Final Report

Project Code 2010 EE 03

Waste Minimization in Moradabad Brassware Industry Cluster

Prepared for

Ministry of Environment and Forests

The Energy and Resources Institute

...towards global sustainable development

Suggested format for citation

T E R I. December, 2013

Waste Minimization in Moradabad Brassware Industry Cluster
New Delhi: The Energy and Resources Institute. 90 pp.

(Project Report No.2010 EE 03)

For more information

Project Monitoring Cell

T E R I

Darbari Seth Block

IHC Complex, Lodhi Road

New Delhi – 110 003

India

Tel. 2468 2100 or 2468 2111

E-mail pmc@teri.res.in

Fax 2468 2144 or 2468 2145

Web www.teriin.org

India +91 • Delhi (0)11

Table of Contents

TABLE OF CONTENTS III
LIST OF TABLES V
LIST OF FIGURES I
ACKNOWLEDGEMENT I
LIST OF ABBREVIATIONS III
EXECUTIVE SUMMARY V
Objectives of Study v
1. INTRODUCTION 1
1.1 Selection of units for detailed assessment 2
2. PROCESS DESCRIPTION 5
2.1 Processes 5
2.1.1 Casting 5
2.1.2 Welding 6
2.1.3 Threading 6
2.1.4 Scraping 7
2.1.5 Grinding and Emery 7
2.1.6 Acid cleaning 7
2.1.7 Engraving and Colouring 7
2.1.8 Polishing 8
2.1.9 Electroplating 8
2.1.10 Lacquering 9
2.1.11 Packaging 9
2.2 Raw material profile 9
2.3 Environmental impacts from the brass industry 10
3 REVIEW OF LITERATURE 13
3.1 Occupational hazards from the industry 15
3.2 Electroplating 16
3.3 Casting 17
4 OBJECTIVES AND METHODOLOGY 19
4.1 Approach 19
4.2 Methodology 20
5 RESULTS AND DISCUSSION 23
5.1 Questionnaire analysis and sample analysis 23
5.1.1 *Silli* (metal slab) making: 23
5.1.2 Presence of heavy metals in waste streams 25

6 SUGGESTED WASTE MINIMIZATION STRATEGIES 27
6.1 Waste minimization techniques 27
6.2 Product modification 28
6.3 Implementation of waste minimization at small scale industry levels 28
6.3.1 Waste minimization circles 29
6.4 Waste minimization methodology 29
6.5 Environmental benefits of implementing waste minimisation in brassware cluster 30
6.5.1 Waste minimization in casting 30
6.5.2 Waste Minimization in Spent Casting Sand 31
6.5.3 Waste Minimization in Electroplating 34
6.6 Best Available Technology (BAT) options: 35
6.6.1 Specific BAT approach: 35
6.7 Potential initiatives and cost estimates: 37
6.8 Recovery of Metals 37
6.8.1 Filtration and Centrifugation- 38
6.8.2 Evaporation losses- 38
6.8.3 Electrolytic recovery and its economics- 39
6.8.4 REVERSE OSMOSIS: 42
6.9 Energy saving and use of energy efficient techniques in casting and electroplating 42
6.9.1 Energy saving in metal casting/ reheating: 42
6.9.2 Energy saving in electroplating: 45
6.10 Socio-Economic Benefits 47

List of Tables

Table 3.1 Site wise calculated values of water quality index at Moradabad 13

Table 3.2 Atmospheric concentrations of Pb, Cd, Zn and Cu in different cities in India . 15

Table 5.1 Heavy Metals Content in Various Components 26

Table 6.1 Specific CP (Cleaner Production) approach in Pre-Treatment: 36

Table 6.2 Specific CP approach in Plating 36

Table 6.3 Cost Analyses of Various Kinds of Initiatives 37

Table 6.4 Economic Comparison of Waste Treatment vs. Waste Recovery (Basis: 2.5 kg $NiSO_4$ per day).. 40

Table 6.5 Economic comparison of Advanced Ion-exchange Nickel Recovery Vs. Waste Treatment (Basis: 2.5 to 3.0 kg / hr dragout operation) 40

Table 6.6 Economic Comparison of Waste Treatment vs. Chrome Recovery (Basis: 2.5 kg Chromic acid from static Rinse water per day) 41

Table 6.7 Economic Comparison of Chrome Bath Recovery with Treatment (based on 3,785 litres bath volume; 240 g/ l chrome; 15g/ l metals) 42

Table 6.8 Energy and Material Losses in Different Kinds of Furnaces 43

Table 6.9 Recommended Excess Air for Different Fuels 44

Table 6.10 Efficient Operation of Furnaces and Combustion Systems 45

Table 6.11 Benefit Analysis of Clean Production Techniques 50

List of figures

Figure 1.1 Distribution of Artisan units ... 3

Figure 2.1 Principle of Casting Process ... 5

Figure 2.2 Threading Process ... 6

Figure 2.3 Electroplating Process ... 8

Figure 4.1 Approach Adopted for the Study ... 20

Figure 4.2 Various Steps Involved in the Study ... 21

Figure 5.1 Material flow of the Metal Waste, Wastewater and others ... 25

Figure 6.1 Waste management techniques ... 27

Figure 6.2 Steps involved in Waste Minimization Strategy ... 30

Figure 6.3 Simplified Process Flow Diagram for Sand Treatment in Brass Foundries (AFS, 1989) ... 32

Figure 6.4 Schematics of an Efficient Rinse Tank Design ... 46

Figure 6.5 Schematics of Counter Flow Rinsing ... 46

Figure 6.6 Spray Rinse method for Reducing Drag-out in Electroplating ... 47

Figure 6.7 Drain Board method for Reducing Drag-out in Electroplating ... 44

Acknowledgement

This research project was sanctioned by the Ministry of Environment and Forests (MoEF). The support provided by MoEF in facilitating contact with various stakeholders including the local office of the UP State Pollution Control Board is acknowledged.

We would also like to thank the industrial unit owners who cooperated with us throughout the duration of the study. Without their support, the study would not have been a success. The contribution of the members of Hind Mazdoor Sabha, Moradabad, was vital to the complete the project activities.

List of Abbreviations

AAS	Atomic Absorption Spectrophotometer
AFS	American Foundry Society
ASTM	American Standard Testing Methods
BAT	Best Available Technology
Ca	Calcium
Cd	Cadmium
Cl	Chlorine
CP	Process Change
CPCB	Central Pollution Control Board
Cr	Chromium
Cu	Copper
DIC	District Industries Centre
EC	Electrical Conductivity
Fe	Iron
GDP	Gross Domestic Product
HCO_3	Bicarbonate
ILO	International Labour Organization
IM2	India Mark II
INR	Indian Rupees
ISTA	International Safe Transit Association
LPG	Liquefied Petroleum Gas
MDI	Methylene biphenyl di-isocyanate
Mg	Magnesium
MoEF	Ministry of Environment and Forests

Na	Sodium
Ni	Nickel
NOx	Oxides of Nitrogen
NPC	National Productivity Council
OOS	Occupational Overuse Syndrome
OSHA	Occupational Safety and Health Administration
Pb	Lead
RO	Reverse Osmosis
RPM	Revolutions per minute
SDI	State Department of Industry-
SEZ	Special Economic Zone
SMEs	Small and Medium Enterprises
TDS	Total Dissolved Solids
TERI	The Energy and Resources Institute
VOC	Volatile Organic Compounds
WHO	World Health Organization
WM	Waste Management
WMCs	Waste Minimization Circles
WQI	Water Quality Index
Zn	Zinc

EXECUTIVE SUMMARY

Moradabad's brassware manufacturing industry has gained international name and recognition for the quality of work and intricacy of pieces produced from it. It is a major industrial cluster in India that contributes about INR 2500 crores annually to India's Gross Domestic Product (GDP) and accounts for about 40% of the total handicraft exports (Sekar, 2007)[1]. Typical of the industrial development scenario in India, the brass industry of Moradabad primarily consists of small and medium enterprises (SMEs), all the way down to individual artisans working out of their homes, which is also contrasted by large export oriented units catering to international demand from such big retailers as Walmart.

Pollution from industrial clusters is a major problem in India. Central Pollution Control Board (CPCB) has identified several industrial clusters in its assessment exercise in 2009, and expressed concern for the high levels of untreated waste and wastewater as well as the exposure of toxic waste to the local populace, in particular the factory workers and artisans (CPCB, 2009)[2]. However, waste minimization strategies that could be applicable to the local industry received little attention previously. Keeping these things in mind, The Energy and Resources Institute (TERI) proposed to MoEF for examining the waste generated by the brassware industry of Moradabad and

- Identifying areas to minimize waste generation in the brassware industry
- Identifying areas of recovery and recycling
- Broad identification of areas where energy can be saved.

Objectives of Study

- Identifying areas to minimize waste generation in the brassware industry
- Identifying areas of recovery and recycling
- Broad identification of areas where energy can be saved.
- Waste recovery techniques like sand recovery and electrolytic bath recovery
- Adoption of BAT across the industry
- Development of waste minimization strategy
- Information dissemination of Best practice

A comprehensive assessment of the brass industry of Moradabad was carried out over the duration of eighteen months. Random sample surveys, and sampling of air, water and wastewater quality, soil sediment as well as sampling were undertaken for its contents. Moreover, discussions were held with local people from the industry and experts from various institutions such as local colleges, State Pollution Control Board's field officers.

[1] Impact of Technological Change on the Demand for Child Labour in Brassware industry of Moradabad, Helen R Sekar, V.V. Giri National Labour Institute Research Studies Series No: 074/ 2007

[2] Comprehensive Environmental Assessment of Industrial Clusters Central Pollution Control Board December 2009

There are various practices being undertaken to recover metal waste. Ash, metal scraps and waste metal dust is recovered to the maximum possible extent and sold off. Electroplating baths are also recycled in a primary way. Primary treatment facilities are present at larger facilities.

A few broad suggestions for the brassware industry's various components include the following:

- Casting units could look at the installation of induction furnaces that reduce both energy consumption and waste metal generated during the casting process. Also, sand reclamation could be sought. Various techniques such as acid treatment and thermal treatment exist, and could be actively considered.
- Modern techniques for the recovery of electroplating baths help to save considerable amounts of resources otherwise spent on buying materials. These electrolytic bath recovery operations are very economical compared to treatment of the sludge generated at the end of the process, and hence deserve serious consideration
- Best Available Technology (BAT) approach: Shifting towards improved technology can certainly help minimize waste across various sectors. These are also economical in the long run, and therefore the brassware industry look towards adopting them.
- Waste minimization strategy can be designed for the new artisan park facility being set up. Similarly, a best practices manual that disseminates information about the ways to reduce waste generation and increasing resource recovery could prove beneficial.

1. INTRODUCTION

Moradabad was established by Rustam Khan in 1624, after he was made Subedar (Governor) by Emperor Shahjehan. Rustam Khan had named the town after Prince Morad. The town however was accorded the status of a city only in 1994. Two considerations had gone into this conversion: one is the population growth and the other is the geographical spread connected with the growth of brassware industry. About 161 kilometers away from Delhi, the city is connected by roadways and a railway station to regional and national centres, including the Indian capital and the state capital of Lucknow. Moradabad town was converted into a city in 1994 by incorporating 19 villages, and its municipal administration was put under a Corporation. With this, the brassware household industry had come under one urban conglomeration, thus ending the previous rural-urban divide.

Moradabad city, the study area, is also known as *Peetal Nagari* or the city of brassware. The city is situated on the left banks of river Ramganga. From when and how the place became associated with brass works is not exactly known. It may be noted that the original method of moulding was the *Para* Method in which earthen moulds were used to give shape to molten metal. This was replaced by the *Darja* Method in the 1920s. Soil today is not essential for purpose of making moulds for brass works. However, a tradition of craftsmanship had definitely developed it seems, on two counts: one from the manufacture of heavy kitchenware and other utility utensils serving the local and regional market, and the other from ornamentation known from the Mughal days as *Naqqashi* or Engraving. Today, Moradabad is globally recognized for its brass works of exquisite beauty. Behind this development tradition has played a role by adjusting to the demands created by the global market forces.

India has 4.5 million small-scale industries located in industrial clusters across the country. The brassware industry cluster in Moradabad is one among these. The brassware industry is essentially home based and the handicraft items defined as artware products that are manufactured in Moradabad can be broadly classified into 10 items such as Electroplated nickel silver ware, Brass utensils, Copper utensils, Copper alloy utensils, Copper alloyware electroplated with nickel/ silver, Brass artware, Copper artware, artware of bronze/ similar alloys, artware of Bidri and artware of aluminum.

The industry employs around 200,000 people and exports goods worth INR 2,500 crores annually. Overall, the city accounts for 40 percent of the country's handicrafts exports. However, due to rising costs and difficulty in procuring raw materials, the brassware industry is reported to be on a decline. In recent years, many of the brassware units have switched operations to iron and aluminum works, and to other products such as glassware, carpets, and wood works.

Brassware manufacturing in Moradabad takes place in three types of establishments - the factories, which are larger enterprises owned by the large-scale exporters; the workshops or *karkhanas*, which are smaller multi process manufacturing units; and the single process household units or artisan units. Sekar (2007)[3] reported that the industry has about 25,000 units, of which 20,000 are unregistered units, 4300 are registered units, and about 850 are large exporting units. There is a 14 acre area in Harthala and some areas along the Moradabad-Delhi road where some of the brassware units are located. Most of the artisan units operate illegally from the inner city residential areas. The casting and engraving works are mostly done by these artisans, which have traditionally formed the backbone of the Moradabad brassware industry for the past 150 years.

There is a proposal to move the industry to an 'artisan park', for which about 300 acres of land has been identified near the bank of the Ramganga river. The proposal has been submitted to the Development Commissioner (Handicrafts), Ministry of Textiles. The Brassware Artisan Society supports the proposal, as this would help regularize the unregistered units, provide them modern facilities, and enable better access to raw materials and market for the manufactured goods. An SEZ (Special Economic Zone) has been under development in the city since 1995-96. The SEZ has an area of 450 acres, with 140 industrial plots. Only 10-12 of these have started developing so far. The cost of land in the SEZ is INR 1000/ sq. m. Some believe that entrepreneurs are reluctant to take the risk of locating an industry within the SEZ as the land cannot be resold at a higher value. The artisan units could potentially be relocated there, however, the cost of land would be prohibitive.

1.1 Selection of units for detailed assessment

The old township is heavily populated by inhabitants who had settled earlier. The rural-turned-urban areas can be seen divided into two distinct settlement patterns—New Moradabad, with affluent to comfortable residential quarters and new production units, and the unplanned spread of working class settlements with least municipal facilities. By carrying out fieldwork in 'core' and 'new' areas, an attempt was made to identify factors, which were responsible for dispersal of the industry. The working class settlements here are about nineteen years old. Households engaged in brass works can be found all over the City, but some areas find heavy concentration. Based on interactions with Government officials and other social partners as well as various secondary sources, it was ascertained that Moradabad houses nearly 25,000 small artisan or household units, around 2,500 multi-process units or *karkhanedar* units and around 25 fully mechanized units. Since the artisan units constitute 70% of the total volume of production, care was taken to select over 65% of these units and the level of mechanization was observed in each of these processes and activities. It was also found that, of the total artisan units or household units nearly 28.10% constitute casting units, 20.39% engraving units, 15.5% polishing units, 11.63% scrapping units, 5.63% welding units, 5.5% shaping units, 3.3% electroplating units and 1.1% enameling units.

