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An Exploratory Study of Environmental Pollution by Small Scale Industries Sector in Karnataka

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FINAL REPORT

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PREFACE

Small Scale Industries have grown to acquire a prominent place in the socio-economic development of India since independence through their ever increasing contribution to national income, exports and employment. This contribution is all the more significant because the sector as a whole is known for its meagre financial, managerial, technical and infrastructural resources. This crucial contribution of the sector, made within its constraints, is well known and well recognised in literature.

Another significant feature of small industry growth in India is that despite the promotion of industrial estates across the country, small scale industries have come up in every possible location: near to the resources, to the skills and/or to the markets, they have come up in rural areas, towns and cities, they have come up in residential as well as commercial areas, and they have come up in clusters as also in isolation. All these have characterised in unplanned, uncontrolled and haphazard growth of small scale industries across the country. One inevitable outcome of this kind of growth is environmental pollution, particularly because a greater proportion of them use outdated and inefficient technologies.

But the environmental status of small scale industries in India is largely unknown even to this day. Of course, owing to growing environmental awareness and information available on some product clusters, the Government of India has launched programmes in the mid 90s to promote cleaner production technologies and waste minimization techniques. This is a heartening development.

But the problem of pollution abatement is not simply technological alone. It has a larger socio-economic perspective. Accordingly, it is essential to understand the basic features of each small industry/cluster in terms of human resource, technological and structural factors. That would throw light on the pollution profile, causal factors, quantum of pollution and enable identification of appropriate pollution abatement measures.

It is precisely with these objectives that the current study has been undertaken under the aegis of the Environmental Economics Research Committee (EERC) of the Indira Gandhi Institute of Development Research (IGIDR), Mumbai. The project has been funded under “India: Environmental Management Capacity Building (EMCaB) Technical Assistance Project” of The Ministry of Environment and

Forests, Government of India aided by the World Bank. The study has been conducted with reference to four small industry clusters in Karnataka state to arrive at appropriate policy measures to promote environment friendly small industry growth.

We place it on record our humble gratitude to the EERC, IGIDR, Mumbai and its Chairperson Prof. Jyoti Parikh for the financial support extended to this research project. In fact, Prof Jyoti Parikh has been a great source of support and encouragement to us throughout the duration of the project. We thank Prof. Kirit Parikh, who has been kind enough to make suggestions for the improvement of our analysis at the mid-term review of our project, which helped us a great deal. We are also grateful to Prof. Robin Mukherjee, Prof. Paul Appasamy, Prof. Sudarshan Iyengar and Mr. K K. Narang, - members of the EERC for their valuable comments and suggestions at different stages of our work.

The role played by the Project Expert, Dr. R. Rudra Murthy, Professor, PSG College of Technology, Coimbatore in the evaluation of the draft report and his contribution to its improvement through comments and suggestions was significant. We thank him for his positive contribution.

The project was undertaken through Society for Innovation & Development (SID), Indian Institute of Science. Prof. H.P. Khincha, former Chairman, Prof. S. Mohan, Chairman and other staff members of SID have been very cooperative and cordial at every stage of our project work. We are grateful to them.

The project got full cooperation and support from the Ministry of Environment & Forests, Government of India, Central Pollution Control Board, New Delhi, National Productivity Council, New Delhi, Karnataka State Pollution Control Board, Bangalore and Directorate of Industries and Commerce, Government of Karnataka, Bangalore. This has facilitated smooth progress and completion of the research project.

We also got constant support from the officials of the respective District Industries Centres and Taluk Industries Centres in all the four clusters. In addition, in Ramanagaram, officials of Central Silk Technological Research Institute provided us valuable information about the technologies, number and location of silk reeling units. All these helped our work to a great extent.

Prof. Sudhakara Reddy, IGIDR, helped us whenever we approached him for the discussion of issues related to the project. This has contributed to the strengthening of our project work.

The role of Dr. Raghu Ram Tata, Project Coordinator, EERC, IGIDR, Mumbai has been a special one. He has been courteous and helpful to us at every stage of our work.

Our project consultant, Mr. Muralidhar Reddy has played an important role in the completion of this project by providing us valuable inputs at the stage of analysis and also in improving our understanding of pollution parameters. We are, indeed, thankful to him.

All through the research project, we got impeccable cooperation from the Chairman and staff members of the Department of Management Studies, Indian Institute of Science. This has greatly helped us in carrying out the project.

The process of literature searching & survey, data collection and tabulation is a tedious one. Project Assistants namely Malavika, Raviprasad, Ramakrishna, Santhosh, Abhijit and Mahadev have done the job meticulously and sincerely. But for their hard efforts, data collection from 189 small scale industrial units located in four different clusters in four different regions of the state would have been extremely difficult. In fact they have done a commendable job.

Dr Vasumathi, Central Silk Technological Research Institute, Bangalore and N V Raghavendra, Research Scholar of our department provided valuable inputs on silk reeling of Ramanagaram and foundry cluster of Belgaum, respectively. This has benefited the project immensely.

Finally, the small scale industry entrepreneurs of the four small industry clusters in Malur, Ramanagaram, Davangere and Belgaum have provided us excellent support by revealing us the precious data by sparing their valuable time. But for their memorable role, this project could not have been completed.

We express our deep sense of gratitude to all those who helped us directly and indirectly in carrying out this work. However we alone are responsible for the deficiencies, if any, in the project report.

