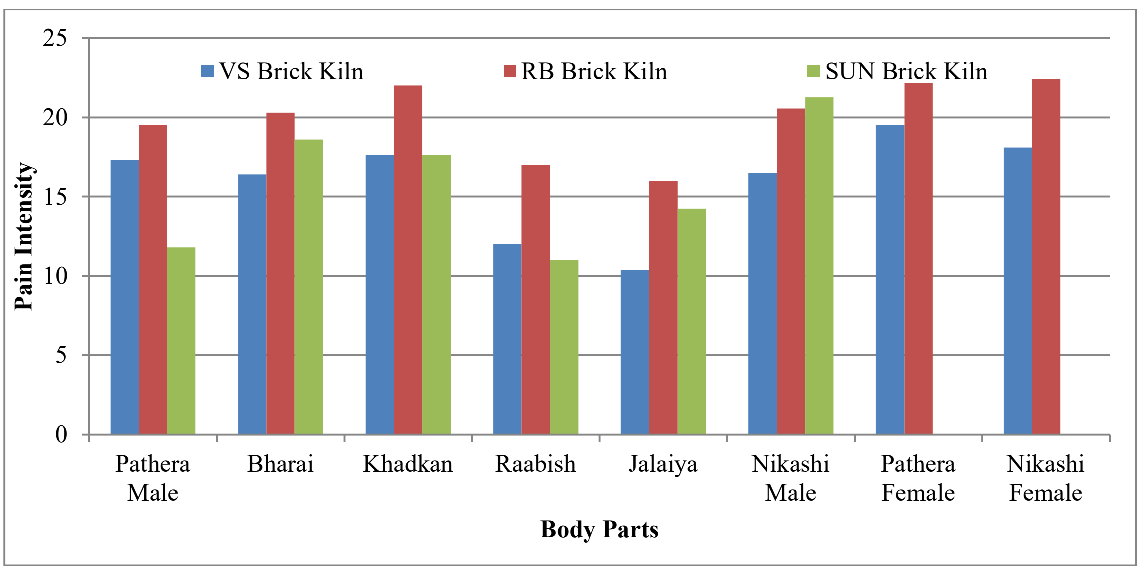


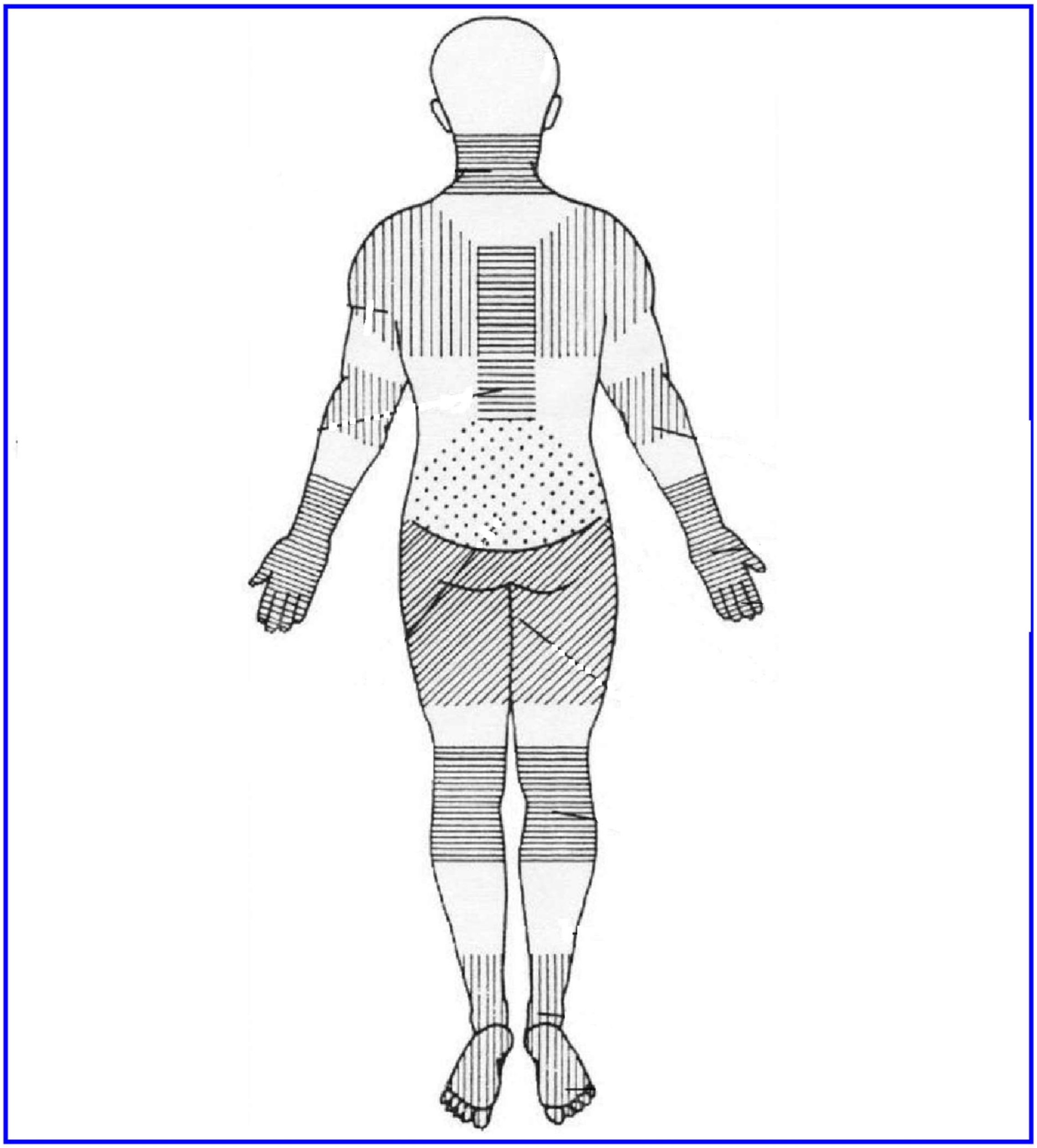
Figure 7-11: Whole body discomfort among different brick kiln activity in three studied brick kilns