[3] Impact of Technological Change on the Demand for Child Labour in Brassware industry of Moradabad, Helen R Sekar, V.V. Giri National Labour Institute Research Studies Series No: 074/ 2007

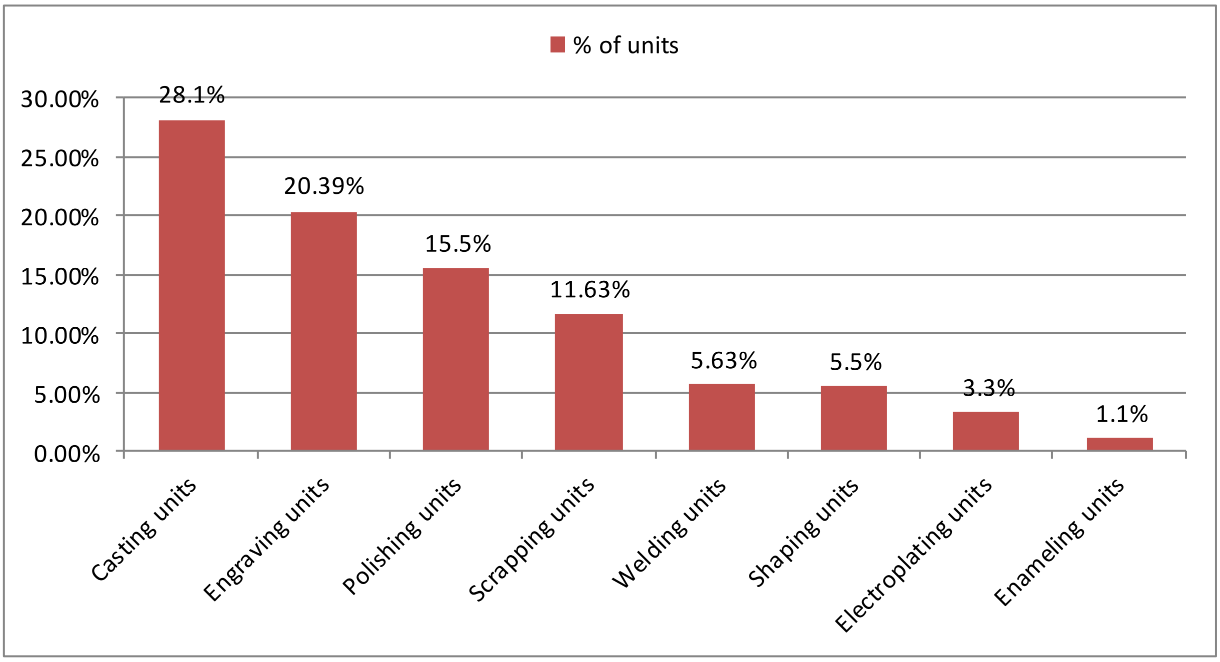

Figure 1.1 Distribution of Artisan units

Sample was so selected that these units were represented as per their proportion, in order to have adequate representation of all the units. Similarly, according to their proportion in the total units, 10 fully mechanized units or exporter units were selected for the study. Thus, a total of 150 units were selected for the study, of which artisan units constituted 65.33%, *karkhanedar* units or multi-process units constituted 28% and exporters or fully mechanized units constituted 6.67%.

2. PROCESS DESCRIPTION

The main processes/ stages involved in brassware manufacturing include: [1] casting; [2] welding; [3] threading; [4] scraping; [5] grinding and emery; [6] acid cleaning; [7] engraving and colouring; [8] polishing; [9] electroplating; and [10] lacquering. Processes like polishing, electroplating and lacquering are done in the larger factories and one or two smaller workshops. All other processes are subcontracted to the multi-process units (*karkhanas*) or the artisans.

2.1 Processes

2.1.1 Casting

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Sand casting process is the most prominent method in use by Moradabad's brassware industry. For this, the raw material, i.e. brass ingots (also known as *silli*) and scrap metal are heated in graphite crucibles up to a temperature of 900 to 1100°C.

At the same time, preparations are started for a casting mixture consisting of sand and molasses, sand and water, sand and coal tar and sand and brake oil. This mixture is placed inside an iron mould so as to develop specific patterns and designs. Once ready, the mould is filled up with the molten metal, which is done by picking up the graphite crucible with large tongs, and upon cooling, the mould is opened. The casted brass piece generally comes out in two parts. The basic process of casting is highlighted below.

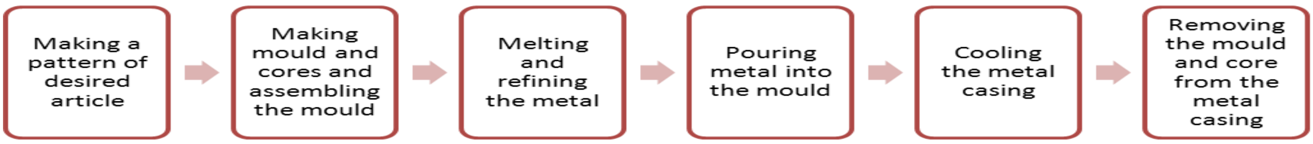

Figure 2.1 Principle of Casting Process

2.1.2 Welding

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is done to join casts to form an intricate/ elaborate piece and for pieces involving complex geometrical structures. Certain welding techniques have been observed in the brassware industry in Moradabad (Sekar 2007). These are:

- Welding can be done using coal fired furnace and heating the pieces by applying borax powder or suhaga at the edges. This method is locally called as *Bhatti ki welding*
- Industrial / technical welding is done using L.P.G cylinder and Oxygen cylinder. Welding by this method is comparatively cheap and very popular in Moradabad brassware manufacturing
- Stove welding is done using kerosene oil stove
- Electric welding is also an option, albeit a costly one

Another alternative, laser welding seems to be unpopular with the brassware manufacturing units of Moradabad.

2.1.3 Threading

Threading process often follows the welding process. It is the process of creating a screw thread. More screw threads are produced each year than any other machine element (Sekar, 2007)[4]. Locally, it is known as *chudi katai*. The product is kept under the pointer of a machine attached to an electric motor. It is a job requiring high skill and is usually done by experts. The process is described briefly through the following figure2.2.

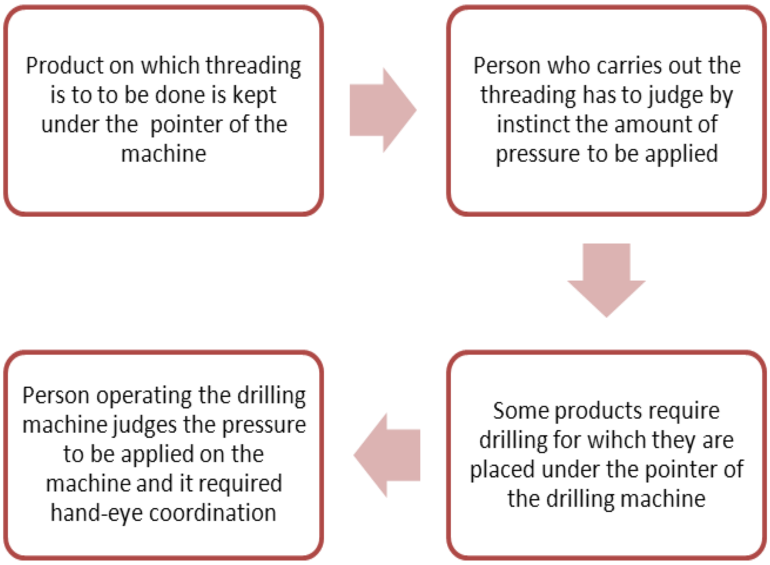

Figure 2.2 Threading Process

[4] Impact of Technological Change on the Demand for Child Labour in Brassware industry of Moradabad, Helen R Sekar, V.V. Giri National Labour Institute Research Studies Series No: 074/ 2007

There are many methods of generating threads, including subtractive methods (many kinds of thread cutting and grinding, as detailed below); deformative or transformative methods (rolling and forming; moulding and casting); additive methods (such as 3D printing); or combinations thereof.

2.1.4 Scraping

Oddly shaped, round articles have to be scraped out by manual chiselling and filing. By mounting the round shaped article on a rotating shaft and holding a tool against it, the excess brass coming from the casting of articles is scraped out. The tool is attached with a motor, and this motor is connected to the rotating shaft. Based on his own judgment, a skilled worker scraps out the excess brass to make the piece in desired shape and weight. He is usually helped in his work by an unskilled helper.

2.1.5 Grinding and Emery

If the articles that are to be scraped or smoothened are of any other shape other than round, then scraping is done by using Grinding machine or Emery machine. The machine is essentially the same, though fitted with different wheels. For products or articles to be scraped by the grinding machine, Grinding wheel used has a R.P.M. of 2800/ minute. This wheel, called the Grinding wheel, is made of stone. If the article is to be scraped by using Emery machine then Emery wheel made of crushed stone is used. The machine is attached to a motor, which rotates the shaft, where on both the side Grinding/ Emery wheel is fixed. Carrying out this process requires strong hand eye coordination and judgment.

2.1.6 Acid cleaning

The process follows the scraping process. It is a straightforward process of dipping articles into hydrochloric acid baths for a period of five to ten minutes using a copper wire. The process is repeated prior to polishing as well.

2.1.7 Engraving and Colouring

Engraving is the delicate and artistic work of cutting pre-decided designs on the surface of metal with the help of engraving tools and a lightweight mallet or hammer. It is then painted with different colours to enhance its beauty. In case of ordinary work, the engraver carves the design from memory. For intricate designs, paper drawings are first made, and these are then outlined on the ware. After engraving, the resultant depressions are filled with shellac by heating the articles and applying shellac sticks. The articles are then glazed by rubbing with wood ash.

The main raw materials used include shellac, lacquer, colours, thinners, soft coke and zinc oxide. Goods are polished both before and after engraving. Engraving is believed to be one of the earliest processes of embellishing metal ware. The engraved metalwork of Moradabad is highly intricate and decorative. Various tools such as the *kalam* (a steel pointed pencil) are used to trace the pattern on to the brass, silver or copper. A *thapi* and *tipai* are used for the actual engraving. Moradabad engravers produce extremely fine and delicate work.

2.1.8 Polishing

Articles are polished after engraving by holding them against an electrically rotating bob made up of waste cotton. To obtain a glittering appearance a polishing aid locally known as 'polishing masala' or emery powder is used. Normally one adult skilled worker is involved in the polishing work. Polishing machine is also known as buffing machine. The process thus is alternatively also known as buffing.

2.1.9 Electroplating

It is a plating process in which metal ions in a solution are moved by an electric field to coat an electrode. The process uses electrical current to reduce cations of a desired material from a solution and coat a conductive object with a thin layer of the material, such as a metal. Electroplating is primarily used for depositing a layer of material to bestow a desired property (e.g., abrasion and wear resistance, corrosion protection, lubricity, aesthetic qualities, etc.) to a surface that otherwise lacks that property.

The steps that an article must pass through before it may be successfully electroplated are as follows:

1. Preliminary cleaning or degreasing
2. Descaling
3. Polishing
4. Hot alkaline cleaning or degreasing and
5. Final cleaning

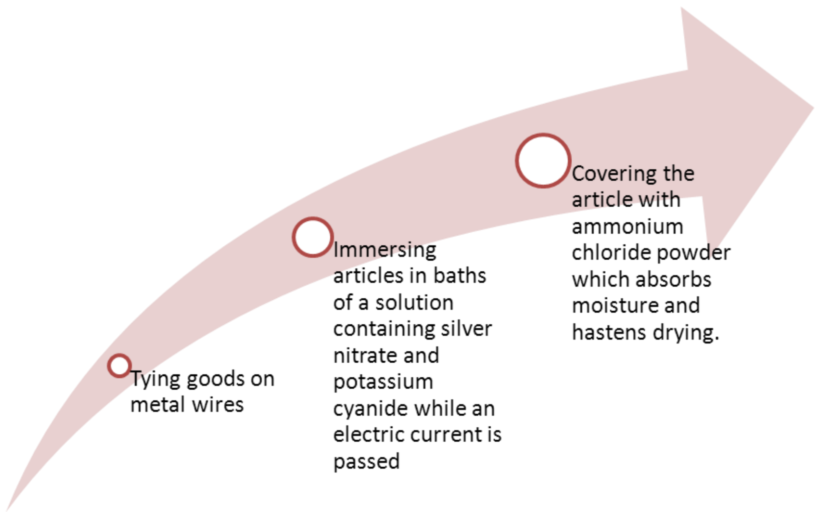

Figure 2.3 Electroplating Process

2.1.10 Lacquering

Lacquer is a somewhat imprecise term used for a clear or coloured varnish that dries by solvent evaporation and often a curing process as well that produces a hard, durable finish; in any sheen level from ultra-matte to high gloss and that can be further polished as required. Lacquering is done on brass and metallic items, especially in furniture, door handles, brass lamps in temple, as brass on exposure to atmosphere get tarnished. The brass surface is also affected due to chemical fumes of industries, city pollution and dust, etc.

Before lacquering the surface of the article is cleaned with solvent with very fine grinding papers ensuring that there are no scratch marks left. The metal surface is once again wiped with soft cloth before lacquering process starts.

2.1.11 Packaging

Packaging, packing and labelling is done as per the buyer specifications. Depending on the products the type of packaging required is chosen. Precious items, which have been gold-plated or silver-plated are first rolled in cotton and then packed in thermocol boxes. The articles/ products are packed into corrugated boxes, which are taped and then tied up by using plastic ribbons, which are stapled using packing machine. Generally unskilled workers are employed in the packing process. The packages undergo Vibration and Drop Test (ISTA 1A) at the Metal Testing Laboratory, the only laboratory in India certified by International Safe Transit Association for carrying out this test. The packaged product is subjected to vibration tests depending on the weight of the package.

2.2 Raw material profile

The primary raw material used by the industry is the brass sheet (*silli*) which undergoes a series of melting, pouring, and finishing operations. Coal is the main fuel to fire furnaces (*bhattis*) where the brass is melted. Other energy sources include LPG and kerosene oil, used in welding, and electricity for scraping, threading, welding and polishing. A large number of chemicals (including several hazardous chemicals) are used in the manufacturing process. Water demand is primarily for preparing chemical solutions for electroplating and acid cleaning baths. Sekar (2007) reported the use of the following raw materials at various stages of the industry (Table 2.1).

