CHAPTER – II

REVIEW OF LITERATURE

A survey of literature was undertaken to be familiar with the subject matter concerned with the present research problem, which proved helpful in planning and execution of the study. The review of literature is a condensed version of an exhaustive literature survey (Kamath & Udipi, 2010). The reviewed literature provides the basis to understand the importance of undertaking research in the chosen area to obtain knowledge on the methodology used in past researches and to identify the need for future research (Kothari, 2012). The major sources of review of the present study were the surveys, scholarly articles, books and other sources. The researcher also accessed the other sources like sources relevant to particular issues, area of research, or theory, providing a description, summary and critical evolution of each work are presented here. In order to make the review clear and understanding, the present chapter was divided into the following section:

2.1 Theoretical Orientation

2.1.1. Classification of Marble
2.1.2. Processing of Marble in India
2.1.3. Production of Marble – World
2.1.4. Production of Marble- India

2.2 Empirical Studies

2.2.1. Working Condition of the Workplace
2.2.2. Musculoskeletal Discomfort/Disorders experienced
2.2.3. Postural Discomfort
2.2.4. Vibration at Workplace
2.2.5. Noise at Workplace
2.2.6. Light at Workplace
2.2.7. Temperature at Workplace
2.2.8. Physiological Cost of Work
2.2.9. Fatigue experienced
2.2.10. Studies on Marble Industry

2.1 Theoretical Orientation

This section describes the theories related to Marble, processing of Marble.

2.1. Classification of Marble

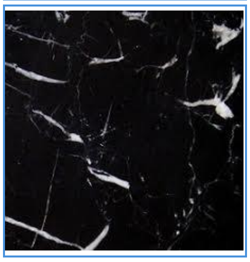
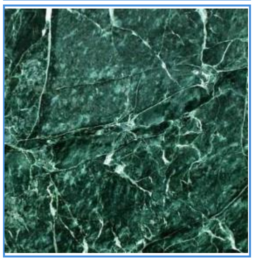
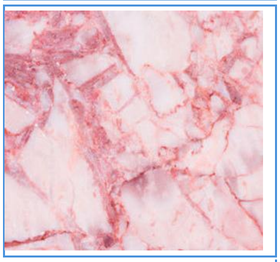
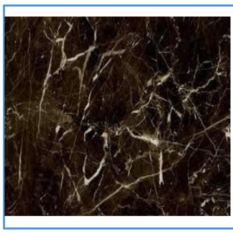
The term "Marble" is derived from Latin word "Marmor" which itself comes from the Greek root "Marmaros" meaning thereby a shining stone. Technically marble is a recrystallised, compact variety of metamorphosed limetone capable of taking polish. Commercially, marble is any crystalline rock composed predominantly of calcite, dolomite or serpentine, having 3-4 hardness, which can be excavated as blocks and can be sawed and takes good polish[11].

Marble has been classified into 10 groups by Bureau of Indian Standards (Indian Standard Institute i.e. ISI) (IS 1130-1969) on the basis of colour, shade and pattern. Rajasthan is the most fortunate state where all the 10 groups are available

1. Plain White Marble
2. Panther Marble
3. White Veined Marble
4. Plain Black Marble
5. Black Zebra Marble
6. Green Marble
7. Pink Adanga Marble
8. Pink Marble
9. Grey Marble
10. Brown Marble

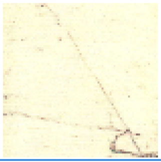
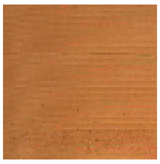
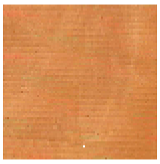
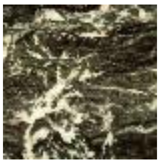
Figure 1: Types of Marbles as per BIS Classification

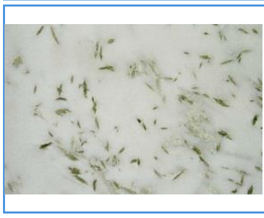
Plain White Marble	Panther Marble	White Veined Marble	Plain Black Marble
			

Black Zebra Marble	Green Marble	Pink Adanga Marble	Pink Marble
			
Grey Marble	Brown Marble		
			

In addition, many new varieties of marble have been brought into the folds of classification especially after opening of new mining areas.

Figure 2: Other Types of Marbles available in Rajasthan

Makarana Kumari	Fancy Brown Churu	Andhi Indo	Andhi Modern Art
			
Jaisalmer Yellow	Jaisalmer Yellow	Bhainslana Black	Jhiri Onyx
			
Rampura Black	Fancy Green Bidasar	Keshariyaji Sea Green	Olive Keshariyaji
			

Agaria	Morwar	Pista marble (amphibolite variety)	Brown green
			
English teak wood marble	Makarana Albeta	Makarana Doongari	
			

The Pista marble (amphibolite variety) from Andhi-Jhiri belt, Jaipur, Alwar and Dausa districts, Rajasthan, Brown green and golden ultramafics from Dunkar, Churu district, Rajasthan and Chocolate-brown and English teak wood marble from Jodhpur district, Rajasthan. The other various varities of marble are Parrot green marble from Jhilo in Sikar district, Rajasthan, Chocolate-brown or wood-finish marble from Mandaldeh, Chittorgarh district, Rajasthan, Purple marble from Tripura Sundari in Banswara district, Rajasthan and Blue marble from Desuri in Pali district, Rajasthan[11].

The marbles have also been classified by their genesis and chemical composition as under:

- **Calcite Marble**: It is a crystalline variety of limestone containing not more than 5 per cent magnesium carbonate. Colour and design wise, it may vary from grey to white to any colour, and even figurative light- brown to pink.

- **Dolomitic Marble**: It is a crystalline variety of limestone containing not less than 5 per cent or more than 20 per cent magnesium carbonate as dolomite molecules.

- **Dolomite Marble:** It is a crystalline variety of dolomite containing in excess of 20 per cent magnesium carbonate as dolomite molecules. It has variegated colours and textures. As the whiteness increases, the luster and translucency increases to an extent that it starts resembling with onyx. The main advantage of this marble is availability of exotic colours and patterns and its low maintenance cost. Marbles of Banswara in Rajasthan and Chhota Udaipur in Gujarat belong to this category.

- **Siliceous Limestone**: It is a limestone containing high silica with smooth appearance due to fine-grained texture. It is difficult to cut and polish this type of marble but once polished, it gives a pleasant look. It is available in several colours and designs. The pink marble of Babarmal and Indo-Italian variety from Alwar belongs to this category.
- **Limestone:** Several varieties of limestone are being used as marble. The Oolitic limestone of UK, Black Marble of Bhainslana, Katra & Sirohi and Golden-yellow Marble of Jaisalmer belong to this category. This type requires frequent maintenance in the form of polishing as they are non-metamorphosed and hence are softer in nature.
- **Serpentine or Green Marble:** This marble is characterised mainly by the presence of a large amount of serpentine mineral. It has various shades of green varying from parrot-green to dark-green and is known for having varying degrees of veinlet intensities of other minerals, chiefly carbonate of calcium and magnesium. Most of the green marbles from Gogunda, Rikhabdeo, Kesariyaji and Dungarpur belong to this category. This marble is mostly used for panelling. The darker variety of this marble, which is so dark-green that it looks like black, has been termed as Verde Antique.
- **Onyx:** It is a dense crystalline form of lime carbonate deposited usually from cold water solutions. It is generally transparent to translucent and shows a characteristic variegated colour layering due to mode of deposition. Such type of marble is found in Kupwara district in Jammu and Kashmir. It is used for making decorative articles.
- **Travertine Marbles:** It is a variety of lime- stone regarded as a product of chemical precipitation from hot springs. The depositional history has left

exotic patterns, when this is cut into thin slabs and polished it become translucent. (Indian Minerals Yearbook, 2018)

2.1.2. Processing of Marble in India

The production of marble passes through several stages. The main stages are demonstrated in Figure 1.

2.1.2.1. Mining and Processing of Marble

- **Extraction:** There are about 4000 marble mines in Rajasthan state alone. Querries of size of less than 1 hectare and large open-cast mines(maximum allowed area 50 hectares) are in operation at various regions of Makrana (Nagaur), Morwad area, Rajnagar (Rajsamand), Andhi(Jaipur), Salumbar, Jaisalmer, Bidasar (Churu) etc.

  Presently, mining of marble is done by manual, semi-mechanised and mechanised means. But in general, majority of mines adopt the semi-mechanised method of mining. The various stages in mining marbles are as follows:

  - The removal of overburden is generally carried out with heavy earth-moving machinery. In some cases, the weathered zone is removed by drilling holes by jackhammers and slim drill machines. These holes are charged with explosives and under controlled blasting methods, the overburden material is loosened out. It is then removed using heavy earth-moving machinery.
  - After studying the topography and keeping in view the further development of quarry, a key block is marked for removal from the quarry. At this stage, it is necessary to study the joint or fracture pattern in order to ascertain recovery of large-size block.