Appendix E: Design Validation Datasheet

Testing of new moulding workstation (i.e. Moulding with Sitting-Standing posture)

<table>
<tr><td>Date & Time</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Name</td><td colspan="5"></td></tr>
<tr><td>Sex & Age</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Height</td><td colspan="5"></td></tr>
<tr><td>Weight</td><td colspan="5"></td></tr>
<tr><td>Resting HR</td><td colspan="3">75 bpm^{-1}</td><td colspan="2">75 bpm^{-1}</td></tr>
<tr><td></td><td colspan="3">Existing Workstation, i.e. Brick moulding on ground</td><td colspan="2">New workstation, i.e. Moulding with Sitting Standing posture</td></tr>
<tr><td>Working HR (Existing mould)</td><td colspan="3">1.
2.
3.
Avg. 106 (5.45)</td><td colspan="2">1.
2.
3.
Avg. 101 (4.18)</td></tr>
<tr><td>Productivity Bricks/time</td><td colspan="3">120 (15) / 40 minutes</td><td colspan="2">155 (12) / 40 minutes</td></tr>
<tr><td>REBA Score</td><td colspan="3">12</td><td colspan="2">7</td></tr>
<tr><td rowspan="2">Rate the existing workstation</td><td>Bad</td><td>Poor</td><td>Acceptable</td><td>Good</td><td>Excellent</td></tr>
<tr><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td rowspan="2">Rate the New workstation</td><td>Bad</td><td>Poor</td><td>Acceptable</td><td>Good</td><td>Excellent</td></tr>
<tr><td>☐</td><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td></td><td colspan="3"></td><td colspan="2"></td></tr>
</table>

Appendix F: Body Part Discomfort Analysis Map



Appendix G: Publications

1. Seat design of Driver's cabin for new EMU rakes of Mumbai by **Kundu A**, Sharma N., Ray G.G. Paper presented HWWE 2013; International Conference organised by Indian Society of Ergonomics, Vidyasagar University, India.

2. Work posture analysis of brick moulding operation in brick kiln industry and design intervention by **Kundu A**., Bandhyopadhay B., Bachwal L., Ray G.G. Paper presented at APCHI-ERGOFUTURE 2014, International Conference, Denpasar Bali, Indonesia.

3. An Ergonomic assessment of brick moulding operation in India as against the nutritional status of the moulders by Bachwal L., **Kundu A**., Ray G.G. Paper presented at APCHI-ERGOFUTURE 2014, International Conference, Denpasar Bali, Indonesia.

4. Load-carrying in two different modes by the brick kiln workers – A comparative analysis by Bandyopadhay B., **Kundu A**., Bachwal L., Ray G.G. Paper presented at APCHI-ERGOFUTURE 2014, International Conference, Denpasar Bali, Indonesia.

5. An ergonomic assessment of green brick transfer operation in brick kiln industry, India by **Kundu A**., Bachwal L., Ray G.G. Paper presented HWWE 2014, International Conference organised by Indian Society of Ergonomics, IIT Guahati, India.

6. An ergonomic assessment and the human cost per brick of the baked brick removal operation (Nikashi) in India by Bachwal L., **Kundu A**., Ray G.G. Paper presented HWWE 2014, International Conference organised by Indian Society of Ergonomics, IIT Guahati, India.

7. Respiratory response to tobacco dust exposure among biddi binders: A follow-up and bronchodilator study by Chattopadhyay B.P., Gangopadhyay, Das A., Sk J. Alam, Hossain M., Chowdhury A., **Kundu A**, Regional Occupational Health Centre (Eastern), (Indian Council of Medical Research) Block DP, Sector-V, Salt Lake City, Kolkata, India published by Indian Journal of Occupational and Environmental Medicine, August 2014, Volume 18, Issue 2.
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