Table 2.1 Raw Materials used in Various Processes

Processes	Raw Materials Used	Cost (INR)	Procured From
Casting	Silli	120 to 135/ kg	Local shops
	Coal	1200/ quintal	Local shops/ depots
	Borax (Suhaga)	50 to 60/ kg	Local shops
	Molasses	8/ kg	Local market
	Coal Tar		
	River sand (Yellow Mud)		Riverbed
Welding	Oxygen cylinder	220/ kg	Local agency
	L.P.G. cylinder	330/ kg	Local agency
	Borax (Suhaga)	50 to 60/ kg	Local shop
Grinding	Grinding wheel	60/ kg	Local shop
	Resin	40/ kg	Local shop
	Diesel for generator	29/ litre	Petrol pump
	Mobil oil for generator	90/ litre	Petrol pump
Emery	Emery wheel	40 to 60/ kg	Local shop
	Resin	40/ kg	Local shop
	Diesel for generator	29/ litre	Petrol pump
	Mobil oil for generator	90/ litre	Petrol pump
Scraping	No raw material used		
Polishing	Polishing buff (1” to 14”)	1” buff cost 2/ -14” buff cost 150/ -	Local shop
	Polishing chemicals	10 to 12	Local shop
Electroplating	Rectifier	10,000	Agency
	Silver (999 pinch purity)	10,500 to 11,500/ kg	Local shop
	Sulphuric acid	10/ bottle	Local shop
	Potassium Cyanide	600/ kg	Chemist shop
	Other chemicals		Chemical agency
Packing	Packing paper		Local shop
	Polythene		Local shop
	Corrugated sheets		
	Cotton (for EPNS products)		

Source: Impact of Technological Change on the Demand for Child Labour in Brassware industry of Moradabad, Helen R Sekar, V.V. Giri National Labour Institute Research Studies Series No: 074/ 2007)

2.3 Environmental impacts from the brass industry

A comprehensive study of the types of fuels and materials used, the amount of water and energy consumed, and waste streams generated by the various operations could help design interventions for resource conservation and waste minimization, which in turn would improve environmental performance and lead to economic efficiency. It should be noted that an environmental study of the brassware industry has not been reported thus far and there is no primary data available to assess the environmental performance of the industry.

Studies in the past focusing on workplace health and safety issues have brought out the serious environmental impacts of brassware manufacturing.

Based on a preliminary assessment of the manufacturing operations, the following potential waste streams can be identified:

- Wastewater: discharges from acid cleaning baths and electroplating operations;
- Solid waste: ash and cinder from the *bhattis*; casting sands from the casting processes; and scrap metal from various scraping, threading and polishing operations; and
- Air pollution: vapours and mist from the electroplating and acid cleaning baths and lacquering operations; particulates, SO_2, NOx from the combustion of coal in the furnaces; toxic metal fumes from the casting and welding processes; and metal dust emitted during the scraping and polishing operations.

3 REVIEW OF LITERATURE

At least three studies published in the year 2008 indicate high level of pollution in the groundwater of Moradabad city. Kumar et al (2008)[5] calculated Water quality index (WQI) for underground drinking water of India Mark II (IM2) hand pumps at Moradabad for 5 different sites with the help of estimated values of 13 different physico-chemical parameters and WHO drinking water quality standards and found that the drinking water was severely contaminated at all the sites of study. The assumptions made by the researchers for extent of contamination or water quality status were: WQI < 50: Fit for human consumption; WQI < 80: moderately contaminated; WQI > 80: excessively contaminated and WQI > 100: severely contaminated. Site-wise calculated values of WQI are given in Table 3.1.

Table 3.1 Site wise calculated values of water quality index at Moradabad

Name of site	Water quality index
Handpump at balmiki shiv mandir, kushalpur	191
Handpump at Ambedkar park, Alakhnanda Colony	222
Handpump at Shiv Mandir, buddh vihar	257
handpump at police station, mandi samiti	274
Hand pump at putlighar square, Majhola	176

Pathak et al (2008) analyzed[6] groundwater samples from Moradabad city for chemical parameters. 58 water samples were collected from different localities on the basis of various land use patterns. The higher values of most of the parameters were found in the area of old settlement, where most of the brassware manufacturing units exist. The concentration of TDS, EC, Ca, Mg, Na, HCO_3^- and Cl at most of the sampling stations was found to exceed the safety limits for drinking water.

Various studies have also been conducted to assess the water quality of the Moradabad stretch of river Ramganga and Gagan. One such study by Sinha et al (2008)[7] estimated the amount of heavy metals at thirteen different sites of Gagan river water in and around Moradabad and the data was compared with water quality standards prescribed by the WHO. River water was found to be excessively contaminated with iron, copper, lead concentrations and moderately contaminated with nickel metal concentration which is reported to be carcinogenic. Downstream samples, after the mixing up of effluents indicated a marked increase in heavy metals concentration. Another study by Sinha et al. (2007)[8] had determined the WQI for Gagan river water in and around Moradabad for thirteen different

[5] Kumar N. et al., 2008, Underground drinking water contamination at Moradabad: A quantitative assessment, Indian Journal of Environmental Protection 28(9): 823-826

[6] Pathak, J.K. et al., 2008, Interpretation of groundwater quality using multivariate statistical technique in Moradabad City, Western Uttar Pradesh State, India, E-Journal of Chemistry, 5(2): 607-619

[7] Sinha, D.K., et al., 2008, Quantitative assessment of heavy metals in Gagan River Water at Moradabad, Indian Journal of Environmental Protection, 28(9): 804-808

[8] Sinha, D.K., et al., 2008, Quantitative assessment of aquatic environment of Gagan River in and around Moradabad, Indian Journal of Environmental Protection, 27(8): 696-703

sites with the help of WHO water quality standards and using the data of seventeen water quality physico-chemical parameters. The aquatic environment of river has been found to be severely polluted (WQI > 100), invariably at all the sites during the course of study. Sinha et al (2006)[9] had also collected and analyzed water samples at 10 different sites from Ram Ganga River at Moradabad at pre-monsoon period and after the onset of monsoon following standard methods of sampling and testing. And found the river water to be contaminated with reference to almost all the physico-chemical parameters studied at almost all the sites of sampling for pre-monsoon period as well as after the onset of monsoon.

Tobschall et al (2003)[10] conducted an exhaustive study to analyze heavy metals in the sediment samples collected from river stretches in the Moradabad area, after studying the geomorphology of the area. They found that in one of the stretches of the Moradabad area which has mainly brass and textile industries (in and around Chaudharpur), the effluents were being dispersed into the landscape or in ponds adjacent to the industries. The sediments of this basin showed significant contents of arsenic, chromium, copper, nickel, lead, zinc and organic carbon.

Saraswat (2007)[11] conducted an impact assessment for effluent from brass and electroplating industry on some physico-chemical and biological properties of soil in Moradabad. The study revealed that except for pH, all parameters were maximum in summer in surface soil at each of the sampled site. Significant inhibition of microbial biomass C and N, respiration, and dehydrogenase activity occurred in soils highly contaminated by heavy metals. The study was conducted at three sites of 500 m longitudinal transect along the drain, where soil was irrigated by toxic metal rich brass and electroplating industrial effluent in suburban area of Moradabad. Physico-chemical values (for pH, EC, organic carbon, and available N etc.) were found minimum at the first site and maximum at the third.

In addition to the underground water, surface water, sediments and soil that have been severely impacted by the toxic waste generated from the brassware industry in Moradabad, the atmosphere has also been seriously impacted. Tripathi et al (1989)[12] had concluded that brass industry is responsible for enhanced concentrations of Pb, Cd, Cu and Zn in the atmosphere of Moradabad. Table 3.2 indicates the atmospheric concentrations of these metals in different cities of India including Moradabad, as has been presented in that study.

[9] Sinha, D.K., et al., 2008, Seasonal variation in the aquatic environment of Ram Ganga River at Moradabad: A quantitative study, Indian Journal of Environmental Protection, 26(6): 488-496

[10] Tobschall H.J., et al. 2003, Environmental Impact Assessment in the Moradabad industrial area (rivers Ramganga-Ganga influve), Ganga Plain, India, Environmental Geology, 43(8): 957-967

[11] Saraswat S., 2007, Impact of brass and electroplating industry effluent on some physic-chemical and biological properties of soil, Journal of Scientific and Industrial Research, 66(11): 957-962

[12] Tripathi, R.M., et al. 1989, Assessment of atmospheric pollution from toxic heavy metals in two cities in India, Atmospheric Environment, 23(4): 879-883

Table 3.2 Atmospheric concentrations of Pb, Cd, Zn and Cu in different cities in India

Place	**Concentration in $\mu g/m^3$**			
	Pb	**Cd**	**Zn**	**Cu**
New Delhi	0.34	0.012	0.64	0.34
Faridabad	0.51	0.06	2.74	2.16
Moradabad				
Hindu college	0.3	0.02	2.46	0.56
Khushal nagar	2.71	0.07	41.44	56.02
Nai basti	6.51	0.09	52.33	40.74
Bombay				
King's circle	0.75	0.013	1.95	0.5
Haji ali	0.95	0.014	1.28	0.32
Byculla	1.1	0.018	2.12	0.56
Matheran*	0.016	0.0017	-	-

*Background station

3.1 Occupational hazards from the industry

Many occupational hazards are associated with the brassware industry. On a broader scale, one can identify areas that have the maximum potential hazard, namely:

- Casting and
- Electroplating

Apart from these, there is a lot of exposure to brass and other metal dust. Smelting activities (*silli* making) has been linked to chronic obstructive pulmonary disease by Hnizdo (2010)[13]. Even sheet metal work was conclusively linked with pulmonary diseases by Hunting and Welch (1993)[14], and this dust, laden with heavy metals, is a result of the various activities like scraping, grinding, etc.

As a result of pollution caused by the brassware industry, the health of the people in general and of those who are directly involved in brassware manufacturing has been affected. A study by Rastogi et al (1992)[15] conducted to evaluate the long-term effects of metal dusts on the broncho-pulmonary system, by conducting a comparative study of spirometric measurements in 104 polishers and 90 unexposed controls in 25 brass and steel ware polishing industries at Moradabad revealed that a total of 58.6% of the polishers had one or more respiratory symptoms, compared to only 25.5% of the controls. Chronic cough was present in 21 polishers (20.2%) as compared to 11.1% of the controls. Incidences of chronic phlegm were nearly three times as frequent among the polishers as among the controls (17.5% vs. 4.4%). The prevalence of dyspnea of varying grades was also significantly higher

[13] Hnizdo, Eva, Lung function loss associated with occupational dust exposure in metal smelting, American Journal Of Respiratory And Critical Care Medicine Vol 181, 2010 Pp 1162-1163

[14] Hunting, K.L, and Welch,L.S., Occupational exposure to dust and lung disease among sheet metal workers, British Journal of Industrial Medicine 1993;50:432-442

[15] Rastogi S.K., et al., 1992, Respiratory symptoms and ventilator capacity in metal polishers, Human and Experimental Toxicology 11(6): 466-472

(16.3% as opposed to 4.4%) among the exposed groups. Chronic bronchitis (6.7%) and occupational asthma (4.8%) were found to be confined to polishers. The polishers also experienced acute respiratory symptoms during the work shift. The prevalence of acute respiratory symptoms was recorded for cough in 19 workers (44.1%) followed by dyspnea in 14 workers (32.5%) and throat irritation in 11 workers (25.5%). The polishers exhibited significantly greater acute reductions in various lung functions over the work shift. The duration of exposure showed a direct correlation with the acute fall in lung function. Polishers who were exposed to dusts of various metals for more than 10 years showed a significantly greater acute reduction in all the pulmonary functions.

In another study, fifty seven male children between ages of 10-16 years engaged in the brassware industry at Moradabad in Northern India were studied for occupational morbidity by Bihari et al (1992)[16]. The findings were compared with those obtained in the children (n = 29) engaged in other ancillary units, which did not involve exposure to the metal fumes and dust in their work environment. The study showed a high prevalence of respiratory morbidity in the children engaged in the main units in comparison to those employed in the ancillary units (40.3 vs. 27.6%). This was associated with significantly higher prevalence of pulmonary impairment in the former group (21.0%) particularly demonstrating restrictive ventilator abnormality (10.5%) followed by bronchial obstruction (7.0%). The high respiratory morbidity may be attributed to chronic exposure to the fumes and dust of the metals such as nickel, chromium and cadmium.

3.2 Electroplating

Electroplating involves the usage of hazardous substances, including heavy metals and acids. The Department of Commerce, Government of Western Australia listed out various ways in which exposure to these substances in the electroplating units[17]. These substances are mainly in the form of:

- fumes
- vapours or mists
- metal dusts

Occupational hazards in electroplating involve the use of:

- electricity
- mechanical plant
- manual handling

Hazardous substance can enter the body through the skin, respiratory tract, oral or eyes, following contact with liquids or droplets, the lungs and nasal passages, when fumes,

[16] Bihari, V., et al. 1992, Occupational morbidity among children employed in brassware industry, Indian Pediatrics, 29(2): 195-201

[17] **Controlling hazards in the electroplating industry** Guidance Note viewed at http://www.commerce.wa.gov.au/worksafe/PDF/Guidance_notes/Guide_electroplating.pdf on December 19, 2011

droplets, gases or dusts are inhaled, or the mouth, when eating or smoking with contaminated hands[18]. Workers exposed to electroplating chemicals can develop many kinds of health problems. While in the short-term health problems such as throat, lung, sinus, skin and eye irritation and burns can develop, long term exposure makes workers vulnerable to such problems as asthma, skin, heart, lungs and nerve disorders and, in some cases, cancer. Risk of developing health effects will depend on the amount of chemical that is absorbed into the body[19].