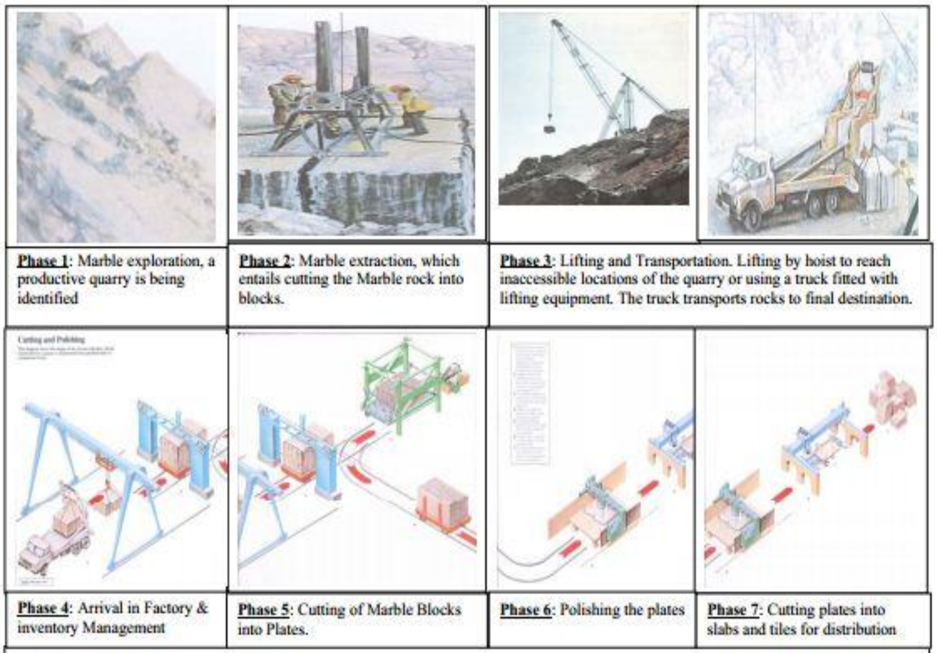


Figure (2): Marble Production Process

Source: http://www.aucegypt.edu/Business/econ/Documents/marble.pdf,

Figure 3: Processing of Marble

- In manual operation, a line of shallow holes is made and by driving in wedges with feathers by continuous hammering, a fracture is developed along the already drilled holes, and the block is made free from all the sides. After the block is toppled, it is again cut and dressed for getting a parallel-piped shape.

- In the semi-mechanised operation, jackhammers, slim drills, line drilling machines are used for drilling holes in a predetermined line. The remaining operation is more or less similar to manual mining except for lifting and pulling where cranes, winches, dozers, etc. are used. But in the above mentioned processes, the wastage is high and the size of the blocks recovered is small and seldom free from defects. However, to overcome these problems, the quarry front cut is made by using slim drill machines, diamond wire saw, quarry master, diamond belt saw machines and chain saw machines. Once the block is cut, it is toppled with the help of hydrobags, pneumatic pillows, air-jacks, etc. The lifting and loading of blocks are done by Derrick cranes and using various types of loaders.

2.1.2.2. Lifting and Transportation: After cutting the rocks of marble, marble blocks need to be lifted to a truck for transportation to the factories. Lifting happens either by using a hoist which lifts the cut blocks from inaccessible parts of the quarry to where they can be loaded to the truck, or by using a truck fitted with lifting equipment which lifts the blocks of stone from where they are to the truck.

2.1.2.3. Inventory Management: The Inventory of raw stone blocks is very bulky and requires a very spacious area. An "inventory room" usually occupies the backyard of a typical marble factory. One of the characteristics of the marble stone is its durability which allows its storage as inventory in the open air with no special maintenance or security measures. Nevertheless, the raw stone block is very heavy and this needs special skills and experience in storing the blocks: first, to take the least possible space and second, to allow the accessibility of all types of stored marble or granite and third, to insure safety of the personnel working in the factory and safety of the blocks from any damage. Once the raw blocks of stone arrive at the factory, they are loaded from the trucks with the crane in the backyard of the factory, where usually the storage area for the raw material is located. Usually the backyard space is divided into vertical lanes to store the different types of rocks and make them accessible when these are needed for processing. The raw blocks of marble are usually placed one block on top of each other, separated by a wooden "chair", with a maximum of three blocks feasibly placed on top of each other. Inventory management is done through manual bookkeeping. Inventory bookkeeping registers the date, the number and dimensions of the blocks, and the quality of marble received. Only very few factories have a computerized inventory management system. Deciding on the inventory to be stored depends on contracted client demand. If an agreement is signed between the factory and a client, the factory tries to store as much of the required blocks as inventory to secure the order and hedge against possible risks. The order is then processed in due time. Marble types that enjoy a high demand in the market are kept in special inventory stakes.

2.1.2.4. Stone Cutting: When a certain order is placed, the raw stone block is transported to the factory to be cut as demanded either into tiles or slabs of various thickness (usually 2 cm or 4 cm). Stone-cutting is a lengthy process that can take more than a continuous 12-16 hours of operation, depending on the model of the cutting machine as well as the status of its diamond wire or diamond blades. Though less expensive than imported machinery, locally manufactured cutting machines have only 40-45 blades which are usually not very accurate and produce inconsistent thickness, particularly of marble tiles which fail to measure up to international standards.

Processing of marble is done in two stages. The first stage of processing involves cutting the blocks into 2 to 3 cm thick slabs by using gang saws, wire saws and circular saws. In marble tile plant, the required thickness of tiles is 10 or 12 mm. For cutting, circular saws are used. To polish the tiles polishers, trimmer machines are used before being sold.

On one gang saw on an average 20-40 tonnes of marble is processed daily. During operation water is continuously sprinkled on the block to reduce the heat generation. The water requirement is fulfilled by processors through water tankers. Average water loss per day is 1000 liters. The marble blocks processed on gang saw results in 30 per cent waste generation.

- **Processing Centres in India**

  Rajasthan has more than 95 per cent marble processors. Important processing centres in the State are Makrana, Jaipur, Alwar, Ajmer, Udaipur, Nathdwara, Rajsamand, Abu Road Banswara, Chittorgarh and Kishangarh.

Rajnagar is the world's largest marble producing area, large number of gangsaw units are located in the nearby town of Kishangarh to process the produced materials.

In Gujarat, processing units are located at Ahmedabad, Ambaji and Vadodara. India has a rich tradition of processing stones and carving jalis, pillars, garden furniture, floral and other design by expert craftsmen.

Principal marble producing & processing companies in India are: R. K. Marble Ltd, a world's largest marble miner having its processing unit at Kishangarh in Ajmer district; Bhandari Marble Group; Classic Marble company have four processing plants at Silvasa in Dadra & Nagar Haveli; Anil Marble & Granite Exports is also a leading manufacturer and exporter of wide range of marble. Other prominent producers in Udaipur district are Arti Marble & Granite Pvt. Ltd, Mumal Marbles Ltd, Madhusudan Marble Pvt. Ltd, Arihant Marbles, Khetan Marbles, etc (Mineral Yearbook 2018).

2.1.2.5. Polishing: After the stone has been cut to the specific dimensions, there are different techniques towards reaching a “finished” product. The most known of these techniques is

(a) Polishing and (b) Tumbling.

The polishing operation is fully automated with the use of powdered abrasives that keeps on scrubbing the surface of the marble until it becomes smooth and shiny. The smoother the abrasive used, the shiner and smoother is the surface of the marble. Here, water showers are essential to prevent overheating. The process of polishing allows the full color, depth and crystal structure of the stone to be visible which reflects the beauty of the stone. Tumbling creates a rough finish to the surface of the stone. This is achieved by turning the stone at slow speed, in a rotating barrel with abrasives and water for extended hours. Then, sometimes, a thermal or a flame finish is given to the marble by applying a high temperature flame to the surface of the stone. The flame fractures crystals on the top, leaving a rough-textured finish. A rotating saw is used to trim the edges of each polished slab. After that, the finished product is ready for transportation and delivery to the end user.

2.1.2.6. Distribution: The distribution channels depend on the end product produced by the factory. If the factory produces finished tiles and slabs, then this is a finished order, processed according to the customer requirements and a customer delivery takes place. The final product is delivered to the customer according to an agreed upon time and place. As finished marble product is very fragile and needs special care in handling, it is usually packaged, loaded on a truck and delivered to the client. The same factory could be producing marble plates. These require distribution efforts. Distribution often goes to workshops which are usually the middleman between the supplier and the end user. These workshops receive the cut plates of marble and store them in their shops for the end user to choose from. There are marble showrooms where they display a wide choice of colors and types of marble to the end user. These smaller workshops constitute a good percentage of the clientele base for the bigger factories. Factories that are involved in cutting the plates of marble into tiles and slabs usually deal with bigger orders where the marble is required for a whole building and a contract is signed between the marble supplier and the building contractor for the quantity supplied. Hence, distribution is directly related to the scale of client demand (Kandil and Selim, 2015).

- **Specification for Marble Production**

Indian standards for marbles (blocks, slabs and tiles) IS:1130-1969 (reaffirmed in 2008) are summarised as under:

- **Classification:** Marble shall be classified as white and coloured categories.

- **General requirements:** Marble shall be free from foreign inclusions and prominent cracks.
- **Sizes:** Marble blocks shall be supplied in lengths ranging from 30 to 250 cm, widths 30 to 100 cm and thicknesses 30 to 100 cm. The slabs shall be supplied in lengths ranging from 70 to 250 cm, widths 30 to 100 cm and thicknesses from 20 to 150 mm. The tiles shall be supplied preferably in sizes of 10 x 10 cm, 20 x 20 cm, 30 x 30 cm, 40 x 40 cm, 50 x 50 cm and 60 x 60 cm with thickness ranging from 18 to 24 mm in the same piece. Other sizes as agreed upon by supplier and purchaser may also be supplied.
- **Physical properties:** The physical properties of blocks, slabs and tiles shall comply to the requirements, as given under:

Table 1: Physical Properties of Marble

S.No.	Characteristics	Requirement	Method of Test
1.	Moisture absorption after 24 hours immersion in cold water	0.4% max.	IS : 1124-1974 by weight
2.	Hardness	3 min.	Mohs' scale
3.	Specific gravity	2.5 min.	IS : 1122-1974

- **Workmanship:** The edge of slabs and tiles shall be true. The finishes shall be sand and/or abrasive-finish, honed-finish or polished finish[12].

2.1.3. Production of Marble – World

According to Mehdi (2006), the world total production of marble and granite reaches over 100 million tons and total consumption is valued about $40 billion per year. In 2010, the world export value of marble and granite was $62 billion. Since 1999, world marble production grew at a high rate of 8.7 per cent and the industry is expected to grow over 8 per cent till 2025.

Marble and granite are produced in more than 40 countries in the world. Italy, Turkey, Spain, India and China are the top five dominant countries in terms of marble production. These countries control over half of the world market – only Italy produces over 17 per cent of world marble. A major part of production is consumed locally by producing countries, and only a small percentage of total production is exported. This fact indicates that local supply of marble remains less costly, while the transportation cost increases the price of exported marble products[13].

2.1.4. PRODUCTION OF MARBLE- INDIA

India possesses a wide spectrum of stones ~ granite, marble, sandstone, limestone, slate, and quartzite. It is amongst the largest producer of raw stone material. The occurrences of marble have been reported from many states, viz, Rajasthan, Gujarat, Haryana, Andhra Pradesh, Madhya Pradesh, Jammu & Kashmir, Maharashtra, Sikkim, Uttar Pradesh and West Bengal. Among the above states, marble deposits of economic importance are localized in Rajasthan, Gujarat, Haryana, Andhra Pradesh and Madhya Pradesh. Rajasthan has the distinction of having the best among Indian resources of good quality marble. Out of 32 districts, 20 districts have marble in one or the other form.

- Udaipur - Rajsamand - Chittorgarh region;
- Makrana - Kishangarh region;
- Banswara - Dungarpur region;
- Andhi (Jaipur) - Jhiri (Alwar) region; and
- Jaisalmer region.

The marbles of Rajasthan are in various colours and shades. The Makrana area is famous for pure white crystalline marble. Other varieties found in Makrana area are Albeta, Adanga, Dongri Pink. The marble from Rajsamand area is mined extensively. It is off-white and greyish-white. The internationally acclaimed variety of green marble comes from Rikhabdeo-Kesariaji area, 60 km away from Udaipur. The green marble has various shades of green with white and black network and patches. The marble from Babarmal is pink and is marketed as Indian Pink. It is a fine-grained hard marble having black and white bands. The marble from Bhilwara is white to off-white, fine to mediumgrained hard marble having black and white bands. The marble from Banswara is white to off-white dolomitic marble and is soft. It is used generally for cladding purpose. The white to greyish-white marbles of Jaipur area are being sold under the trade name Andhi Pista, a white marble having green laths of serpentine; onyx; Indo-Italian and Black Marble. The Bhainslana marble is dark-black. The important regions of marble occurrences in Rajasthan are (Table 2):

Table 2: Important deposits of marble in Rajasthan

S.No.	Name of Deposit	District
1.	Agaria, Amet, Kilwa, Morwad, Dharmita, Katre, Parvati Koyal, Morchana, Arana, etc	Rajsamand
2.	Makrana, Borawad (White), Chosira Dwagri (Pink), Kumari	Nagpur
3.	Kesariaji (Rikhabdeo), Odwas	Udaipur
4.	Babarmal (Devimata), Rajnagar	Udaipur
5.	Tripura Sundari-Talai-Odabagi-Bhimkund Vithaldeo, Prithvipura, Paloda, etc	Banswara
6.	Andhi, Bhainslana, Todi-ka-Bas	Jaipur
7.	Jhiri, Sariska, Rajgarh, Badampur, Moti-Dungri, etc.	Alwar
8.	Selwara-Dhanwar-Koteswar	Sirohi
9.	Jahazpur, Kekri, Manoharpur, Asind, Banera, Shahpura	Bhilwara
10.	Kalyanpur-Narwar-Sardhana	Ajmer
11.	Patan-Rampura, Kela-Dungari	Sikar
12.	Dagota	Dausa
13.	Umar	Bundi
14.	Sabla, Nandli-dad, Peeth, Manpur, Dachki, etc.	Dungarpur
15.	Mandal, Deh	Chittorgarh
16.	Pachori Chadi, Moriya Munjasar, etc.	Jodhpur
17.	Bar-Sendra Sarangwa, Sevari, Kundal	Pali
18.	Dunkar, Bidasar, Dujara	Churu
19.	Mooisagar, Amarsagar, Habur, Naripa	Jaisalmer
Source: (Indian Mineral Yearbook, 2018)		

Gujarat has vast resources of marble in Banaskantha, Bharuch, Vadodara, Kachchh and Panchmahal districts. The Ambaji area in Banaskantha district and Chinchpura area in Vadodara district are the main producing centres. The white marble of Ambaji is known for its amenability to carving. Other deposits in Banaskantha district are Jarivav, Kumbharia, Kateswar, Bheroj and Khikla. Marble of Vadodara district occurs in various shades, viz, green, white, pink and cream. Marble of Bharuch varies in colour from black to green and red. The yellow marble of Kachchh is thin-bedded, sometimes fossiliferous and blockable deposits occur at Bhulawara-Chinchpura belt (Indian Minerals Yearbook,2016 & 2018).

In Haryana, marble deposits are located in the district of Mahendragarh. Most important localities are Antri-Beharipur, Zainpur, Chappra Bibipur, Nangaldur gu, Islampur and DhanotaDhancholi. Marble of this area occurs in variegated colours and banded forms. It enjoys the reputation as 'Patiala Marble' with black and white bands. Of late, the world-famous marble rocks 'Bhedaghat' near Jabalpur in Madhya Pradesh have attracted entrepreneurs from Rajasthan. The extension of these rocks located in between Jabalpur and Katni is being quarried. The marble from these areas is exploited for its off-white, fine-grained, banded attributes. A number of quarries are under operation (Indian Minerals Yearbook,2016 & 2018).

Marble deposits of Maharashtra are of calcitic and dolomitic type which are located in the areas of Katta-Hiwara, Kadbikhera, Sakaritola, Pauni, Chorbaoli, Deolapar, Mansar, Kandri, Chargaon, Junewani villages in Nagpur district. In KattaHiwara, the marble is light-pink to grey in colour. The marble of Kadbikhera-Sakaritola is pink calcitic marble while the marble deposits of Mansar and Kandri areas are dolomitic type (Indian Minerals Yearbook,2016 & 2018).

In Uttarakhand, thick impersistent bands of white marble occur in massive limestone in Pithoragarh district (Indian Minerals Yearbook, 2016 & 2018).

In Mirzapur district of Uttar Pradesh, two marble deposits at Hingha and Geria are of good quality and can yield blocks for limited requirement (Indian Minerals Yearbook,2016 & 2018).

In Jharkhand, huge deposits of marble are available in Semra-Salatua and adjoining areas of Palamau. Pink marble occurrences are reported from Hesadih area, Singhbhum district (Indian Minerals Yearbook,2016 & 2018).

According to Indian Minerals Yearbook (2016 & 2018), the marbles of Khammam area Andhra Pradesh are white and green. Occurrences of pink, purple, yellow and variegated marbles are reported in Cuddapah, Kurnool and Anantapur districts. The dolomitic marble of Cuddapah, Kurnool and Anantapur districts is other upcoming resource centre for off-white, coloured, greyish-black marbles which take good polish and are being exploited by private entrepreneurs.

The total resources of all grades of marble have been estimated at 1,945 million tonnes. Of these, only about 4.5 million tonnes (0.23 per cent) fall under 'reserves' category and about 1941.3 million tonnes (99.77 per cent) under 'remaining resources' category. Gradewise, about 27 per cent resources fall under unclassified and not-known grades, 55 per cent under off-colour grade and 17 per cent under white colour grade. The available data on marble resources reveal that about 63 per cent resources are in Rajasthan, 21 per cent in Jammu & Kashmir, Gujarat 6 per cent and Chhattisgarh 4 per cent. The remaining resources are distributed mainly in Maharashtra, Haryana, Uttarakhand and Sikkim in descending order (Indian Minerals Yearbook, 2016 & 2018).

According to Indian Minerals Yearbook (2016 & 2018),the total production value of marble increased to 1885.84 crore in 2014-15 from `1541.91 crore in 2013-14. Rajasthan alone accounted for about 89 per cent output value followed by Gujarat (10 per cent) and nominal 1 per cent shared by Madhya Pradesh, &Andhra Pradesh (Table - 3).

Table 3: Value of Production of Marble, 2009-10 to 2014-15

(Value in Rs '000)									
State	**2007-08**	**2008-09**	**2009-10**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
India	**6741120**	**11506043**	**12819800**	**12794100**	**13954172**	**16012403**	19129861	15419081	18858433
Andhra Pradesh	18227	176	170	170	138	81534	13744	37	103
Gujarat	448310	448310	448310	422610	136248	399729	1945115	1607500	1895600
Jammu & Kashmir	-	76	96	96	539	295	537	310	-
Madhya Pradesh	192591	288084	290965	290965	344304	358015	54565	262388	115730
Rajasthan	6081992	10769397	12080259	12080259	13472943	15172830	17115900	13548846	16847000
Source: (**Indian Minerals Yearbook 2012 & 2013, 2016*)***									

2.2 Empirical Researchers

This section comprises of the various studies conducted outside India and India related to working conditions, Musculoskeletal disorders/discomfort and health of various profession. The section also covers the researches related to environmental factors like noise, light, temperature, humidity and vibration. The researches conducted on posture, physiological cost of work and fatigue are also reviewed in this section. They are further clubbed in within India and outside India categories. The studies conducted are as follows:

2.2.1. Working Condition of the Workplace

A study with the aim to identify working conditions and work characteristics that were associated with workers' perceptions and to find out that their work was harmful to their health undertaken by **Arial (2011)**. The Swiss data set from the 2005 edition of the European Working Conditions Survey was used for collecting data. A total number of 1040 people (448 women and 580 men) of Switzerland aged 15 years and above and who performed at least one hour per week of work were interviewed for the study. The results revealed that a total of 330 (32 per cent) participants reported having their health affected by work. The most frequent symptoms included backache (17.1 per cent), muscular pains (13.1 per cent), stress (18.3 per cent) and overall fatigue (11.7 per cent). Scores for self-reported exposure to physicochemical risks, postural and physical risks, high work demand, and low social support were all significantly associated with workers' perceptions that their work is harmful to their health, regardless of gender or age. The study concluded that compared to participants with a low level of education, participants with a high educational level were more likely to report that their health was affected by their work.