3.3 Casting

Many kinds of health hazards arise during the casting process. OSH and Casting Technology, New Zealand (1997)[20] noted that Workers maintaining and replacing the refractory material may be exposed to dust containing significant amounts of cristobalite which is highly fibrogenic (causing the disease silicosis if inhaled into the lung). During moulding, some "Parting powders", containing a high content of fine silica dust, add to this hazard and should not be used if possible. The use of compressed air to clean dust from moulds is likely to produce airborne respirable dust[21]. Same is the case in such processes as sand handling, shakeout of castings and the development of the mould casting itself. Foundries melting leaded copper base alloys are at greatest risk form the evolution of lead fume and dust[22], which is common in Moradabad as well. Even chemicals such as phenols, methylene biphenyl di-isocyanate (MDI) and polymeric isocyanate solutions commonly used in foundries nowadays pose dangers when present in the fume forms. The following potential risks have been identified in foundries[23]:

1. Occupational Overuse syndrome (OOS)
2. Cancer
3. Dermatitis
4. Stress
5. Fatigue
6. 0200 - 0500 (Night shift workers)

[18] **Controlling hazards in the electroplating industry** Guidance Note viewed at http://www.commerce.wa.gov.au/worksafe/PDF/Guidance_notes/Guide_electroplating.pdf on December 19, 2011

[19] **Controlling hazards in the electroplating industry** Guidance Note viewed at http://www.commerce.wa.gov.au/worksafe/PDF/Guidance_notes/Guide_electroplating.pdf on December 19, 2011

[20] Casting Technology NZ Inc and Occupational Safety and Health (OSH) **HEALTH AND SAFETY GUIDELINES ON THE MANAGEMENT OF HAZARDS IN THE METAL CASTING INDUSTRY** November 1997 http://www.osh.dol.govt.nz/order/catalogue/ipp/metalcasting.pdf viewed on December 19, 2011

[21] Casting Technology NZ Inc and Occupational Safety and Health (OSH) HEALTH AND SAFETY GUIDELINES ON THE MANAGEMENT OF HAZARDS IN THE METAL CASTING INDUSTRY November 1997 http:/ / www.osh.dol.govt.nz/ order/ catalogue/ ipp/ metalcasting.pdf viewed on December 19, 2011

[22] Casting Technology NZ Inc and Occupational Safety and Health (OSH) **HEALTH AND SAFETY GUIDELINES ON THE MANAGEMENT OF HAZARDS IN THE METAL CASTING INDUSTRY** November 1997 http://www.osh.dol.govt.nz/order/catalogue/ipp/metalcasting.pdf viewed on December 19, 2011

[23] Casting Technology NZ Inc and Occupational Safety and Health (OSH) **HEALTH AND SAFETY GUIDELINES ON THE MANAGEMENT OF HAZARDS IN THE METAL CASTING INDUSTRY** November 1997 http://www.osh.dol.govt.nz/order/catalogue/ipp/metalcasting.pdf viewed on December 19, 2011

7. Metal fume fever
8. Vibration white finger
9. Burns
10. Soft tissue injuries
11. Lead poisoning
12. Respiratory disease
13. Sprains and strains
14. Eye injuries
15. Silicosis
16. Noise-induced hearing loss
17. Severe injury
18. Carbon monoxide poisoning

4 OBJECTIVES AND METHODOLOGY

The objectives of the study were to analyze the brassware industry operations at the unit level:

(I). To assess the overall resource use and pollution generated;
(II). To identify opportunities for waste minimization;
(III). To assess the feasibility of the waste minimization measures; and
(IV). To identify scope for further interventions, particularly the environmental and economic benefits of networking individual units.

4.1 Approach

Based on the objectives, the study team looked at various possibilities and option at its disposal for achieving the same. A list of all the registered units in Moradabad was prepared Based on discussions and secondary data from the State Department of Industry (SDI) and the industry associations in the area. Subsequently, a questionnaire survey of a selected sample (about 10%) of registered units was determined to be the right approach to verify the type of processes, resources used, and waste streams generated. This was paralleled by primary data collection for testing and analysis of each stage brassware manufacturing so that a subsequent audit methodology could be generated.

For the audit purpose, discussions were held with the SDI and industry representatives, and it was mutually decided that one representative unit for each stage of brassware manufacturing will be selected from among the registered small-scale *karkhanas* for audit purposes. Assuming operations to be relatively cleaner and more efficient in the export houses, one representative enterprise was also shortlisted from among the multi-process larger factories for benchmarking purposes. Moreover, the audit methodology and data collection protocols were discussed with the concerned enterprises.

Sampling and analysis of air, wastewater and solid wastes was carried out so as to enable a characterization the waste streams. Simultaneously, data was also gathered for the development of materials and water balances so that opportunities for waste minimization and water saving could be identified. A secondary review through literature review was undertaken at the same time so that overall impacts and identification of potential opportunities of waste minimization could be undertaken. This was vetted with a feasibility assessment exercise so that the appropriate recommendations could be put forward that can be implemented during the development of the artisans' park as envisaged for the brassware industry of Moradabad.

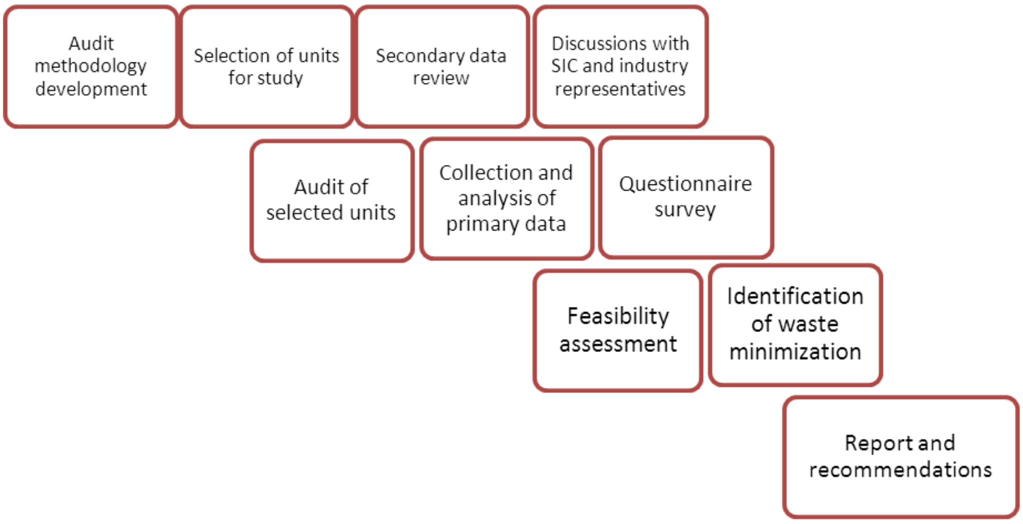

Figure 4.1 Approach Adopted for the Study

4.2 Methodology

Being an industrial area, it is imperative to develop a network of key local contacts so as to facilitate the study in a time bound and efficient manner. With this in mind, the TERI team made repeated visits to Moradabad and developed contacts with many stakeholders. This eventually translated into working relationships with a bevy of stakeholders which have a direct bearing on the study due to their deep involvement with activities in the cluster, namely – artisan society, exporters association, regional officer of State Pollution Control Board, GM, District Industries Center, Hindu College, Moradabad Institute of Technology, DM, Moradabad, and ILO. Thereafter, the study design and execution were undertaken.

Having developed a good working relationship with the various stakeholders, the task of designing the study was undertaken. To develop this, a review of secondary data was found crucial, as it would help to understand the cluster profile in terms of type and scale of units and their manufacturing processes. A list of export units was prepared based on information available from the DIC and Pollution Control Board office, which was collected during the relationship building period. The list of electroplating units regulated under the Hazardous Waste Rules was also developed during the same period, while the list of artisan units was developed based on studies conducted independently by ILO. Moreover, site visits were made to about 20 artisan units and 3 electroplating units to understand the operations and identify the issues to be considered in designing the questionnaire survey. This also helped us to identify the potential waste streams, which were subsequently analyzed for finding ways to minimize the waste being generated in the industry. The phase was concluded with identification of units for site collection as well as the identification of potential sites for audit to determine industrial performance benchmarks.

Based on these initial findings, a set of industrial unit-specific questionnaires were prepared so as to develop a better understanding of the material flow and water flow, while also looking at the areas of concern and the kind of industrial are attached as Annexure 1 of this report. These questionnaires were targeted towards artisan and electroplating units and were thoroughly reviewed internally followed by test runs in the field to train the surveyors and identify any need for revisions. Appropriate local field staff familiar with the brassware cluster was identified to carry out the artisan survey. Simultaneously the electroplaters' survey was carried out. This data was later sent across to analysis for data generation.

Through this study, we managed to identify and characterize waste streams and estimate pollution loads for the major pollutants. Specific waste generation factors were assessed to serve as benchmark for similar units. Current waste disposal methods were studied and measures for reducing emissions and managing residuals in an environmentally sound manner were identified.

Integration of unit level resource flows and pollution and waste loads to arrive at aggregate cluster level data and assess overall impact of the brassware industry in its present location was achieved via this study. Issues and options for networking individual units were identified and assessed. The willingness of participating industries to pay for common facilities was also assessed. Moreover, best practices among the various industries surveyed will be documented.

The study helped develop resource flows for the raw materials, chemicals, and water used at different stages of brassware manufacturing. Material flows were also developed and measures for conserving resources and improving efficiency were identified. Estimates were prepared for reusable wastes such as ash, casting sands and metal scrap, as also recoverable wastes, such as precious metals from electroplating wastewaters, and identify opportunities for waste recycling and reuse.

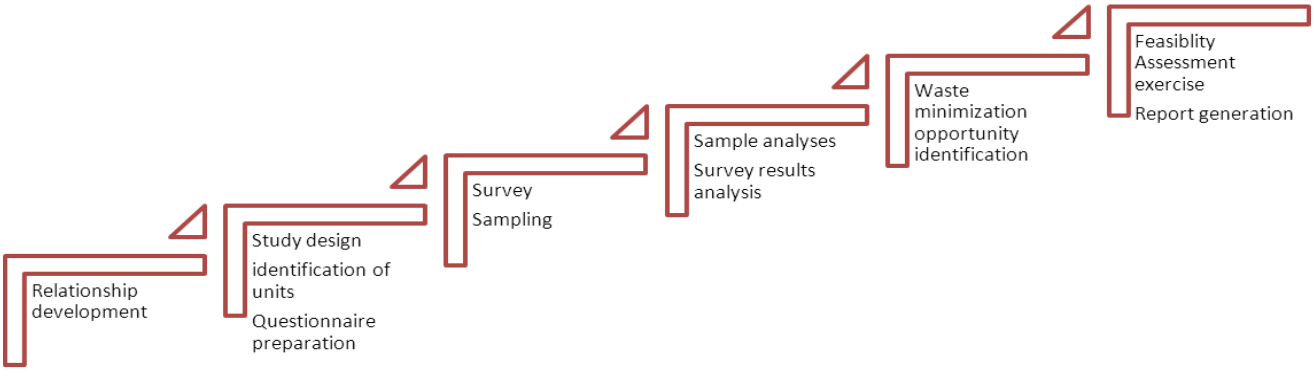

Figure 4.2 Various Steps Involved in the Study

5 RESULTS AND DISCUSSION

5.1 Questionnaire analysis and sample analysis

5.1.1 *Silli* (metal slab) making:

Out of 500-800 units, a sample size of 20 was chosen for analysis. The number of persons working in the *silli* making process varies from 2-4 and operating hours for the process are 7-10 hours. According to them, there is only one *bhatti* in their unit. The production capacity of *sillis* is varies from 50 – 400 kg/ day across different units, and the subsequent turnover lies anywhere between 100-90000Rs/ day. Raw materials used included *Jaali* (Automobile scrap primarily radiators), Metal from E-waste, *Choonas* (powdered waste metal from various processes), *Kit* (metal obtained from waste after decantation), *Jasta* (Zinc), *Taam Chini* (lead or porcelain), Copper, Brass and Aluminum. Coal is the fuel of choice for all the units. Metals recovery from ash is usually high. Ventilation systems in the units are very basic, with the work being done usually in open air, while few places have a chimney or doorways to control the exposure.

Threading: In this process, only one person works on one machine provided in each unit for almost 8-9 hours. Amount of metal threaded by every unit is about 100-140 kg/ day. According to them, scrapings collected are equal to the metal dust recovered in the range of 7-12 kg/ day.

Polishing: For a sample size of 20 units, the number of people involved in this process generally is 2, using a particular machine. This process operates for almost 8 hours. The production capacity is 100-150 kg/ day. The amount of metal polished per day equalled their production capacity. Quantification of the waste powder generated was not possible due to its negligible amounts. The only source of waste metal is cotton puff through which the polishing process is carried out.

Engraving and colouring: There are almost 2000 units of engraving and colouring, out of which 20 units were studied and analyzed. The persons involved in this process are 1-2, working for 6-8 hours. The turnover observed is 200-500 Rs/ day. The production capacity of engraved product is in the range of 3-10 kg/ day, depending on different units. The metal dust collected from engraving area is 1-4 kg/ day. The metal recovered is almost negligible.

Casting: Out of the 500-700 units for casting process, 20 were considered. Here, about 2-4 persons work for 8-10 hours. The number of *bhattis* operating is one. The production capacity varies in different units from 50-70 kg/ day and 110-120 kg/ day. Raw materials used are aluminium and Metal slab (*silli*), which range from 70-80 kg/ day, while coal is the fuel of choice. The metal recovered is 0.5-3 kg/ day. Ventilation system is not an issue as most of the activities tend to take place in open air. The source of casting sand is the bed of the Ramganga River, and amounts to about 75-200 kg/ day. Liquids used for mixing are oil, molasses and water. The amount of casting sand discarded is in the range of 15-75 kg/ day. The metal recovered during this process is 10-40kg/ day and 5000-6000 kg/ day, depending on the usage, while about 1lt wastewater/ kg of metal is generated during this stage.

Etching: Out of 2500 etching units, 20 units to study the etching process were sampled. The number of persons working in the etching units varies from 1-2 and operating hours from 6-8 hours. The production capacity of the etched product varies from 45-70 kg/ day. The turnover is 250-450 Rs/ day. The amount of metal ware etched during the time of survey ranges from 50-70 kg/ day. The water consumption equals wastewater generation according to the people working in the area, *Katghar* and stands at around 20-40 litres/ day.

Scraping: This is often called *chhilai* by the local people. There are almost 3000-4500 units for scraping and out of these 20 units were studied. Only one person usually works for 8-10 hours in each of these units, using a machine. The production capacity is 60-120 kg/ day, in different units. The amount of metal scraped is in the range of 60-120 kg/ day. The amount of scrapings collected is equivalent to the amount of metal recovered which range from 30-50 kg/ day.

Grinding and Emery (*Pisai and Regmaal*): Out of 3000 units of grinding and emery, 20 units were studied. It was found that the number of persons working in these units vary from 1-7, working on machines 1-4, for 8-10 hours. The production capacity varies on the wide scale from 2 kg/ day to 30 kg/ day. The turnover is 100-1000 Rs/ day. The amount of metal processed ranges from 50-300 kg/ day. The amount of metal dust recovered is equal to the metal dust collected without any loss, lies between 5-55 kg/ day.

It is important to note that a large amount of waste generated across various processes is carefully recovered across the units. This is an additional source of revenue for the industry when sold off through *keet* sales. These wastes are then sifted and processed for the recovery of metal from them, and these metals are subsequently sold again to the *silli* making units for use. This recycling industry that runs within the brassware industry plays a key role in reducing the amount of material wasted during the various processes. Based on these results, a material flow diagram was generated for the brassware industry of Moradabad. The same has been presented below.