2.2.2. Musculoskeletal Discomfort/Disorders experienced

Sarkar et.al. (2016) conducted a study which was carried on the workers of a central market area in Kolkata to find out the prevalence of the Musculoskeletal Disorders. 210 male Manual Material Handling workers were randomly selected. Standardized Nordic Musculoskeletal questionnaire was used to assess the prevalence of MSD. Working posture was analyzed by Ovako working posture analysis system (OWAS). SF12 questionnaire was used to assess the physical and mental health status. The results revealed that Lower back was found to be worst affected body part (68 per cent) followed by Knee (63 per cent), Neck (56 per cent) and Shoulder (41 per cent). The Physical composite score (PCS) and Mental composite score (MCS) were found to be 39.7 ± 9.11 and 46.0 ± 9.17 respectively. PCS, MCS and Frequency of lifting were found to be significant predictors of pain intensity rating. The regression model predicted 22.7 per cent of the variability in the scores of the pain intensity rating. It was concluded awkward postures along with the heavy load lead to the development of musculoskeletal disorders.

A study was undertaken by **Dasgupta et.al. (2014)** to assess the ergonomic exposures to risk factors of drywall workers which lead to musculoskeletal injuries (especially back, neck and wrist injuries). The study took place at three construction sites in the greater metropolitan area of Boston, Massachusetts wherein the samples were selected by convenience method. PATH (Posture, Activities, Tools, and Handling) an observational work sampling-based analysis method developed for non-routinized and irregular cycle jobs (Buchholz et al., 1996) was used to collect quantitative ergonomic exposure data during 28 days of observing interior wall systems installation.

Data on working postures were collected for three main body parts: legs, arms and trunk. The study identified several ergonomic exposures in interior systems construction. Several risk factors were found among the respondents like awkward body postures such as overhead arm posture, trunk flexion, and handling of heavy drywall panels. The results also revealed that the drywall panel installation task consists of exposures related to risk factors to the back, arms and shoulders as well as the potential risk of falls from ladders. In addition, a safety hazard frequently resulted when a worker's foot was poorly supported on a ladder while lifting heavy drywall panels to hang them on the ceiling or upper wall.

A study was carried by **Ahmed (2012)** to observe 550 women construction workers of Coimbatore City in their occupational settings for modalities of performance in the job, study the work environmental impact for sources of work-related hazards and on their health status. The study also focused on examining their socio – economic status, knowledge on occupational health hazards, work-related health disorders and access to social security systems and Ergonomically relate the impact of repetitive actions and the postures adopted with objective/ subjective feelings of pain and perceived discomforts during performance. The 500 women construction workers (convenience sampling) for the empirical study and 50 women workers (purposive sampling) were selected for the action research. Semi- structured Interview schedule, check list, test-batteries and action programme were used as tools for eliciting data with interview and observation as effective methods. The findings of the study revealed that the activities performed by the respondents were carrying loads of different building materials in the same floor or up floors, passing bricks manually, sieving sand, shovelling, filling mud in foundations and sweeping, using crude tools and accessories, the use of which impacted their upper extremities. Many of them were worn out and hence were not user-friendly, causing minor injuries and bruises. Work place related health disorders like pain in the shoulder, neck, back; knees, hands and wrists were reported by all the respondents. Exposure to noise, dirt, work over load, paint smell, and the like in the work spot had manifested in the form of various health problems. The findings on the Heart rate revealed carrying load up floors to fall under very heavy to extremely heavy, and carrying load in the same floor as very heavy.

Jansen et.al. (2012), undertook a study to analyze subjective self-evaluation of musculoskeletal discomfort conducted by female production assembly workers in Tartu, Estonia. Thirty-seven female assembly workers aged 20–54 years participated in this study. 35 females of 37 respondents were right-handed. Discomfort in neck, shoulder, upper back, upper arm, low back, forearm, wrist, hips, thigh, knees, lower legs and heels was subjectively evaluated by Cornell Musculoskeletal Discomfort Questionnaire. The results indicated that female assembly workers felt most work-related discomfort in the neck (44 per cent), lower back (19.7 per cent) and in the right wrist (15 per cent). Discomfort was less pronounced in the right knee (0.01 per cent), left upper arm (0.04 per cent) and left hip buttocks (0.1 per cent). In conclusion, this study indicated that subjective discomfort sensed by female production assembly workers was higher in the neck, lower back, right shoulder and the right wrist.

El-Gammal et.al. (2011) undertook a study to evaluate the health risk assessment that might generate from marble manufactures in Damietta City. The study also aimed to investigate the effect of marble dust exposure on lungs of rats. The rats exposed to inhalation of dust induced pathological changes in their lungs which involved the different tissue constituents. The degree of these pathological changes was proportional to the duration of exposure. This study revealed a positive relationships between respiratory lesions and marble dust. The mean concentrations of inhalable dust in marble workshops (A,B,C) were 30.44, 60.41, 68.73 mg/m^3 respectively, whereas the mean concentrations of personal respirable dust in marble workshops (A ,B and C) were 6.10, 6.92, 7.15 mg/m^3 respectively. Most of these measurements were exceeded the permissible exposure limit.Moreover, the data of the present study demonstrated that long period of chronic exposure to dust induced progressive atrophic changes in the alveoli of rats. Therefore, there are some potential risk of such industry lying on the environmental, which requires attention, mitigations, and management to protect the existing human and animal health.

Johnson et.al. (2011) undertook a study to evaluate the prevalence of Musculoskeletal Discomfort in industrial workers of Tamil Nadu, to identify the location specific Musculoskeletal Discomfort, to generate guidelines to optimize the work, to minimize the risk of injury development and to maximize the output quality. The study was a cross sectional pilot study which included 219 subjects of age groups ranging from 18 to 55 years, from three different industries. The questionnaires were administered to assess the work exposure and health. The range of movement of the joints was calculated by using a Goniometer. The postural workload was assessed by using a RULA work sheet. A clinical examination was done to diagnose Musculoskeletal Discomfort. The results revealed that 32.6 per cent of the subjects suffered from Musculoskeletal Discomfort. The highest prevalence of Musculoskeletal Discomfort was seen among pyrotechnics (44.4 per cent), followed by match makers (32.7 per cent) and litho offset printers (19.2 per cent). An increased prevalence of symptom severity was observed in women (36.1 per cent) and in individuals who performed moderately strenuous tasks (52.8 per cent).

Caban-Martinez, (2011) conducted a study using the 1997-2008 National Health Interview Survey (NHIS) Study Database and the 2001-2003 Medical Expenditure Panel Survey (MEPS), wherein they examined the musculoskeletal disorders in the US workforce, focusing on the under-explored associations between US worker occupation, health behaviors (physical activity patterns, obesity, and cigarette smoking), geographical location, and health-related quality of life impact of musculoskeletal disorders. The overall prevalence of arthritis was 21.7 per cent with 14.2 per cent for employed adults and variation in rates by occupation type (e.g., Computer/Mathematical occupations (11.2 per cent) versus Healthcare support occupations (17.5 per cent). Overall rates of specific arthritis conditions, which also varied by occupation included: arthritis (19.3 per cent), rheumatoid arthritis (2.3 per cent), gout (1.4 per cent), lupus (0.3 per cent), and fibromyalgia (1.2 per cent). Health behaviors mediated the relationship between occupation and both motor functional limitations. Workers with arthritis that were current smokers and did not engage in physical activity reported significantly greater levels of both types of motor functional limitations. Health behaviors appeared to partially mediate the relationship between musculoskeletal conditions and functional limitations.

Yiin et. al. (2011) assessed occupational exposure and health threats for current stone workers of Taiwan. Six stone industrial factories were selected with governmental assistance. The possible agents that affected health in the work places, such as dust, noise and hand-arm vibration were measured. The data was also collected with the help of self-reported questionnaire survey to discover the health statuses of the workers, and attempted to find the associations between exposure and health. The dust sampling included sampling of total and respirable dust. All airborne dust levels, if categorized as Class 4, were complied with the regulations. However, some of the levels exceeded the standards, if categorized as Class 1 or 2. Dry sanding did not significantly generate more dust than the wet method, suggesting the effectiveness of using ventilation equipment. Noise and hand-arm vibration, however, were equal to or above the standards, and hand held dry sanding machine produced the largest acceleration (7.02 m/s^2, X axis). The spectrum analysis indicated that the peak values of noise occurred between 1 k – 4 kHz, which had the most impact on the hearing ability; either dry or wet sanding could produce the harmful frequencies (8 – 16 Hz) of vibration. The survey via questionnaire revealed that more than 30 of stone workers thought they had problems with hearing, and one-third felt they had nerve impairment of their fingers. The odd ratio for hand-arm vibration in relation to finger numbness is 6.75 with 95 per cent CI of (1.32, 34.6).