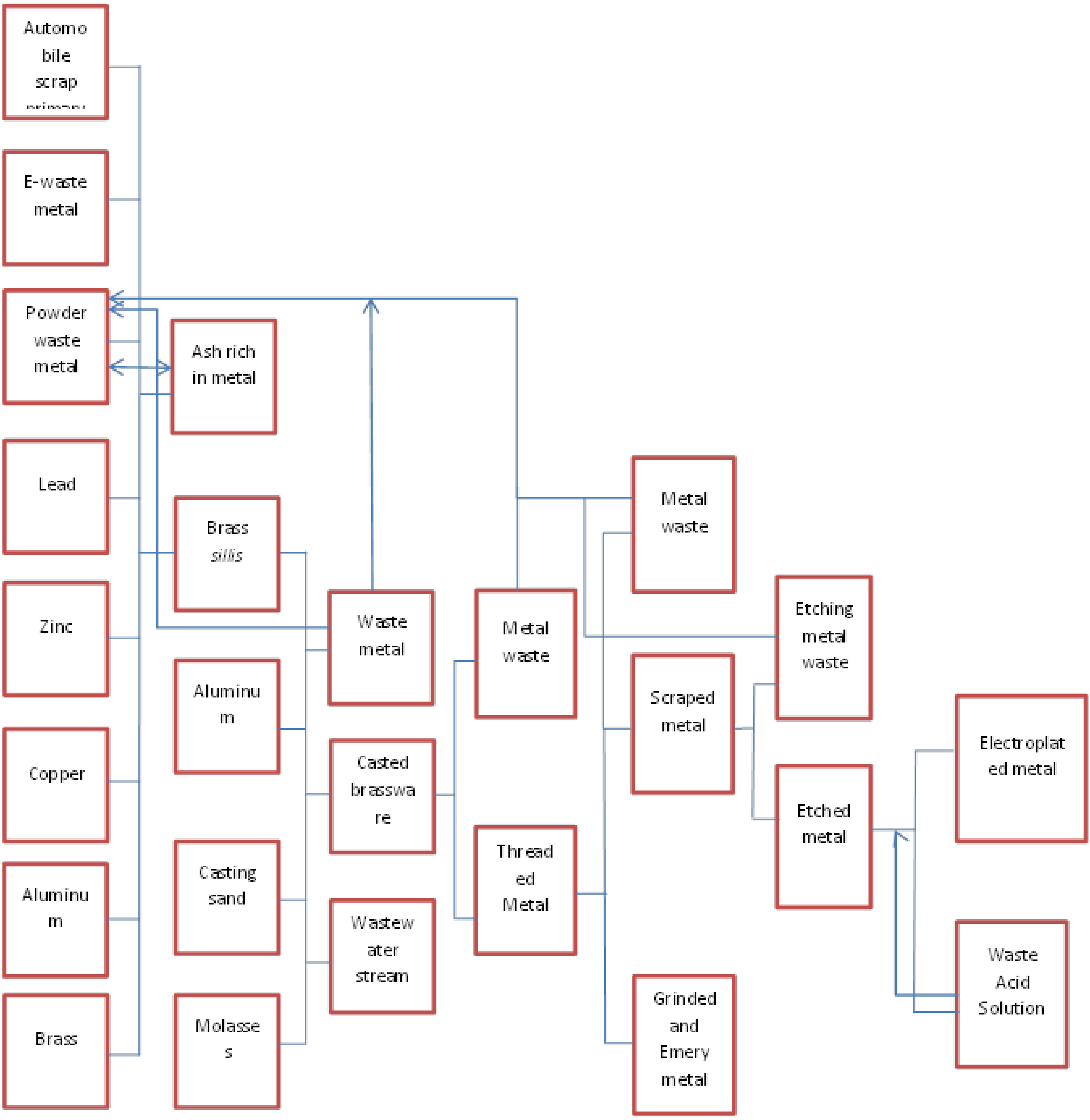

Figure 5.1 Material flow of the Metal Waste, Wastewater and others

5.1.2 Presence of heavy metals in waste streams

Waste Stream samples were collected from the different processes in the industry and analyzed for the presence of heavy metals by the Atomic Absorption Spectrophotometry (AAS) method. Many heavy metals were identified in the waste streams generated from different steps of the brassware industry. These included copper, zinc, lead, chromium and aluminum, which are also in use within the industry for various purposes such as alloying etc.

Table 5.1 Heavy Metals Content in Various Components

Description/Collection Source:	Copper Concentration	Zinc Concentration	Lead Concentration	Aluminum Concentration	Chromium Concentration
River Water	45.14 mg/ L	9.74 mg/ L	1.6893 mg/ L	3.1484 mg/ L	0.0529 mg/ L
Polishing and Buffing dust	56423.85 mg/ kg	8114.1 mg/ kg	7088.49 mg/ kg	3666.9 mg/ kg	20.52 mg/ kg
Aluminium Slab making and Metal Ash	5970.57 mg/ kg	8873 mg/ kg	515.6 mg/ kg	329740 mg/ kg	1180.14 mg/ kg
Aluminium Melting and Slab-making; Bottom ash+ coal ash	2828.46 mg/ kg	1548 mg/ kg	91.13 mg/ kg	40875.48 mg/ kg	101.19 mg/ kg
Raw dust used for washing	67246.05 mg/ kg	24566.7 mg/ kg	7681.11 mg/ kg	31474.65 mg/ kg	49.96 mg/ kg
Water sediment from washing	8241.6 mg/ kg	60550 mg/ kg	10230.09 mg/ kg	29672.82 mg/ kg	107.84 mg/ kg
Final washed soil	52932.9 mg/ kg	23189.7 mg/ kg	4100.4 mg/ kg	29783.49 mg/ kg	54.13 mg/ kg

The results clearly show high concentration of copper, zinc and aluminium in the samples collected from all the processes. Of particular interest is the especially high content of Aluminium found in metal ash during Al slab making. High content of copper was found in raw dust for washing and for zinc in water sediment from washing, followed by polishing and buffing dust and final washing. Brass water is the water collected from the river after washing process and it was found that brass water contains maximum of copper (45.14 mg/ L) and zinc (9.74 mg/ L).

6 SUGGESTED WASTE MINIMIZATION STRATEGIES

Waste minimization can be defined as "systematically reducing waste at source". It means:

- Prevention and/ or reduction of waste generated.
- Efficient use of raw materials and packaging.
- Efficient use of fuel, electricity and water.
- Improving the quality of waste generated to facilitate recycling and/ or reduce hazard.
- Encouraging re-use, recycling and recovery.

6.1 Waste minimization techniques

Waste minimization is best practiced by reducing the generation of waste at the source itself. After exhausting the source reduction opportunities, attempts should be made to recycle the waste within the unit. Finally, modification or reformulation of products so as to manufacture it with least waste generation should be considered.

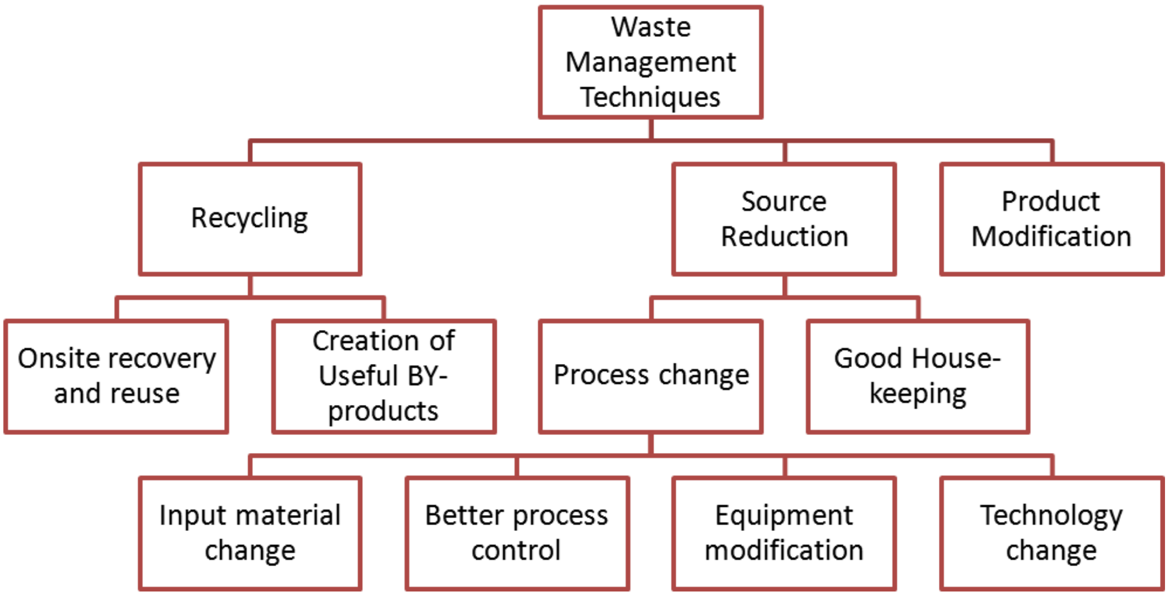

Figure 6.1 Waste management techniques

1) Source reduction:

Under this category, four techniques of WM are briefly discussed below:

a. Good Housekeeping- Systems to prevent leakages and spillages through preventive maintenance schedules and routine equipment inspections. Also, well-written working instructions, supervision, awareness and regular training of workforce would facilitate good housekeeping.
b. Process Change: Under this head, four Cleaner Production (CP) techniques are covered:
   - **Input Material Change** - Substitution of input materials by eco-friendly (nontoxic or less toxic than existing and renewable) material preferably having longer service time.
   - **Better Process Control** - Modifications of the working procedures, machine-operating instructions and process record keeping in order to run the processes at higher efficiency and with lower waste generation and emissions.
   - **Equipment Modification** - Modification of existing production equipment and utilities, for instance, by the addition of measuring and controlling devices, in order to run the processes at higher efficiency and lower waste and emission generation rates.
   - **Technology change** - Replacement of the technology, processing sequence and/ or synthesis route, in order to minimize waste and emission generation during production.

2) Recycling

a. On-site Recovery and Reuse - Reuse of wasted materials in the same process or for another useful application within the industry.
b. Production of Useful by-product - Modification of the waste generation process in order to transform the wasted material into a material that can be reused or recycled for another application within or outside the company.

6.2 Product modification

Characteristics of the product can be modified to minimize the environmental impacts of its production or those of the product itself during or after its use (disposal).

6.3 Implementation of waste minimization at small scale industry levels

Small and medium enterprises (SMEs) are the backbone of the Indian economy. With three million SMEs, this sector contributes 40 per cent of the national income. SMEs provide employment to more than 16 million people in the country, and are growing at the rate of 20 per cent annually.

SMEs are also a major area of concern as they account for about 70 per cent of industrial pollution. Due to obsolete technologies and poor operation and maintenance, these SMEs have a high specific-waste generation factor.

6.3.1 Waste minimization circles

The Ministry of Environment and Forest (MoEF), New Delhi, India has developed appropriate supportive mechanisms to help Small and Medium Industrial Clusters to adopt waste minimization in their industries. In this regard, MoEF initiated the project titled "Waste Minimization in Small Scale Industries" using the concept of "Waste Minimization Circles" (WMCs). This project is being implemented since 1992 with the assistance of National Productivity Council (NPC), New Delhi and the MoEF is funding this project.

The waste minimization concept was applied to various medium and small scale industries spread across the various states of India. The key objective was to realize benefits of Waste Minimization Concept and achieve conservation of resources and environmental improvement accompanied by enhancement in the financial efficiency of the circle by way of adoption of group efforts at industrial cluster level. This initiative was specially tuned to the needs of the SME's to involve them in a sharing and learning experience. The scope of WMC was to develop innovative ideas towards identifying waste minimization options and implementing waste minimization solutions for achieving economic and environmental benefits through collective efforts.

6.4 Waste minimization methodology

Waste minimization can be defined as "A new and creative way of thinking about products and the processes which makes them. It is achieved by the continuous application of strategies to minimize the generation of wastes and emissions". The underlying principle on which all the WM methodologies are based is on the famous DEMING cycle of Plan-Do-Check-Act. A structured methodology helps in detailed assessment rather than making one jump to conclusions based on incomplete data. It also helps one to fix the targets more objectively aiding the organization to allocate resources efficiently. The methodology adopted in waste minimization circle is explained below:

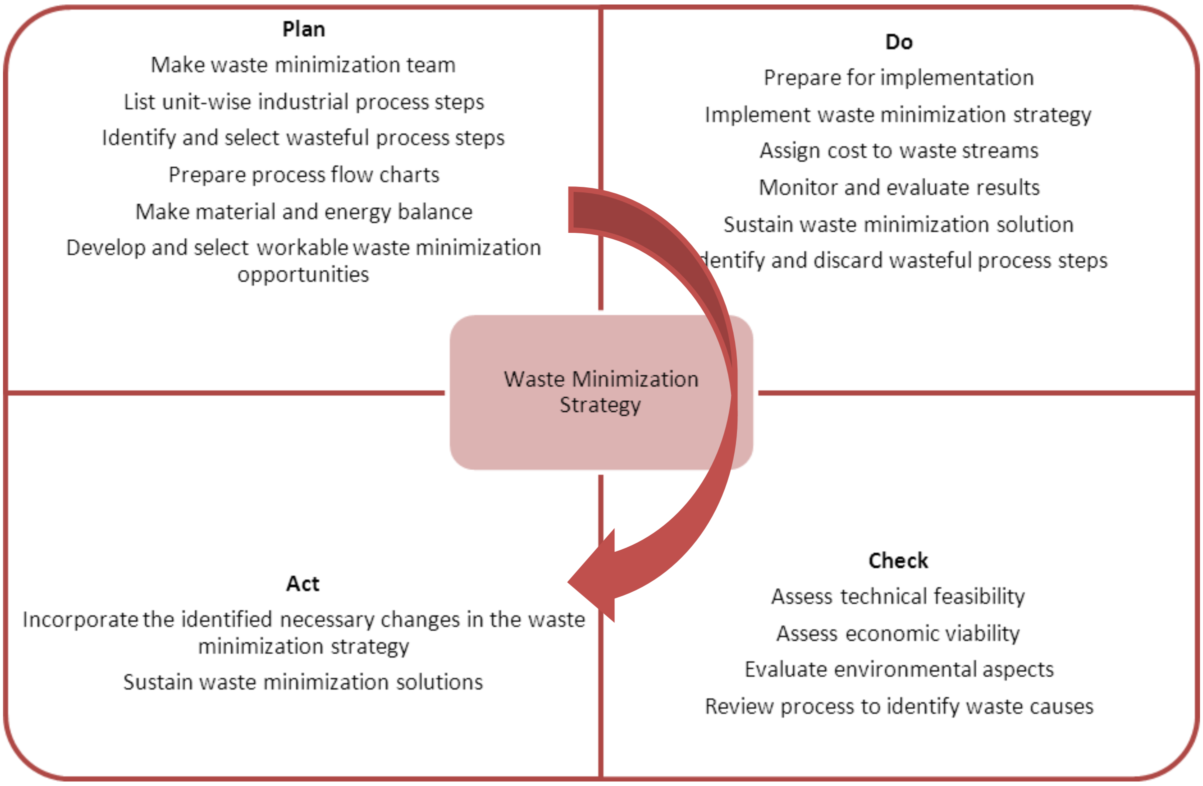

Figure 6.2 Steps involved in Waste Minimization Strategy

6.5 Environmental benefits of implementing waste minimisation in brassware cluster

6.5.1 Waste minimization in casting

Wastes produced in casting operations primarily are spent sand from moulding and core-making processes, investment casting shells and waxes, bag-house dust, scrubber waste and slag.