A study was undertaken by **Najenson et. al. (2010)** to assess the prevalence of low back pain among 384 Male full time Israeli professional urban bus drivers, to evaluate the association between low back pain (LBP) in drivers and work-related psychosocial and ergonomic risk factors. Information on regular physical activity and work-related ergonomic and psychosocial stressing factors was collected during face-to-face interviews. The prevalence of Low Back Pain was assessed using the Standardized Nordic Questionnaire. The results indicated that 164 bus drivers (45.4 per cent) reported experiencing Low Back Pain in the previous 12 months. Ergonomic factors associated with Low Back Pain were uncomfortable seat (odds ratio 2.6, 95 per cent confidence interval 1.4–5.0) and an uncomfortable back support (OR 2.5, 95 per cent CI 1.4–4.5). In the group of drivers with LBP, 48.5 per cent reported participation in regular physical activities vs. 67.3 per cent in the group without LBP ($P < 0.01$). The following psychosocial stressing factors showed significant association with LBP: “limited rest period during a working day” (1.6, 1.0–2.6), “traffic congestion on the bus route” (1.8, 1.2–2.7), “lack of accessibility to the bus stop for the descending and ascending of passengers” (1.5, 1.0–1.5), and “passengers' hostility” (1.8, 1.1–2.9). The researcher concluded that work-related ergonomic and psychosocial factors showed a significant association with LBP in Israeli professional urban bus drivers.

Gangopadhyay et. al. (2010) conducted a study to assess occupational related disorders and to conduct ergonomics assessment among stonecutters in West Bengal. The study focused on the duration of work per day, the working environment and working activities and the feeling of discomfort in different parts of the body. A detailed posture analysis was performed with the Ovako working posture analysis system (OWAS). It was observed that stonecutters worked continuously in awkward postures during stonecutting and setting. Consequently, they suffered from discomfort in different parts of their body, specifically in the lower back, knees and shoulders, which mainly prevented them from continuing their work. This study also revealed that stonecutters had to work in congested work areas with a poor level of illumination.

An investigation was undertaken by **Gangopadhyay et. al. (2007)** to establish the prevalence of upper limb MSD among the brass metal workers and to identify the causative factors behind its development in West Bengal, India. In this study, 50 male brass metal workers (Experimental Group) and 50 male office workers (Comparison Group) were selected. For the symptom survey, a questionnaire on discomfort symptoms was performed. The repetitiveness of work and Hand Grip Strength of both the groups were measured. It was revealed that upper limb MSD was a major problem among brass metal workers, primarily involving the hand, wrist, fingers and shoulder.

Among the workers reporting subjective discomfort, most of them felt pain, followed by tingling and numbness in their hands. The respondents complained of swelling, warmth and tenderness in their wrists. Their activities were highly repetitive and the handgrip strength of these workers was significantly less than that of the comparison group. It was concluded that high repetitiveness, prolonged work activity (10.5 hour of work per day with 8.4 hours spent on hammering) and decreased handgrip strength could be causative factors in the occurrence of upper limb MSD among brass metal workers in West Bengal, India.

A research on work related Musculoskeletal Disorders and The Crab Processing Industry was undertaken by **Barron (2007)**. The study surveyed the gender differences and the prevalence, type, and symptoms of work-related musculoskeletal disorders (WMSDs) resulting in disability among the sample of 107 crab plant workers in Newfoundland, Canada. An analysis comparing the survey responses of women (n=74) and men (n=33) revealed few differences in the prevalence, type or symptoms of WMSDs and resulting disabilities by gender. Some of these differences included that female workers were more likely to experience a neck injury than males and that males were more likely to have injuries to their arms than females. Pain was the predominant symptom experienced. Disability scores were high for men and women, but no significant differences. The second purpose was to assess what role physical risk factors plays in the presence of WMSDs. Overall, the results suggested that jobs in which employees engage in repetitive motion, work at high speeds and use precise movements of the hands and finger are associated with increased evidence of WMSDs. However, no significant relationship was found for gender differences on these physical risk factors.

Sobeih (2006) conducted a study on One hundred and forty seven construction workers (representing 3 trades namely carpenters, electricians, and plumbers) from Greater Cincinnati area, Ohio. The purpose of the research was to assess the prevalence of Musculoskeletal Disorders among construction workers and identify the psychosocial and physical risk factors associated with their occurrence using an onsite survey instrument. Data were collected by means of a questionnaire that was handed out to subjects during the data collection visits. The questionnaire consisted of 4 parts: personal information, musculoskeletal disorders, stress symptoms, and psychosocial factors. The results revealed that 1-year prevalence of Musculoskeletal Disorders was high with 61.2 per cent reporting severe symptoms and 39.7 per cent having some functional impairment due to Musculoskeletal Disorders. Lower back and knee symptoms were the most prevalent disorders among the different trades. Physical task requirement was the most important factor associated with Musculoskeletal Disorders reflecting the physical nature of construction work. After controlling the physical requirement of work and the personal characteristics of subjects, psychosocial factors were significantly associated with Musculoskeletal Disorders. Economic and performance factors were the most stressful psychosocial factors reported and significantly increased the risk of Musculoskeletal Disorders. Organizational, mental, and individual growth factors were also significantly associated with increased risk of Musculoskeletal Disorders however; some demonstrated an additional protective effect where they were associated with decreased risk of Musculoskeletal Disorders.

A study was undertaken to assess the contribution of work-organizational factors, including ergonomics and psychosocial factors, to the prevalence of WMSDs among sewing machine operators in Los Angeles, California by **Wang, (2005)**. 520 immigrant workers were recruited from 13 garment industry sewing shops between October 2003 and March 2005 and considered for enrollment in an ergonomic intervention study. The information about individual characteristics and work organization, including ergonomic and psychosocial factors was collected in a face-to-face standardized interview conducted in the language of the employee. Logistic regression modeling was performed for two models with different covariate adjustments: adjusting for age, gender, and ethnicity, and another adjusting in addition to smoking, body mass index (BMI), medical history related to musculoskeletal disorders, and shop size. The results revealed that the majority of the study population were females (64.4 per cent) and Hispanic or Asian (67.1 per cent and 28.3 per cent respectively), with a mean age of 38 years (range 18-65 years). Of all, 32 per cent met the criteria of suffering from an upper body disorder. For these sewing machine operators, several individual factors, including age, gender, ethnicity, marital status, smoking behaviors, and medical history of musculoskeletal disorders or systemic illness, were associated with an upper body disorder. In addition, several ergonomic factors, such as repetitive movements, non-flexible work schedules in large shops, working on a schedule with a maximum work cycle of more than 2.75 hours, less than two rests in a workday, short total rest periods, a work-rest ratio over 8.7, and psychosocial factors, including high psychological job demands, job dissatisfaction, and perceived high physical exertion, were associated with an elevated prevalence of upper body disorders.

Shikdar (2004), conducted a study with main objective to conduct an assessment of ergonomic-related problems in oilrigs in a desert environment of Oman. A checklist, physical audit and medical records were used in the investigation. The samples of the study were 32 employees**.** Two types of instruments were developed for data collection in the rig: checklists distributed to workers and team leaders, and physical measurement of environmental attributes. The questions included in the checklists were related to ergonomic problems, such as worker health issues, work, environment and worker satisfaction. The categories of questions in employee checklist were demography, work, health issues, environment, and satisfaction. To examine how the temperature varied during the day and night in the oilrig during mid-summer, measurement of temperature and humidity was conducted every 2 hrs for 2 days in July. The results revealed that the peak temperature of 46 ºC was approached at about 2 p.m. The air temperature remained above 30 ºC for about 14 hrs. Noise on the rig floor was measured at various points, at ear height of the crew. It was observed that the level was above 80 dBA on the rig throughout the day. High noise of 95 dBA was observed around the center of the rig where the power station was located. The results also showed significant health, environment and work-related problems that could be attributed to ergonomic deficiencies in the work system of the oilrig. Some major ergonomic issues identified were hard physical work, back pain, discomfort, hot environment, long shift, and diverse schedule. Ninety-four per cent of the employees perceived the workday as very long, 79 per cent were dissatisfied with the work schedule, while 61 per cent of the employees perceived the summer work environment as extremely hot.

Joshi et.al. (2001) undertook a study to gain an insight regarding musculoskeletal disorders in industrial workers in Delhi, 631 workers from 60 factories representing small and medium-sized enterprises located in Delhi were interviewed. Majority (59.4 per cent) of the workers had musculoskeletal disorders. The tailors, workers working near furnaces, cooks, workers in buffing, checking and assembly work, and those working with chemicals had the most joint complaints. Cervical pain was more frequent in tailoring and packing work. Lumbar pain was more common in buffing, operators working on presses, workers using hand and power tools, and the workers who lifted heavy manual loads. Contract workers had less musculoskeletal morbidity than regular and temporary workers. Skilled workers also had less morbidity. The findings also revealed that workers experiencing more job satisfaction reported fewer musculoskeletal disorders.

Nursalim (2000) undertook a study to determine the prevalence of Upper Extremity Work-related Musculoskeletal Disorders (UEWMSDs) among Textile Industry workers in West Java province of Indonesia and explore the association between Rapid Upper Limb Assessment (RULA) score and the prevalence of UEWMSDs. A cross-sectional study was conducted wherein 596 textile workers completed a combination of the NIOSH's Symptom Survey and the standardized Nordic Musculo-skeletal Questionnaire. Out of 596 workers, 391 workers (65 per cent) had upper extremity complaints. Among these, 205 workers (52.4 per cent) met symptomatic UEWMSDs criteria and were then examined by orthopedic specialists and diagnosed for the presence of UEWMSDs. Of these 205 workers, 132 workers (64.4 per cent) examined, and were assigned an UEWMSDs diagnosis. Of these 132 workers with UEWMSDs, the diagnoses and the prevalence were: Bicipital Tendinitis (25 per cent) Impingement Syndrome (14.6 per cent), Carpal Tunnel Syndrome (8.3 per cent), Medial Epicondylitis (6.8 per cent), DeQuervains' Syndrome (5.9 per cent), Supraspinatus Tendinitis (5.4 per cent), Lateral Epicondylitis

(4.4 per cent), Ganglion (2.0 per cent), and Trigger Finger (1.5 per cent). Upper limb assessment for work-related musculoskeletal disorders was performed on 497 workers; using video recording of their jobs, the RULA scores were then calculated. Chi-square analyses determined the significant association between RULA score and UEWMSDs (p = 0.00 1). In multivariate logistic regression analysis, work for 10 years or more on the job, RULA score, physical fatigue, house chores performed more than four hours per day, gender and smoking proved to be significant predictors for UEWMSDs.