Waste reduction options for metal cast industries include source reduction and recycling.

Waste Minimization Techniques for Bag-house Dust and Scrubber Waste include the following:

1) Source reduction:

a. **Alter Raw Materials-** The predominant source of lead, zinc and cadmium in ferrous foundry bag-house dust or scrubber sludge is galvanized scrap metal used as charge material. Charge material, containing lower concentrations of these contaminants should, therefore, be acquired.

b. **Install Induction Furnaces-** Induction furnaces offer advantages over electric arc and cupola furnaces. An induction furnace emits 75% less dust and fumes because of the absence of combustion gases or excessive metal temperatures. With relatively clean scrap material, the need for emission control equipment may be minimized.

2) Recycling options

a. Recycle to original process- If the zinc and lead levels of metal dust are relatively low, return of dust to the furnace for recovery of base metals (iron, chromium or nickel) is feasible. Many methods have been proposed for flue-dust recycling including direct zinc recovery. Most recovery options require the zinc content of the dust to be at least 15-20 %, for the operation to be economical. If the dust is injected into the furnace after the charge of scrap metal is melted, temperatures are high enough for most of heavy metals to fume off.

b. Recycle outside the original process- Waste can be reused outside the original process by reclaiming the zinc, lead and cadmium, concentrated in emission control residuals. This application is quite useful in brass foundries. Some of the methods employed are:
   - **Pyro-metallurgical Methods:** This method is useful for metals recovery based on reduction and volatilization of zinc, lead, cadmium and other dust components. A reducing environment favours zinc and cadmium oxide vaporization and removal, while oxidizing environment favours removal of lead by oxide vaporization.
   - **Rotary Kiln Technology:** This process can simultaneously reduce ferrous oxide to solid iron and lead and zinc oxide to their metallic forms, using a reducing atmosphere such as carbon monoxide and hydrogen. The disadvantage is that it must be fairly large to be economically and thermally efficient.
   - **Electro-thermic Shaft Furnace:** This furnace can extract zinc from a feed containing 40% of the metal. Zinc is recovered in its metallic form, from which a very saleable Prime Western Grade can be made.
   - **Zinc Oxide Enrichment:** To recycle dust by direct reduction of oxides, iron oxide is reduced to iron and water using pure hydrogen at a temperature range of 1000 to 1100℃. Zinc oxide is reduced by reacting it with hydrogen that produces zinc vapours and steam. Zinc reacts with water to produce zinc oxide, and hydrogen is recycled and recovered.

c. **Recycle to Cement Manufacturer-** Silica-based bag-house dust from sand systems and cupola furnaces may be used as raw material by cement manufacturing industries. Bag-house dusts constitute about 5-10% of the raw material used by cement manufacturers.

6.5.2 Waste Minimization in Spent Casting Sand

Casting sands used in production of brass castings may be contaminated with zinc, lead and copper condensates, and must be disposed of as hazardous waste.

1) Waste segregation

- Re-plumbing the dust collector ducting on the casting metal gate cut-off saws to collect metal chips for easier recycling.

- Installing a new bag-house on the sand system to separate the sand system dust from the furnace dust.
- Installing a new screening system on the main moulding sand system surge hopper to continuously clean metal from the sand system.
- Installing a magnetic separation system on the shot-blast system to allow the metal dust to be recycled.
- Detoxifying sand that remains unusable as a result of size reclassification after sand reclamation.

2) Recycling options

- Screen and Separate Metal from Sand - Coarse screens are used to remove large chunks of metal and core butts. The larger metal pieces collected in the screen are re-melted in the furnace or sold to secondary smelter. Fine screens remove additional metal particles and help classify the sand before it is moulded.
- Reclaim Metal and Sand: A process for reclaiming sand and metal in brass foundries is shown in figure 6.3. First, the sand is processed to physically remove as much of the brass metal as possible. This material has relatively high value, and constitutes from one-half to two-thirds of heavy metal in the sand. The physical separation units include gravity, size and magnetic separation units. The second stage removes the heavy metals found in the fines and the coatings from the sand. The chemical process consists of mineral acid leaching, and metal recovery.

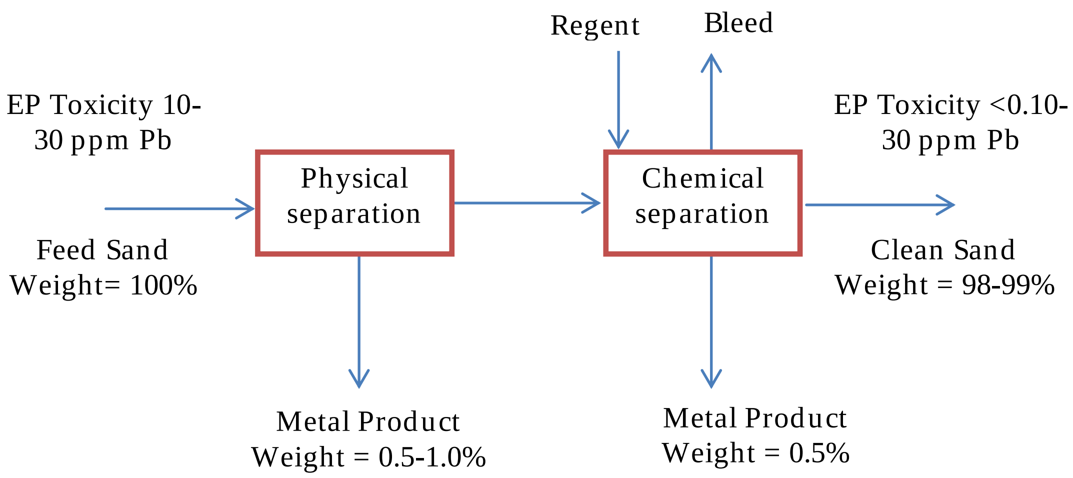

Figure 6.3 Simplified Process Flow Diagram for Sand Treatment in Brass Foundries (AFS, 1989)[24]

[24] Guides to Pollution Prevention: The Metal Casting and Heat Treating Industry, United States Environmental Protection, DIANE Publishing, 01-Jul-1996

- Reclaim Sand with Thermal Systems: A typical system to reclaim chemically bonded sands for reuse in core-room and molding operations consists of a lump reduction and metal removal system, a particle classifier, a sand cooler, a dust collection system and, a thermal scrubber (two-bed reactor).
- Thermal Calcining/ Thermal Dry Scrubbing: These systems are useful for reclamation of organic and clay-bonded systems. The application of heat with sufficient oxygen calcines the binders or burns off organic binders. Heat offers a simple method of reducing the encrusted grains of moulding sand to pure grains.
- Rotary Drum: This is used for reclamation of shell and chemically bonded sands. The direct-fired rotary drum is a refractory lined steel drum that is mounted on casters. The feed end is elevated to allow the sand to flow freely through the unit. The burners can be either end of the unit with direct flame impingement on the cascading sand. In indirect-fired units, drum is mounted on casters in horizontal position. Burners line the side of the drum, with flames in direct contact with the metal drum.
- Multiple-Hearth Vertical Shaft Furnace: This furnace consists of circular refractory hearths placed one above the other and enclosed in a refractory-lined steel shell. A vertical rotating shaft through the centre of the furnace stirs the sand and moves it in spiral path across each hearth. Hot gases rise counter-currently burning the organic material and calcining clay. Discharge of reclaimed sand can be directly from the bottom hearth into a tube cooler or other cooling methods may be used.
- Use Sand as a Construction Material: Non-hazardous foundry waste has been used in municipal waste landfills as a supplement for daily earth cover. But, a good alternative is using selected foundry wastes for both final cover and as a topsoil substitute for foundry landfills. Also, foundry sands and other wastes can be used for construction fill.

Applications

Bituminous concrete, commonly called asphalt, is a potential reuse market for foundry wastes. AFS research (1991) has verified that asphalt made using foundry sand as partial aggregate replacement will meet standard ASTM specifications[25].

Most portions of foundry sands can be used as substitute to raw materials used in the manufacture of Portland Cements. Spent sand would provide silica, green sand fines would provide alumina, and slag would provide quicklime and silica.

Advantages

AFS research (1991) has reported that use of spent foundry sand in cement manufacturing results in increased compressive strength over control mixes. This effect increases with the addition of foundry sand[26].

[25] Guides to Pollution Prevention: The Metal Casting and Heat Treating Industry, United States Environmental Protection, DIANE Publishing, 01-Jul-1996

[26] Guides to Pollution Prevention: The Metal Casting and Heat Treating Industry, United States Environmental Protection, DIANE Publishing, 01-Jul-1996

AFS also reports that using chemically bonded shells sands in concrete mixes slightly increased the observed compressive strengths.

6.5.3 Waste Minimization in Electroplating

Electroplating generates all three forms of waste – liquid, gaseous and solid. Of these, liquid wastes are predominant. Such liquid wastes include : (i) spent chemicals and solutions such as acids, alkalis, cleaning agents, bath chemicals comprising plating chemicals as well as additives such as brighteners, levellers etc. and rinse waters, which may contain some or all of these depending upon sources, method of plating and housekeeping practices.

Gaseous wastes include solvents vapours and fumes from hot pre-treatment and process/ baths. They include acid alkali mist and Volatile Organic Compounds (VOCs). In some cases, mists and VOCs may contain metals in addition to process chemicals. It is estimated that approximately 30% of the solvents and degreasing agents used can be released as VOCs when baths are not regenerated.

Solid wastes include, sludge generated from wastewater treatment, sludge from cleaning and bath tanks and various residues like, cleaning powder, buffing compounds, spent anodes and various scraps. Unused chemicals, spent resins from ion-exchange/ metal recovery systems also contribute to solid waste. Much of the solid waste contains hazardous and toxic substances.

1. Minimization of Wastewater Generation

This is the single most significant step towards waste minimization. While the large and organized units practice full or partial wastewater minimization, small scale units remain ignorant. The following practices can be easily adopted at any large-scale or small-scale plating units:

- Introduction of rinse water recirculation with automatic benefit of chemical recovery and reuse.
- Static rinse water recovery.
- Avoiding and controlling spillage, which is the single largest cause of high wastewater generation in the unorganized sector. Using troughs between tanks and using well defined linear configuration in place of barrels and avoiding haphazard rinsing and washing ensures significant reduction in the quantum of wastewater generated.
- Introduction of cascade and/ or counter-current rinsing.
- Use of fogging and spraying on objects (rack plating).
- Introduction of metal recovery by electrolytic method (ion exchange and its advanced application leading to high recovery ratio of water (up to 80%).

2. Minimization of Gaseous Emissions

Gaseous emission takes place as vapours from hot baths, normal evaporation from cold baths do not constitute significant source of such emission and VOCs from organic cleaning baths.

The use of collecting hoods and scrubbers can significantly control or eliminate vapours from baths. Collection arrangements have improved substantially but older plants either have no collecting hoods or have suction arrangements which are ineffective. Completely covered baths are desirable; however, they are useful in completely automated plants. Use of top suction hoods with properly designed scrubber system certainly controls much of the gaseous emission. As far as emission of VOCs are concerned, avoidance of those compounds that are associated with high environmental concerns should be attempted, and where there are no alternatives, it would be best to keep the tanks fully covered at all times and using vapour arresting devices.

3. Minimization of Solid Waste

A major part of the solid waste is the hazardous sludge generated from wastewater treatment plants. Hence, measures to control wastewater generation can prove beneficial in reducing the formation of sludge as well. While empty containers of chemicals are usually sold off to scrap dealers, tank sludge and spent carbon filters containing hazardous metal salts need to be disposed in conformation with regulatory requirements pertaining to hazardous substances. Using non-hazardous chemicals can lead to minimization of hazard in solid waste from process chemicals. Use of Cyanide free process (e.g. Alkaline Cyanide Free Zinc plating) and the use of trivalent Chromium in place of hexavalent Chromium are examples of such hazard minimization.

6.6 Best Available Technology (BAT) options:

Best Available Technique (BAT) means the most effective and advanced stage in the development of activities and their methods of operation, which indicate the practical suitability of particular techniques for providing in principle the basis for minimum emission values designed to prevent and, where it is not practicable, generally to reduce emissions and the impact on the environment as a whole.

6.6.1 Specific BAT approach:

Ideas to implement some specific BAT measures are summarized herewith under the heading of:

- Pre-treatment activity
- Plating activity

Table 6.1 Specific CP (Cleaner Production) approach in Pre-Treatment:

Application of Pre-treatment	**Method**	**Benefit**
Pre-cleaning of small size work-pieces	Use centrifuge to remove all dirt prior to de-greasing or Impose cleanliness requirement onto the customer (medium tech)	• Reduce lengthy pre-treatment • Reduce electricity consumption in surface preparation
Removal of accumulated oil and grease	Use centrifuge (medium tech)	• Reduce infiltration of impurities (undesirable salts and organics including oil and grease) in degreaser tank • Prolong life span of degreaser bath
Ultra-filtration of alkaline degreaser bath for inlet water	Self-explanatory (high tech)	As above
Ultrasonic degreasing	Self-explanatory (high tech)	As above

Table 6.2 Specific CP approach in Plating

Application in Plating	**Method**	**Benefit**
Water flow and conductivity meter	• Introduce on-line flow meter in intake water pipe • Introduce on-line conductivity meter in process tank	Water savings from correct adjustment of • Water flow into last rinse tank • Plating chemical replenishment
Reverse osmosis (RO) on last Rinse water for inlet water	Ro is not recommended for use in systems where • pH is 12-14 or pH is 0-2 • Organics in influent water > 5 g/ l	Reduce infiltration of impurities (undesirable salts and organics) into rinsing tanks
Zinc plating	Place evaporator next to the plating bath. The inlet pipe and back-filling pipe is installed in the process tank	Reduce consumption of zinc
Nickel, chrome, copper and tin plating	Recover heavy metals from used rinsing water for reuse in plating baths by means of electrolysis cell or ion exchanger (and evaporation unit if required)	Savings of raw materials Reduce amount of sludge Reduce concentrations of heavy metals in wastewater Recover heavy metals for re-use or secondary raw materials to be sold off

6.7 Potential initiatives and cost estimates[27]:

The tabulation given below offers an idea of the different cost range relating to the various initiatives. It is to be noted that the costs are broad estimates only.

Note: In view of the availability of different designs and systems, the details of costs can vary. The industry is encouraged to acquire the latest cost information from the equipment supplier if any cleaner production initiative in the above is taken up.

Table 6.3 Cost Analyses of Various Kinds of Initiatives

Applicability	Initiative/Actions	Cost Range (INR)
Low tech measures	Cleaning + maintenance	Negligible
	Drip guard (polypropylene plastic material) between tanks	Negligible
	Replace leaky tanks and repair leaky pipes	Negligible
	Sheltered storage for chemical drums with secondary containment but without drainage	Negligible
Medium tech measures	Insulation of hot process tanks and piping	Negligible
	Air blower in separate enclosure	10,000-50,000
	Water flow mater and conductivity meter*	5,000
	Multiple counter flow rinsing/ sequence	10,000-50,000
	Barrel rotation* (at top position)*	15,000-25,000
	Spray rinsing*	10,000-35,000
	Centrifuge (pre-treatment)	70,000-1,00,000
High tech measures	Introduce/ improve vapor collection hoods and scrubber systems	50,000-1,50,000
	Reverse osmosis or ion exchanger	50,000-3,00,000
	Ultra filtration/ ultrasonic (pre-treatment)	1,00,000
	Back filling to plating baths	
	• Evaporator bath and activated carbon filters	• 15,000-50,000
	• Electrolysis cell	• 30,000-1,00,000

*Includes construction and installation of electrical contacts for operation mechanisms

6.8 Recovery of Metals

During electroplating operations, metal salts are used in electro-deposition of metals and rinsing and washing. While the first part i.e. the rinse goes into plating, the second part, washing, is lost and poses a problem in wastewater treatment. Even in plating baths,

[27] Parivesh, "Waste Minimization and Eco-friendly Electroplating Operations", Central Pollution Control Board, Delhi; September 25,2008; accessed at http://www.cpcb.nic.in/upload/Newsletters/Newsletters_60_newsletter_electroplatin02.12.08.pdf

solutions often need to be discarded because of build-up of impurities, which then hinder the efficiency of plating process or cause deterioration in quality of plating. Either way, the baths are to be discarded before fresh bath is made. Bath regeneration is, therefore, done to counter discarding it entirely.

Several methods of bath regeneration are discussed below with their advantages and constraints of use. Of these, metal recovery through ion exchange presents highest potential and serves the dual purpose of resource (metal) recovery and waste minimization (by re-use of water of regenerated bath solutions).

6.8.1 Filtration and Centrifugation-

Filtration with or without centrifugation is a widely used and effective method for prolonging and improving the life of bath. Although it does not directly recover metals, it enhances the use of metal salts thus controlling and reducing the wastage of metal salts. Activated carbon filter is widely used to remove dissolved organic impurities (example: Nickel Baths) in addition to its action in removing solids. Such filters are used continuously or intermittently during plating.

6.8.2 Evaporation losses-

a. Simple Measures:

Many plating units in the small scale sector in India employ these techniques. Direct recovery of plating baths is realized with a static drag-out tank. Rinse water from this tank is used for the replenishment of volume losses of the process bath due to evaporation. Periodic water transfer from drag-out into the process tank is made manually or by a small pump. Practical recovery ratio realized by this method is not usually higher than 50 – 60 %.

b. Advanced Techniques -Tin, Copper and Zinc plating:

Efficiency of direct recovery can be significantly improved by the introduction of several drag-out/ rinse tanks arranged in series. Such a technique has been developed and applied in Poland and several other countries. Air lift pumps (made of PVC) are used for rinse water transfer from tank to tank and from the first rinse tank to the plating tank. The return rates and opening and closing of valves are automated (controlled by electronic level controller and conductometric probes). Depending upon the plating line output, evaporation losses of the bath and the space available in the shop, four drag-out tanks in a series can be introduced. The tanks can work in closed loop system with zero discharge.

This technique has been successfully used for Nickel, Tin and Copper plating baths and other hot baths recovery with an efficiency of 85 – 95%. It has also been used for recovery of cold baths such as Zinc, wherein a small evaporator is used. Such a system for Zinc barrel plating line has been quite successful. Recovery ratio of Zinc plating bath was 98% (about 300 kg of Zn per year). Average water consumption for rinsing was reduced from 200 lt/ m^2 to 18 lt/ m^2, a reduction of 91%.

Other savings included:

- Reduction of Energy cost in plating shop.
- Reduction of consumption of anode and plating salts.
- Reduction in cost of waste water treatment.
- Reduction of sludge volume.

6.8.3 Electrolytic recovery and its economics-

This is a well-developed technique in use both at large and small scale industries. A major constraint is that complete recovery of metal from dilute solutions cannot be achieved.

a. **Nickel Recovery/Recycling by Ion-Exchange**[28]:

Nickel baths are followed by several counter current flowing water rinse tanks to prevent carry over and contamination of subsequent chrome plating baths.

There are two options to deal with the waste water. The waste water can be treated by alkaline precipitation, and the sludge is disposed of to a secure landfill. Alternatively, recovery of Nickel and recycling to Nickel plating bath (recovery rate >97%), treating the balance 3% or so can also be adopted. A plater would choose the more economical between the two desired alternatives.

There are conventional ion exchange units as well as advanced ion-exchange units. In a conventional unit, the rinse water is pumped to an ion-exchange column containing strong acidic cation exchange resin. This resin is characterized by high capacity, good chemical resistance and stability. The resins exchange hydrogen ions and Nickel ions are retained on resin which gets saturated with Nickel Salts after sometime. Then passing of Nickel solutions are stopped and resin regenerated with 55% pure Sulphuric or Hydrochloric acid. The regenerated solution contains Nickel ions in the form of $NiSO_4$ or $NiCl_2$. All brightener and products of its breakdown are also removed leaving regenerated solution free from organic contamination. The solution can now be returned to plating tanks-semi-bright Nickel and/ or tri-Nickel.

The comparative economic comparison of a small plant is given below.

[28] Parivesh, "Waste Minimization and Eco-friendly Electroplating Operations", Central Pollution Control Board, Delhi; September 25,2008; accessed at http://www.cpcb.nic.in/upload/Newsletters/Newsletters_60_newsletter_electroplatin02.12.08.pdf

Table 6.4 Economic Comparison of Waste Treatment vs. Waste Recovery (Basis: 2.5 kg $NiSO_4$ per day)[29]

Component	Waste Disposal Cost (Rs/day)		Operating Cost (Rs) of Recovery System	
Nickel salt@165 per kg	2.5 kg	412.50		
Sulfuric acid @6/ kg	-	-	3 kg	16
Electricity @4 per kWh	3	12	3	12
Labour	LS	50	LS	50
Chemical for sludge handling	LS	2	-	-
Total per day		476.5		80
Total per year@300 working days/ year		1,42,950		24,000
Net savings per year				1,18,950

In the advanced recovery system using ion-exchange process, some of these problems have been tackled to provide better efficiency and performance. This type of system uses two short packed resin columns (i.e., cation and acid sorption) with fully automated operation. Economic comparison is shown in the following Table 6.5:

Table 6.5 Economic comparison of Advanced Ion-exchange Nickel Recovery versus Waste Treatment (Basis: 2.5 to 3.0 kg / hr dragout operation)[30]

Component	Waste Disposal Cost (Rs/day)		Operating Cost (Rs) of Recovery System	
Nickel salt Sulfate+chloride @165 per kg	20,000 kg	33,00,000	200 kg	33,000
32% hydrochloric acid@4,000/ tonne	-	-	2,000 kg	8,000
93% sulfuric acid @6,000/ tonne	-	-	9,000 kg	54,000
100% caustic soda@15,000/ tonne	6.3 tonne	94,500	7.5 tonne	112,500
10% sludge+handling@500 per tonne	75 tonne	37,500	0.75 tonne	375
Plant water @15/ m3	45,000 m3	6,75,000	-	-
D.M. water @25/ m3	-	-	5,400 m3	1,35,000
Total per year		41,07,000		3,42,875
Net savings per year				37,64,125

The operating advantages are:

- Very dilute rinse feed solution (<0.5 to 1.0 g/ l as Nickel) resulting in high concentration purified product (>35 – 40 g/ l as Nickel)
- Organic brighteners are rejected allowing direct recycle to semi-bright baths
- Prevents Sodium build-up in plating bath
- Regeneration of resin with a mixture of Sulphuric and Hydrochloric acid produces a mix of Nickel Sulphate and Chloride that matches bath chemistry. Excess regenerant

[29] Parivesh, "Waste Minimization and Eco-friendly Electroplating Operations", Central Pollution Control Board, Delhi; September 25,2008; accessed at http:/ / www.cpcb.nic.in/ upload/ Newsletters/ Newsletters_60_newsletter_electroplatin02.12.08.pdf

[30] Parivesh, "Waste Minimization and Eco-friendly Electroplating Operations", Central Pollution Control Board, Delhi; September 25,2008; accessed at http:/ / www.cpcb.nic.in/ upload/ Newsletters/ Newsletters_60_newsletter_electroplatin02.12.08.pdf

acids from the initial product of the first resin bed are sorbed out in the second resin bed resulting in the final Nickel products having a pH suitable for direct recycle.

b. Chrome Recovery/ Recycling by Ion-Exchange

Factors such as defects in surface coating, material loss and costs of treatment and disposal to comply with pollution control regulations lead to dire need for purification and recycling of Chromic Acid in the plating industries.

Conventional ion-exchange based recovery system comprises cation and anion exchange columns. The first column, containing cation exchange resin, removes trivalent Cr, Ni, Fe, Cu etc. The effluent, then containing only hexavalent Cr is passed through anion exchange resin. This removes hexavalent Cr, leaving the effluent free from all metal ions. When the resins get saturated, they are regenerated and recovered Chromic Acid is recycled to baths. The economic comparison is shown in the following Table 6.6.

Table 6.6 Economic Comparison of Waste Treatment vs. Chrome Recovery (Basis: 2.5 kg Chromic acid from static Rinse water per day)[31]

Component	Waste Disposal Cost (Rs/day)		Operating Cost (Rs) of Recovery System	
Chromic acid@110/ kg	2.5 kg	275	-	-
Sodium metabisulphite@12/ kg	7.5 kg	90	-	-
Caustic soda @14/ kg	4 kg	56	4 kg	56
Savings on sulfuric acid @3/ kg	2 kg	6	3 kg	12
Electricity@4/ kWh	3	12	10	40
Labour	LS	50	LS	50
Chemical for sludge handling	LS	2	-	-
Saving on plant water (after recycling)	LS	5	-	-
Total per day		496		158
Total per year@300 working days/ year		1,48,800		47,400
Net savings per year				1,01,400

Despite such encouraging results, conventional ion exchange recovery systems have one problem. Direct recycle of the drag-out solution to the plating bath will also recycle the metal contaminants and lead to build-up of contaminants as recycling goes on. An effective recycling system has to incorporate both recovery and purification. A good arrangement would be to use an atmospheric evaporator for the purified recycled solution. The availability of two or three counter flowing rinse tanks in the plating line could ensure a high degree of recovery with such a system (over 90 – 96% of drag-out losses) with the possibility of also reducing rinse water requirements by 70 –80% .

The economic comparison of larger capacity plants is given in the following Table 6.7.

[31] Parivesh, "Waste Minimization and Eco-friendly Electroplating Operations", Central Pollution Control Board, Delhi; September 25,2008; accessed at http://www.cpcb.nic.in/upload/Newsletters/Newsletters_60_newsletter_electroplatin02.12.08.pdf

Table 6.7 Economic Comparison of Chrome Bath Recovery with Treatment (based on 3,785 litres bath volume; 240 g/ l chrome; 15g/ l metals)[32]

Item	Advanced Ion-exchange system	On-site Treatment	Off-site Treatment
Bath replacement	-	Rs. 1,50,500	Rs. 1,50,500
Chemicals	Rs. 23,177	Rs 74,605	-
Solid Disposal	-	Rs. 57,663	-
Liquid Disposal	-	-	Rs. 3,44,000
Total Costs	Rs. 29,154	Rs. 2,82,768	Rs. 4,94,500

Adoption of a particular technique depends not only on metal and/ or chemical recovery efficiency but also on effect on plating quality, overall economy and availability of operational skill. Whatever the variant, metal recovery means (i) A straight forward pollution abatement approach at source, (ii) A cleaner production process and (iii) Substantial saving of water.

6.8.4 REVERSE OSMOSIS:

Reverse Osmosis is one of the membrane filtration techniques, in which the pore size of the membrane varies from 1 to 15 Angstrom and the liquid is filtered through a semi-permeable membrane, which allows only water molecules since the pressure is more than the osmotic pressure. Application of this process is based on the fact that since the RO membrane normally rejects compounds and ions above a molecular weight of 150, most of the ions will be rejected. When rinse water is subjected to RO, water (with some compounds) will come out as permeate and the rest of the chemicals will remain in the concentrate or rejects. The concentrate can be recycled to bath. This is possible when rinses from various processes are segregated. If they are mixed, the concentrate will contain a variety of chemicals and obviously, it will need to be evaporated (with solar energy) and sludge disposed as hazardous sludge. The major limiting factor for use of RO system is the presence of Iron and free chlorine, which the membranes are not able to withstand, causing fouling of membrane. If sufficient pre-treatment precedes RO, then it is a viable alternative to conventional system.

6.9 Energy saving and use of energy efficient techniques in casting and electroplating

6.9.1 Energy saving in metal casting/ reheating:

In metal casting, the metal is heated several degrees above its melting point and then poured into moulds. Metal casting is only a small part of the entire engineering process, but it consumes a lot of energy and forms a large part of the overall energy cost. Foundries usually install large cupola or induction melting furnaces for metal casting. The smaller engineering units install either crucible furnaces for non-ferrous melting (brass, copper, aluminium, etc.) or small capacity induction furnaces.

32 WASTE MINIMISATION AND ECOFRIENDLY ELECTROPLATING PROCESSES Parivesh Newsletter, Central Pollution Control Board (CPCB) December 2, 2008

Melt losses are a measure of the difference in metal quantity before and after the melting process. The loss can occur for many reasons but the most important one is oxidation of metal. The following table 6.8 compares typical efficiency levels for commonly used melting furnaces.