2.2.3. Postural Discomfort

Ahmedi et.al. (2015) conducted a cross-sectional study on 66 workers of porcelain industry of Rasht, Iran active in different factory units were chosen through stratified random sampling. The aim was to determine the frequency of MSDs symptoms in different body parts of the workers, the Nordic Musculoskeletal Questionnaire (NMQ) and Job Content Questionnaire (JCQ) were used. Rapid Entire Body Assessment (REBA) method was utilized to identify the risk of MSDs. The results revealed that based on the data obtained through the questionnaires, 36 per cent of the studied population had experienced pain at least in one body part in the last 12 months. The frequency of pain in the waist, hand and wrists, and neck was the most. According to the data collected through JCQ, the total score of job content had a statistically significant relationship with subjects' age and their occupational background (P < 0.001, r = -0.549, and r = -0.704, respectively). Mean REBA scores of workers suggested that printing, carpentry, engineering, and material supplement units (scores: 6-6.5) were the most dangerous units, and the enameling unit (score: 4) had the least amount of risk in the porcelain industry.

Ansari & Sheikh (2014) undertook a study on 15 workers engaged in small scale industry situated at MIDC Wardha (Maharashtra, India). A video tape on different activities of the workers was prepared and then images were cropped from it for the analysis for assessment of work posture. Evaluation of posture was carried out using RULA and REBA. The RULA method determined that the majority of the workers were under high risk levels and required immediate change. The REBA method determined that some of the workers were under lower levels and majority at high risk levels. The workers were under moderate to high risk of musculoskeletal disorders. The results also revealed that there was a lack of ergonomics awareness and understanding in small scale industries.

In a study by **Gangopadhyay et. al. (2010)** an attempt was made to identify the work related musculoskeletal disorders among the sand core-making workers. Fifty male workers engaged in carbon dioxide and chemical core making work at an unorganized sector at Baruipur, Calcutta were randomly selected for this study. A detailed modified Nordic questionnaire study on discomfort feeling was performed among the core making workers. REBA method was applied to analyze the working posture. Finally, discomfort level and risk level of the individual working postures were calculated by the use of risk level and discomfort level scale. From the questionnaire study it was revealed that most of the core making workers grind in awkward postures often. The workers were affected by musculoskeletal disorders like pain at low back (100 per cent), hand (40 per cent), shoulder (30 per cent), wrist (20 per cent) and neck (20 per cent). There existed a significant ($p < 0.05$) correlation between discomfort level and risk level of the individual working postures of the workers.

Twenty-five stone carving male workers were selected at Jaipur in Rajasthan from each of the three sections of a stone-carving unit. The focus was to identify different ergonomic risk factors associated in this profession from the field. Still photography and video photography was used to record different activities. Different types of non-invasive tools like Rapid Entire Body Assessment (REBA), Rapid Upper Limb Assessment (RULA), Occupational Repetitive Action Index (OCRA) were used. Psychophysical measures were investigated by Body part discomfort map, rated perceived exertion scale and visual analogue scale. Objective measurements (heart rate and skin temperature) were recorded with stop watch and digital thermometer. The working heart rate after 30 minutes of work was 112.4 beats per minute categorizing 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 indicated that majority of the activities were in the high risk category (**Mukhopadhyay and Srivastava, 2010).**

2.2.4. Vibration at Workplace

Filho (2002) undertook a study with a purpose to investigate the perceived physical demand in a simulated industrial task, where subjects were primarily exposed to hand-transmitted vibration generated by a simulated power hand tool. The dominant frequencies evaluated were 16, 31.5, 63, and 125 Hz, and the accelerations were 3 m/s2 and 5 m/s2 as defined in ISO 5349, 2001. Through a psychophysical methodology extensively used in Ergonomics, the individual's perception of the physical stress associated with the intermittent operation of a simulated power hand tool was measured in a laboratory setting. The researchers conducted eight 40-minute trials (8 treatments = 4 vibration frequencies x 2 vibration accelerations) on sixteen subjects from Morgantown, West Virginia who were instructed to adjust the duration of intermittent rest periods in a simulated industrial task in order to find the maximum acceptable pace at which they estimated to be able to work for a normal 8-hour shift, without feeling sore, aching, with uncomfortable numbness in their hands and arms, or unduly fatigued. In addition to the subjects' adjustment of rest time, their fingertip vibrotactile threshold shift, their maximum isometric grip force shift, and the absorbed power in their fingers were measured in all eight experimental trials. It was indicated that vector sum acceleration had significant effects on selected rest time and digital absorbed power; and that vibration dominant frequency had significant effects on selected rest time, fingertip vibrotactile threshold shift and digital absorbed power. Finally, the dominant frequency of 31.5 Hz appeared to consistently represent the less stressful level for the vibration dominant frequency in this research study.

Gold, (2002) aimed to examine two potential indicators of Upper Extremity Work-related Musculoskeletal Disorders (UEMSDs) - digital vibration threshold testing (VTT) and infrared thermographic imaging in USA. Upper Extremity Work-related Musculoskeletal Disorders (UEMSD) signs and symptoms in automobile manufacturing workers (n = 1187) were examined for their association with vibration thresholds (VTs) in cross-sectional analysis, and one year following such testing. Psychophysical questionnaires were used to assess ergonomic stressors. Using a Borg CR-10 scale, workers rated their exposures to the following stressors: repetition, grip force, awkward neck/shoulder, arm, and wrist/hand postures, whole body effort, contact stress, machine pace, segmental and whole body vibration factors. Associations with workers' estimates of ergonomic stressors were also examined. Three groups of office workers (n = 29) underwent dorsal hand thermographic imaging before and after typing for nine minutes. Changes in mean dorsum temperature through several imaging periods were determined for controls and for subjects with distal UEMSDs, with and without subjectively cold hands exacerbated by keyboard usage. VTs were associated with greater hand/arm numbness frequency in cross-sectional analysis, and also with its persistence one year after VTT. VTs were also associated with de Quervain's disease and extensor and flexor compartment disorders, in cross-sectional analysis and in follow-on incident cases. Associations were found with hand force, vibration intensity as felt through the floor, and a sum of exposures. Three distinct blood flow patterns in response to a typing challenge were seen in the three office worker groups. Warm cases and controls both increased mean dorsum temperature after typing, while cold cases decreased. An ambient temperature effect was seen in both cold cases and controls.

2.2.5. Noise at Workplace

A study aimed at quantifying noise pollution from industrial noise (machine and human generated) at two selected processing and manufacturing industries namely: Denki Wire and Cable Nigeria Limited and Wanwood Nigeria Limited, in Akure and Ondo State, Nigeria was undertaken by **Anjorin, et.al. (2015)**. Data collection was done through the use of one hundred and twenty (120) structured questionnaires were administered out of which one hundred and two (102) were received. The questionnaire comprised of personal information of employee, noise exposure records and site information (history of machines).The experimental apparatus employed in the recording of noise levels consist of a precision grade sound level meter inch condenser microphone and with frequency range and measuring level range of 31.5Hz to 8KHz and 35 to 130 dB(A) respectively. The machines used for processing and production in these two industries were considered for the research study as well as their operators and workers. The average noise equivalent level (LA_{eq}) was studied to identify the noisy machines and to generate baseline data. A precision grade sound level meter was used to determine the various pressure levels of sound at thirty minutes interval for five days. The average noise exposure level (LA_{eq}) in both industries was found to be above 85 dB(A) and that is well above the healthy noise level of 85 dB(A) recommended by World Health Organization (WHO). The workers in the industries were at high risk of developing noise induced hearing loss (NIHL) and other associated ailments due to excessive exposure to industrial noise.

Manna & Basu (2011) undertook an observational, cross-sectional study in a heavy engineering industry in Kolkata, India to find out the prevalence of occupational deafness and the association between occupational noise exposures, socio-demographic and other risk factors with deafness of the employees. Among a total of 278 employees under this study, 235 employees were exposed to more than the permissible occupational noise level (90dB), out of whom 82 (34.90 per cent) employees were deaf; which was significantly (χ^2 = 17.97, df = 2, p = 0.0001) much more than deafness among the non-exposed workers who were 3 (6.98 per cent). Hearing impairment increased as exposure level increased and this trend was statistically significant (χ^2 = 17.97, df = 2, p = 0.0001). Hearing impairment also increased as duration of exposure to occupational noise increased and the relationship was found to be statistically significant (χ^2 = 7.12, df = 2, p = 0.0284). Pre-placement & periodic medical examination is vital before putting up any employee in an industry with high noise exposure. Regular use of personal protective devices by the employees is to be ensured.