Table 6.8 Energy and Material Losses in Different Kinds of Furnaces

Melting Furnace	Common use	Melt Loss (%)	Thermal Efficiency (%)
Cupola	Iron	2-12	40-50
Electric Arc	Steel	5-8	35-45
Electric Reverberatory	Aluminum	1-2	59-76
	Zinc	2-3	59-76
Gas Crucible	Aluminum	4-6	7-19
	Magnesium	4-6	7-19
Gas Reverberatory	Aluminum	3-5	30-45
	Zinc	4-7	32-40
Gas stack Melter	Aluminum	1-2	40-45
Induction	Aluminum	0.75-1.25	59-76
	Copper Base	2-3	50-70
	Magnesium	2-3	59-76
	Iron	1-2	50-70
	Steel	2-3	50-70

Metal casting and reheating processes can be made more efficient by:

1. Minimizing the temperature of exhaust gases from the furnace. The temperature of exhaust gases can be lowered by increasing the length of the preheating zone of the furnace.
2. Reducing the charging time to ensure maximum capacity utilization and faster mass flow rate.
3. Reducing the holding time to ensure minimum fuel/ electricity consumption while holding (non-productive operation). This will also improve the life of the refractory lining in induction furnaces.
4. Planning and scheduling the furnace operation, especially for batch melting furnaces, such that the number of cold starts is minimized. Each cold start consumes 10 – 20% more energy than regular furnace running and also reduces the life of the refractory.
5. Optimizing excess air in the furnace. Excess air (that is, more than the stoichiometric amount) is needed in a furnace to allow complete mixing of air and fuel and maximizing combustion efficiency. However, if too much excess air is added, the furnace temperature will go down, and more fuel will be needed. Too little excess air will lead to incomplete fuel combustion, formation of soot and scale. Excess air in the furnace should be optimized in the following ways:
   a. Controlling the entry of air through furnace openings.
   b. Maintaining proper air pressure.
   c. Monitoring the levels of excess air using a combustion analyzer.
   d. Regulating the supply of air through the blower according to the rate of fuel supply.

e. Turn off combustion air supply with cut off in fuel supply regulated by thermostat. Both combustion air and fuel supply should be interlinked with the auto cut operation of thermostat. This helps in increasing the restart time of fuel supply at ON signal from thermostat.

Table 6.9 shows the optimum levels of excess air for different fuel and furnace types:

Table 6.9 Recommended Excess Air for Different Fuels

Fuel	Type of Furnace/Burners	Excess air (% by weight)
Pulverized coal	Completely water-cooled furnace for slag tap or dry ash removal	15-20
	Partially water-cooled for dry ash removal	15-40
Coal	Spreader stoker	30-60
	Water-cooler vibrating-grate stokers	30-60
	Chain-grate and traveling grate stokers	15-50
Fuel oil	Oil burners	15-20
	Multi-fuel burners and flat flame	20-30
Natural gas	High pressure burner	5-7
Wood	Dutch over (10-23% through grates) and Hofft type	20-25%

Additionally, the following points should be kept in mind by the furnace owners:

1. Fuel should be stored according to the guidelines or that particular fuel. For liquid and gaseous fuels, leakages in storage and supply lines are wasteful and can be dangerous. The supply lines and the storage should be checked for leakages/ blockages once in a week.
2. Never allow the burner flame to directly touch the material or the refractory. Direct touching will increase scale losses, reduce the refractory lining's life and cause inefficient heating. Also, flames from different burners should not touch each other inside the heating chamber of the furnace.
3. Use digital temperature indicators and automatic controllers in place of human monitoring. This will reduce the chances of the material overheating and also prevent energy/ material loss.
4. Heat loss occurs through furnace openings in the following ways:
   I. Direct radiation loss
   II. Leakage of hot combustion gases
   III. Infiltration of cold air
5. To minimize such losses, any furnace openings caused by normal wear should be immediately sealed and material flow gates covered with proper curtains.
6. In heat treatment furnaces, use proper digital temperature indicators so that the furnace gates do not have to be opened to check the temperature.
7. Follow the specified heating treatment cycle for material while using bogey type heat treatment furnaces. Use thermostat based controls to maintain the required temperature.
8. Load the material in optimum sizes in batch type furnaces. This will ensure that there is no obstruction to the flow of hot gases, flame path and the exhaust port.
9. In crucible furnaces, place the stock near the furnace opening for preheating.

Table 6.10 Efficient Operation of Furnaces and Combustion Systems

Do's	Don'ts
Always maintain proper air-fuel ratio. Use combustion analyzers to find air-fuel ratio	Don't estimate furnace temperature
Clean burner nozzles to remove deposits once a month	Don't leave air supply open while fuel supply is closed
Plan production to avoid furnace cold starts	Don't open furnace gates unnecessarily
Use correct/ recommended frequency in induction furnaces for the alloys being melted. This will ensure faster mixing of additives and reduce cycle time	Don't use liquid fuel without proper heating and pumping
Always use calibrated digital meters for reading temperature and pressure. Manual estimation may be incorrect	Don't use adulterated fuel
Seal unnecessary furnace openings and leakages	

6.9.2 Energy saving in electroplating[33]:

The electroplating process involves dipping the semi-finished products into various baths of metallic salts, to coat a metallic layer on the semi-finished product surface. Such metallic baths are placed in series and are separated by one or more rinse water tanks between every two metallic bath tanks. Rinse water tanks are to remove the chemicals from the previous metallic bath and prevent mixing of chemicals into the next metallic bath. Therefore, considerable amount of water is required to be pumped into these rinse tanks to keep the process chemically stable.

The following parameters are required to be monitored in the electroplating section of an engineering unit to make the process more efficient.

Reducing the amount of water used for rinsing:

The amount of water required for the rinsing process plays a crucial role in determining the efficiency of rinsing. Minimizing rinse water requirement will not only conserve water, but also save energy otherwise required to pump and treat waste rinse water before disposal. It also reduces the quantity of costlier metallic salts which are wasted as unrecoverable salts from the rinse water.

The rinsing process can be made more effective and economical by adoption of the following practices:

Proper design of electroplating line and rinse tanks:

- Rinse tanks should have proper agitation of water. Agitation can be created using pressurized water inlet nozzles on the bottom edge of the rinse tank.
- The water inlet pipe should be so located as to create turbulent flow close to the products' surface.

[33] "Energy Conservation Measures in the Engineering Sector", SIDBI (Small Industries Development Bank of India) ; published by Winrock International India; accessed at http://www.msmementor.in/SIDBI_Publications/Energy%20Efficiency%20in%20Engineering%20Sector.pdf

Following figure 6.4 shows the sketch of rinse tank which includes the above mentioned design parameters.

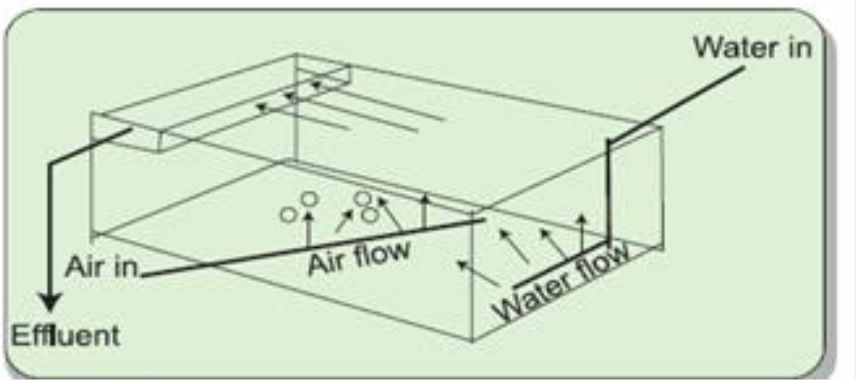

Figure 6.4 Schematics of an Efficient Rinse Tank Design

Installing staged rinsing techniques:

Multi stage rinsing with water conservation: Multi stage rinsing involves the use of two or more rinse tanks with a water flow arrangement such that the least concentrated (effluent) waste water from the final stage of rinsing is directly used in the preceding. The final effluent with highest concentration appears only in the first stage of rinsing.

Figure 6.5 below shows that the water requirement for the later rinsing stages is gradually reduced.

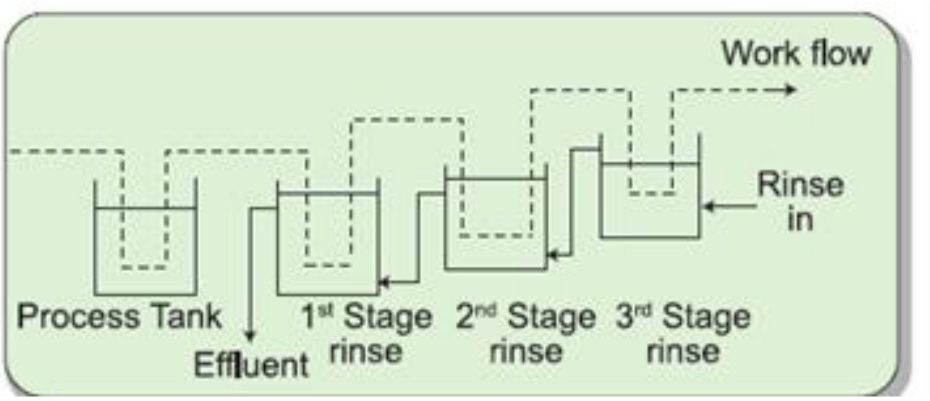

Figure 6.5 Schematics of Counter Flow Rinsing

Minimize bath drag-out:

Spray rinsing with drag-out reduction:

Whenever the hangers carrying the items to be electroplated are taken out from the metallic bath, a considerable quantity of bath solution also comes out of the tank on the surface of articles and the hangers. Such outflow of the chemical bath from the process tank is called drag out. Drag out quantity also depends on the shape and form of articles under process. Reducing the quantity of drag out not only saves the excess water required to rinse off such chemicals, but also saves the precious and costly metallic salts from flowing out of the process tank.

Use of spray rinse, as outlined in Figure 6.6 can save a large quantity of drag out from the process tank by the immediate return of the entire drag out back into the process tank. Pressurized water is sprayed using suitable sized nozzles. Care must be taken in spraying the correct quantity of water so as to prevent dilution of the bath in the process tank.

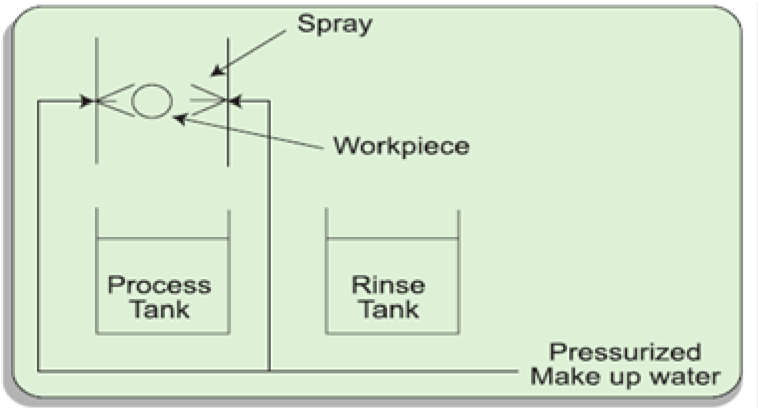

Figure 6.6 Spray Rinse method for Reducing Drag-out in Electroplating

Use of simple drain boards between two tanks in electroplating lines:

One very simple and effective way to reduce drag out from process tanks is to keep the electroplating section free of spills. Use inclined drain boards between every two process tanks (figure 6.7) such that the drag out flows back into the process tank.

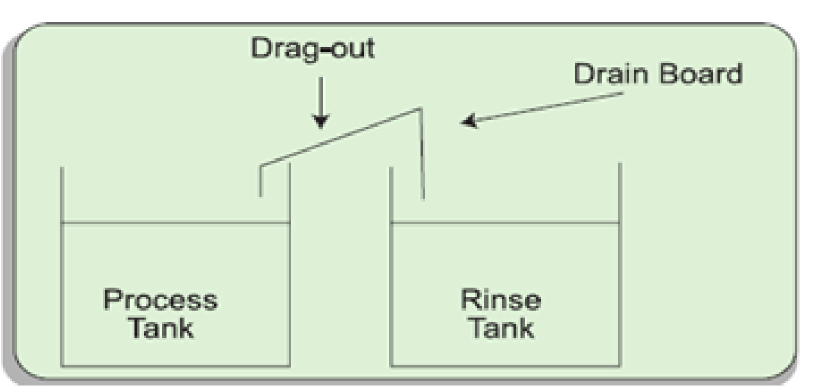

Figure 6.7 Drain Board Method for Reducing Drag-out in Electroplating

6.10 Socio-Economic Benefits

Cleaner production techniques are considered as an expensive proposition. While initial investment costs may sometimes be a little steep, the payback period on the incorporation of these techniques is extremely attractive. A number of options are worthy of consideration:

1. Pre-treatment options are available that can help reduce both material and energy consumption to a significant degree.

2. Waste minimization practices can help reduce material losses, an important factor of consideration since brass alloys are expensive.
3. Optimized furnace and burner operations for air flow and temperature translate into greater savings on fuel expenditure.
4. Metal recovery processes from the electroplating bath rinses can significantly reduce costs of raw material. Optimizing the operations for bath flows can help reduce energy costs significantly.

Cleaner production techniques also offer several non-economic advantages. Reduced fossil fuel consumption can help to reduce the overall impact of the industry, particularly from the casting operations. Similarly, improved electroplating techniques can reduce the amount of heavy metals discharged in the wastewater streams, thus reducing the load on nearby water bodies.

Occupational health is directly linked to the process activities. Cleaner production techniques are a crucial element in improving the working conditions. Control on exposures to acid fumes in electroplating can be easily achieved by covering the electroplating baths suitably. Similarly, the casting and forging operations can be improved upon to prevent exposures to high temperatures and noxious gases that are continuously released due to improper coverings.

Table 6.11 Benefit Analysis of Clean Production Techniques

Clean Production Option	Nature of Benefit Offered (Monetary or Non-monetary)	Economic benefit Offered	Environmental benefits
Pre-treatment of metal surfaces	Monetary	Reduced material costs Reduced electricity consumption Time optimization of process	Significant reduction in the volume of hazardous/ toxic waste stream produced
Optimized casting operation Reclamation of casting sands Optimization of air flow Hot starts for process	Monetary Non-monetary	Reduced fuel costs Reduced energy consumption	Reduced air pollution release Lower occupational exposure to noxious gases
Switching over to induction furnaces Sealing off furnaces	Monetary Non-monetary	Reduced fuel costs Reduced energy consumption	Reduced air pollution release Lower occupational exposure to noxious gases
Hooding electroplating baths Electrolytic solution recovery	Monetary	Material cost reduction	Reduced occupational acid and heavy metal exposures

Moradabad's brassware manufacturing industry has gained international name and recognition for the quality of work and intricacy of pieces produced from it. It is a major industrial cluster in India that contributes about INR 2500 crores annually to India's Gross Domestic Product (GDP) and accounts for about 40% of the total handicraft exports (Sekar, 2007). Typical of the industrial development scenario in India, the brass industry of Moradabad primarily consists of small and medium enterprises (SMEs), all the way down to individual artisans working out of their homes, which is also contrasted by large export oriented units catering to international demand from such big retailers as Walmart.

Pollution from industrial clusters is a major problem in India. Central Pollution Control Board (CPCB) has identified several industrial clusters in its assessment exercise in 2009, and expressed concern for the high levels of untreated waste and wastewater as well as the exposure of toxic waste to the local populace, in particular the factory workers and artisans (CPCB, 2009). However, waste minimization strategies that could be applicable to the local industry received little attention previously. Keeping these things in mind, The Energy and Resources Institute (TERI) proposed to MoEF for examining the waste generated by the brassware industry of Moradabad and

- Identifying areas to minimize waste generation in the brassware industry
- Identifying areas of recovery and recycling
- Broad identification of areas where energy can be saved.

teri
The Energy and Resources Institute
www. teriin.org