Singh et.al. (2009) carried a study in 5 small scale hand tool forging units (SSI) of different sizes in Northern Indian Punjab. The noise levels at various sections were measured. Equivalent sound pressure level (Leq) had been measured in various sections of these plants. Noise at various sections like hammer section, cutting presses, punching, grinding and barrelling process was found to be >90 dB (A), which was greater than OSHA norms. A cross-sectional study on the basis of questionnaire was carried out. 451 randomly selected male workers for the survey. The results of the study revealed that 68 per cent of the workers were not wearing ear protective equipments out of these 50 per cent were not provided with personal protective equipment's (PPE) by the company. There was no isolation among different sections e.g. hammer section and other sections like punching, barrelling, and grinding etc. Majority of the workers (95 per cent) were suffering speech interference though high noise annoyance was reported by only 20 per cent. More than 90 per cent workers were working 12 to 24 h over time per week which lead to very high noise exposure i.e. 50 to 80 per cent per week higher than exposure time/week in USA or European countries.

Mokhtar et.al. (2007) undertook a study which involved the noise measurement method and a questionnaire based survey. 120 subjects for the study were chosen at random among industrial workers from several organizations located in the north of Malaysia. The organizations were the rubber product manufacturing, metal stamping and publication and printing companies. The research covered the physiological and psychological effects of noise and the auditory, hearing loss and sleep disturbance experience among subjects. The noise measurement method used a logging dose meter (type 443; make: Bruel & Kjaer, Denmark) to assess the noise level exposure among workers. The visits to industries were made and the noise levels were measured and recorded for different sections of the factories. The questionnaire for the survey comprised of 37 questions on different effects of noise on workers. Each question was provided with three choices of responses being yes, no, and unsure. The majority of the respondents in all industries indicated that they did not feel any physiological effect of noise. With respect to hearing loss, maximum percentage of workers indicated that noise did not produce any hearing loss effect. Similarly, for auditory, psychological, and sleep disturbance effects of noise, percentage of workers indicating presence of the effect, no effect, and no response from the workers.

The primary data, thus collected, was analyzed using Chi-square statistical technique and it was found that except psychological behavior, the physiology, hearing capability, auditory communication and sleep of the industrial workers were significantly affected by the existing noise levels.

Atmaca et.al. (2005) conducted a study to gain an insight of the problem of noise in the industries around Sivas, Turkey. The survey was carried out at concrete traverse, cement, iron and steel and textile factories located in this region. A questionnaire was completed by 256 workers during this study in order to determine the physical, physiological, and psycho-social impacts of the noise on humans and to specify what kind of measurements were taken both by the employers and workers for protection from the effects of noise. It was specified, during the surveys, that the noise levels detected in all the industries are much above the 80 dBA that was specified in the regulations: 73.83 per cent of the workers in these industries were disturbed from the noise in their workplaces, 60.96 per cent of them had complaints about their nervous situations, 30.96 per cent of these workers were suffering hearing problems although they had not had any periodical hearing tests and they were not using ear protection equipment.

Harger and Barbosa (2004), undertook a study to evaluate the prevalence of hearing loss, its degree and type, among workers in the marble industry in the Brazilian Federal District (FD). The workers from eight marble industries in the FD were evaluated by means of a cross sectional epidemiological study. An audiometry screening test (air conduction) was performed. Workers with hearing loss were submitted to liminal tonal audiometry air and bone conduction and speech audiometry tests using an audiometer AD-28 (Inter acoustics). All subjects studied were submitted to a visual inspection of the external acoustic meatus. One hundred and fifty two workers were examined. The mean age of the respondents was 32 years (SD = 8.6); average occupational noise exposure was of 8.3 years (SD = 6.8). The audiometries demonstrated that 48.0 per cent (n = 73) had some type of hearing loss. Among the workers with hearing loss, 50.0 per cent had results compatible with noise-induced hearing loss (NIHL); 41.0 per cent with incipient noise induced hearing loss, 5.0 per cent with sensorineural hearing loss (all except

NIHL) and 4.0 per cent with conductive and mixed hearing losses. Among workers with Noise induced hearing loss (NIHL), 57.1 per cent had bilateral involvement, 17.1 per cent in the right ear and 25.7 per cent in the left ear. Among those with incipient NIHL, 13.9 per cent were bilateral, 19.4 per cent were only in the right ear and 66.7 per cent were only in the left ear. The study also revealed that abnormal audiograms were found in 48.0 per cent of the sample. Among those with hearing loss, the predominant cause was NIHL, followed by those classified as having incipient noise induced hearing loss. Hearing loss usually started at 6 kHz, frequently in the left ear.

2.2.6. Light at Workplace

Katabaro and Yan (2019) conducted a study to analyze the effects of the lighting quality on working efficiency of workers in Tanzania. Four representative offices from the administration building at Mbeya University of Science and Technology were investigated from June to September 2018. The customized questionnaire survey tool was administered to the randomly selected occupants to survey their perceptions about the quality of lighting in their workplace and its influence on their health and work efficiency. Physical observation and illuminance distribution measurements were also conducted. The statistical analysis indicated that the majority of the occupants were less satisfied with the lighting quality in their working environment, and some respondents reported that it significantly affected their work efficiency and wellbeing. The average desk illuminance and uniformity level were found to be below the recommended values of the Chartered Institution of Building Services Engineers (CIBSE) and the International Commission on lighting (CIE).

Chattomba, (2010), conducted a study on Illumination and Noise Survey in Mines. The study was undertaken to measure illuminance level of luminaries using a digital lux meter in surface and underground coal/non-coal mines, conduct noise survey in few opencast and underground coal/non-coal mines and to assess the adequacy of illumination and noise levels in mines vis-à-vis Indian standards. The illumination survey was carried out at opencast mine of BSL Birmitrapur & Underground Coal Mines of MCL in Orissa, using Digital

Lux meter (Metravi1332). Similarly, noise survey was carried out in opencast mine of BSL Birmitrapur & Underground Coal Mines of MCL in Orissa, using Sound level meter (CEL 283). The results of studies were compared with the existing standards and due inferences were obtained. The results obtained from illumination survey in mechanized unit of pathpahar mines of BSL revealed that at loading points, near crushers, mini crushers & dumping yards were adequate and are within the limits of Indian standards whereas illuminance levels in electrical substation, store room, rest rooms and electrical control rooms were inadequate. The results obtained indicated that the sound pressure levels of various machineries used in Pathpahar mines of BSL, & underground coal mines of MCL were higher than the acceptable limits (>90dB (A). In the mines under study, most of the mine workers were exposed to SPL (sound pressure level) beyond TLV (90dB A) due to machinery noise.

Juslén (2007), conducted a study on Lighting, productivity and preferred illuminances – field studies in the industrial environment. The main objectives were to study which task illuminances industrial workers prefer and to find out if increasing the task illuminance from the levels given in the relevant Norms (CIE S 008/E-2001, EN 12464-1) can increase their productivity, and if so, to understand the possible reasons for the productivity increase when the lighting is changed. Six case studies were conducted in real industrial environments of luminaire factories in Finland. The preferred illuminances of the industrial workers covered a wide range of values. The results from the productivity-related field studies showed that increasing task illuminance above the minimum level given in norms increased productivity even though the effect was influenced by the starting conditions, tasks and subjects. Productivity increase in the field tests were found between zero and 7.7 per cent. Additionally, two field studies where absenteeism was measured showed a decrease in absenteeism when the illuminance was increased. One study also showed that increasing the task illuminance was achieved without increasing the energy consumption.

Ismail et. al. (2007) undertook a study with an objective to determine the effects of lighting on the operators' productivity at Malaysian electronic industry. The subjects were workers at the assembly section of the factory. The environment examined was the Illuminance (lux) of the surrounding workstation area. Two sets of representative data, the illuminance level and production rate were collected during the study. The production rate data were collected through observations and survey questionnaires while the illuminance level was measured using photometer model RS 180-7133.The correlation and linear regression analysis were conducted in order to obtain the relationship between the effects of level Illuminance (lux) and the worker productivity. The results from the correlation analysis revealed that there was a linear relationship between the Illuminance level and the productivity of the workers. The linear regression analysis further revealed that there was a linear equation model with positive slope to describe the relationship of Illuminance level and workers productivity for the assembly section involved. The linear regression line obtained was $Y = 0.5634X – 158.16$.

2.2.7. Temperature at Workplace

Ruslan et. al. (2014) undertook a study to determine the effects of air temperature, humidity and lighting between genders and ages among workers working in Call centres of Malaysia. These data were combined to estimate the exposure level by using statistical analysis. 30 measurements were taken at 10 different locations during 9.00 a.m., 12.00 p.m. and 5.00 p.m. 40 respondents participated in the survey conducted to identify the exposure and symptoms or other health related problems among the workers. The study indicated that the mean value recorded for temperature at 9.00 a.m. was 25.4^{o}C, for temperature at 12.00 p.m. was 23.8^{o} C and mean for temperature at 5.00 p.m. was 23.4^{o} C. While for humidity, the mean value for humidity at 9.00 a.m. is 58.98 (RH %), at 12.00 p.m. is 57.84 (RH %) and the last reading which is for humidity at 5 pm is 60.20 (RH %). The mean value for the lighting was 278.9 lux during 9.00 a.m. and 282.7 lux for the mean at 12.00 p.m. and mean results during 5.00 p.m. shows 280.4 lux. The findings indicated that there is no significant difference between gender and ages towards the effect of the temperature, humidity and lighting on the workers' health.

A study was undertaken to investigate standard illumination levels and conditions for optimum visual comfort of the Ready Made Garments workers in the production spaces and to generate recommended illumination conditions for the production spaces that would be useful to have maximum work efficiency in context of Dhaka region. Field surveys were conducted with detailed experimental study of the selected RMG production spaces on illumination conditions and feedback of the workers. A sample of 60 workers was chosen from each of three production spaces for detail questionnaire study as well as statistical analysis. It was observed that the illumination level in production space type-3 was a bit higher than the other spaces. Among the samples, majority of them expressed that the adequacy of lighting condition is proper to do their sewing related works at their workstation, especially in production space-1 (73 per cent). Among the samples, majority of them said that the there was no contrast between the immediate surroundings and at their work station, especially in production space 1 and 2 (83 per cent and 75 per cent respectively). On the other hand, while asking about the Glare, majority of them said that there was no glare at their work station, especially in production space 1and 3 (93 per cent and 82 per cent respectively). The overall feedback from the respondents revealed that more than 50 per cent of workers were comfortable with the illumination condition at their work station. While focusing on only the illumination level coefficients showed that workers feedback about the brightness and adequacy increased with increasing the illumination level. Considering the mean values and standard deviation from the mean values, it was concluded that the desired illumination level at the work station of the worker in production spaces to achieve workers comfort should be around 700 lux (within range of 601~800 lux) **(Hossain and Ahmed, 2013)**.

The effect of indoor air temperature (17^{o} C, 21^{o} C, and 28^{o} C) on productivity was investigated with 21 volunteered participants from China in the laboratory experiment. Participants performed computerized neurobehavioral tests during exposure in the lab; their physiological parameters including heart rate variation (HRV) and electroencephalograph (EEG) were also measured. Several subjective rating scales were used to tap participant's emotion, wellbeing, motivation and the workload imposed by tasks. It was found that the warm discomfort negatively affected participants' well-being and increased the ratio of low frequency (LF) to high frequency (HF) of HRV. In the moderately uncomfortable environment, the workload imposed by tasks increased and participants had to exert more effort to maintain their performance and they also had lower motivation to do work. The results indicated that thermal discomfort caused by high or low air temperature had negative influence on office workers' productivity and the subjective rating scales were useful supplements of neurobehavioral performance measures when evaluating the effects of IEQ on productivity **(Lin et. al., 2011)**.

Sepannen et.al. (2006) conducted a review study wherein 24 relevant studies were studied which focused on the effects of temperature on performance at office work. The studies that had used objective indicators of performance that were likely to be relevant in office type work, such as text processing, simple calculations (addition, multiplication), length of telephone customer service time, and total handling time per customer for call-center workers were included. The percentage of performance change per degree increase in temperature, positive values indicating increases in performance with increasing temperature, and negative values indicating decreases in performance with increasing temperature was calculated from all studies. The results revealed that performance increases with temperature up to 21-22^{o} C, and decreases with temperature above 23-24^{o} C. The highest productivity is at temperature of around 22^{o}C. For example, at the temperature of 30^{o}C the performance is only 91.1 per cent of the maximum i.e. the reduction in performance is 8.9 per cent.

2.2.4. Physiological Cost of Work

Devi and Vats (2019) conducted a study on forty Indian women tea factory workers, aged between 30 - 60 years were investigated in the factories during eleven selected activities such as Lifting bags, Lifting tubs, Handling of bags, Stacking of bags, Filling tea powder in bags etc. purposive random sampling method was used to select the respondent. The physiological cost of work calculated in terms of heart rate and total cardiac cost. On the basis of heart rate it was concluded that the blending, loading wheelbarrow and wheeling was more strenuous than lifting bag, filling tea powder in bag, loading tea powder in sifting machine. On the basis of TCCW loading wheelbarrow was a most strenuous activity and followed wheeling and least exhaustive activity were lifting bag and packing.

Mehta et.al. (2017) conducted a study to measure and correlate the relationship of energy expenditure of a normal healthy individual with different body mass index (BMI) and age. A total of 115 participants (59 males and 56 females) of Anand, Gujarat were included in this study. Each participant was given rest for 5 min and recorded resting Heart Rate. Participants were asked to walk on 30 m straight floor track for 6-min walk test (6 MWT) at the normal speed. Pre-and post-walked vitals were taken, and Physiological Cost Index was calculated by formula. The results revealed that there was highly statistically significant relation with age and Physiological Cost Index ($P < 0.05$) as age (40.86 ± 15.56) increased, PCI (0.26 ± 0.11) value was increased. It was also found out that the adult age group covered more distance than the older age group. The present study concluded that as the age and BMI increases the Physiological Cost Index increases, suggestive of more energy expenditure. The difference between resting HR and immediate post-test HR was directly proportional to Physiological Cost Index.

Saha et. al. (2008) undertook a study to compare physiological strain of carriers in underground manual coal mines in India. For the study, thirty-nine healthy carriers (23-57 years of age) were investigated in underground manual coal mines in West Bengal, India during two different work spells of a single work shift. The researchers compared physiological strain of workers <40 and > or =40 years of age. For both groups, mean heart rate was 124-133 beats/min, with a mean corresponding relative cardiac cost of 50-66 per cent. Maximum aerobic capacities were estimated indirectly, following a standard step test protocol. Average oxygen consumption was 1.07-1.1 l/min, with an energy expenditure of 5.35-5.5 kcal/min among both age groups. Acceptable levels of physiological strain were well encroached, and older workers faced the maximum burden. The tasks studied were heavy to very heavy in nature.

2.2.9. Fatigue experienced

Salve (2017) conducted a study to establish the relationship between the duration of work exposure and feeling of subjective fatigue. For the purpose of the study twenty-one jewelry manufacturing workers of India as study group and 27 students as control group participated with their signed informed consent. The daily diary method and feeling of subjective fatigue evaluation questionnaire were used as a tool in this study. Three categories of feeling of subjective fatigue were considered in this study. The study was conducted mainly in the middle of the week. The data regarding feeling of subjective fatigue were collected before starting of work and after completion of the work day. The results showed that the time spent on the job by the workers engaged in jewelry manufacturing was 670 minutes and were in four slots with the longest work period being 240 minutes. Sleeping time was found to be around 480 minutes. The study revealed that all three dimensions (general, mental, and physical) were affected by the whole day work exposure. Among three types of fatigues, general fatigue was observed at the beginning and end of the work shift.

Zhang et.al. (2015) conducted a study to assess the association between construction workers' reported fatigue and their perceived difficulties with physical and cognitive functions. The data was collected from a convenience sample of US construction workers participating in the 2010–11. National Health Interview Survey two multivariate weighted logistic regression models were built to predict difficulty with physical and with cognitive functions associated with workers' reported fatigue, while controlling for age, smoking status, alcohol consumption status, sleep hygiene, psychological distress and arthritis status. The findings revealed that of 606 construction workers surveyed, 49 per cent reported being 'tired some days' in the past 3 months and 10 per cent reported 'tired most days or every day'. Compared with those feeling 'never tired', workers who felt 'tired some days' were significantly more likely to report difficulty with physical function (adjusted odds ratio [AOR] = 2.03; 95% confidence interval [CI] 1.17–3.51) and cognitive function (AOR = 2.27; 95% Confidence Interval 1.06–4.88) after controlling for potential confounders. The study concluded that there is an association between reported fatigue and experiencing difficulties with physical and cognitive functions in construction workers.

Lin et.al. (2015) undertook a study with a purpose to explore the prevalence of fatigue and identify the risk factors of fatigue among men aged 45 and older in China. The study was part of a cross-sectional study on community health in Shunde (Guangdong Province, China). A total sample of 1158 men aged 45 and older were included. Sociodemographic characteristics, health and lifestyle factors were measured by structured questionnaires through face-to-face interviews. The Chalder Fatigue Scale was used to measure fatigue. Multivariate logistic regression was applied to determine the risk factors of fatigue. The findings revealed that approximately 30 per cent of participants experienced fatigue. Older age (≥75 years: adjusted OR 3.88, 95% Confidence Interval 2.09–7.18), single marital status (1.94, 1.04–3.62), unemployed status (1.68, 1.16–2.43), number of self-reported chronic diseases (≥2 chronic diseases: 2.83, 1.86–4.31), number of individuals' children (≥4 children: 2.35, 1.33–4.15), hospitalization in the last year (1.61, 1.03–2.52) were all significantly associated with increased risk of fatigue, while regular exercise (0.46, 0.32–0.65) was a protective factor against fatigue. The study concluded that fatigue was usual in males and several factors were associated with the fatigue.

2.2.10. Studies on Marble Industry

Aukor and Al-Qinna (2008) undertook a study to conduct a preliminary environmental impact assessment at eight marble manufacturing enterprises distributed in Zarqa Governorate at North-West of the capital city Amman. The assessment included testing of major chemical and physical environmental resources, products and byproducts generated from each establishment according to the production stages and in accordance to the Jordanian environmental regulations and legislations in force. The results indicated that noise levels were above the International Standards. The findings on water and land resources, ornamental waste products; estimated to be around 10 per cent of the prime material consumed; which form a source of contamination through the unsuitable solid and liquid waste disposal strategies adopted by the inspected manufacturers.

Conclusion

The review of literature revealed that much efforts has been made to research area of Musculoskeletal Problems faced by workers in various fields namely manual material handling, dry wall workers, women construction workers, brass metal workers within India. The MSD studies conducted outside India focused on female production assembly workers, bus drivers, crab processing industry, construction workers, sewing machine workers, oilrigs workers, textile industry workers.

The researches conducted on postural discomfort experienced focused on Small scale Industry, sand core making, stone carving workers, In india and outside India. The researcher while reviewing found related reviews on postural assessment of stone cutters, health risk assessment of marble manufacturers and health threats in stone cutters. A number of studies were also found on the environment of the workplace namely light, noise, temperature & humidity and vibration. Related review was also found conducted on Physiological Cost of Work and Perceived Fatigue.

An overview of the researches highlighted that a dearth of researches conducted on Marble cutting workers focusing on Musculoskeletal Pain and Postural Discomfort. The environment of the workplace namely workplace conditions, light, noise, temperature and humidity and vibration need to be assessed in Indian context. Hence, the researcher was interested in carrying out an investigation on the topic undertaken.