M H Bala Subrahmanya P Balachandra

EXECUTIVE SUMMARY

Backdrop

Small Scale Industry (SSI) occupies a prominent place in Indian economy due to its sustained contribution to industrial production, exports and employment, among others, since independence. However, majority of these units are also known for managing with meagre financial, technical and infrastructure resources.

Till recently, there was hardly any reference made either in government reports and documents or in research literature, to the environmental implications and impact of small scale industries with reference to India. It could be due to the implicit assumption that small enterprises are too small to cause any environmental damage. The environmental impact of an individual SSI unit may be too miniscule to attract attention but the combined effect of operation of a large number of SSI units on the environment can be of a high magnitude, especially when they are clustered in certain locations closer to residential or commercial centres.

India has developed its own environmental policy regime over the period of last three decades, with an exclusive ministry of environment and forests in the Government of India. The policy regime largely comprises legislations and therefore, belongs to the Command and Control (CAC) category. Economic instruments comprising tax incentives and subsidies are the other dimension of the policy regime. Though the environmental policy regime is applicable to all economic activities in the country, the SSIs have to obtain No Objection Certificate (NOC) and consent from the Central Pollution Control Board, Ministry of Environment and Forests, Government of India only in 17 product categories, which are considered highly polluting.

However, in Karnataka, every SSI unit is suppose to obtain consent from Karnataka State Pollution Control Board and renew it every year and tiny SSI units once in every ten years. But, the State Pollution Control Board had a list of only 6000 units as against the SSI population of 0.25 million in Karnataka at the end of March 2001. Therefore, the state machinery does not have the full knowledge of the environmental status of SSIs, comprising kinds and levels of pollution generation, causal factors, etc. in different sectors and clusters of the state.

It is with this backdrop that the current study is undertaken with reference to four small industry clusters in the state. Spontaneous emergence of SSI clusters is an important feature of small industry growth in India. There are about 2000 traditional rural clusters of small enterprises apart from 350 SME clusters in India. Thus, traditional clusters account for a considerable share of SSI population in India.

Therefore, we have chosen four natural and traditional clusters of small firms in Karnataka. These traditional clusters are chosen, in addition, for the following reasons:

- Firms in traditional clusters generally use obsolete technology, which necessarily generates pollution from the processes by consuming more inputs.
- Entrepreneurs are likely to be less educated or illiterate and likely to have less environmental awareness.
- Entrepreneurs' level of income will be low and therefore, cannot think of substituting 'better technology', even if its availability is known.
- Lack of understanding on the technical specification and implications of pollution standards.
- Low level of managerial and technical ability and skills among owners and managers.

Clusters, in general, offer scope for collective action for its own improvement through either technology development and joint R&D or joint marketing strategies, training programmes, etc. However, in the Indian context, limited empirical evidence based on a few clusters reveal that small firms in clusters have not initiated any joint action on their own, to reduce environmental pollution. It is only in response to external threat in the form of legal action towards closure or external assistance for improvements or a combination of both that small firms in clusters have joined together to incur costs for pollution abatement. However, the problem of environmental pollution in SSI clusters need not be and in fact, not uniform in terms of its profile, magnitude and causal factors and therefore, the remedial measures as well.

The major objective of this study is to probe and ascertain the nature and magnitude of environmental pollution in small industry clusters of Karnataka. This is to be done by identifying the pollutants and developing a pollution profile for each cluster; probe the factors that cause the current level of pollution; identify the appropriate pollution abatement measures; determine its costs and benefits and develop a policy framework to promote environment friendly small industry growth in the state.

To study these objectives, four of the environmentally polluting small industry clusters in the state are chosen. They are brick & tiles cluster in Malur of Kolar district, silk reeling cluster in Ramanagaram of Bangalore rural district, puffed rice units cluster in Davanagere of Davanagere district and foundry cluster in Belgaum of Belgaum district.

As the nature of each of these four clusters in terms of technology, material and energy inputs, skill composition of labour force is different, separate questionnaires are developed for data collection. However, the questionnaires, in general, had four sections to cover: (1) Basic information on the industry, (2) Materials consumed/produced, (3) Technology and (4) Human resources.

There was no scope for scientific random sampling due to the absence of systematic and comprehensive data on all the functioning units in the cluster. Therefore, the attempt was to gather data from at least, 40 units from each of the four clusters, quite randomly. However, the data was gathered from 45 units in the bricks cluster, 55 units in the silk reeling cluster, 46 units in the puffed rice cluster and 43 units in the foundry cluster.

The pollutants are identified and pollution profile is developed for each cluster by studying the basic characteristics of the units in each cluster in terms of technology in use, nature of manufacturing, kinds and quantum of material as well as energy inputs, kinds and quantum of wastes, bye-products and final products.

The pollution levels are determined by the consumption of material and energy inputs used for the production process. Thus, quantum of pollution is estimated based on the data gathered from the sample units on these variables and by making use of standard pollution coefficients (emission factors) for various energy inputs from the literature. In addition, the various kinds of wastes generated during the production process are estimated.

The factors - human resource, technological, process, external and structural - influencing the level of environmental pollution are logically identified in consultation with literature and experts. By using multifactor analysis of variance (ANOVA), the significance levels of these factors in explaining the variations in the energy use and thereby pollution levels are determined.

It also facilitated to identify and develop appropriate pollution abatement measures within the constraints of clustered units and their respective costs and benefits. These analyses along with literature survey and discussion with experts enabled us to propose an alternative policy framework to reduce the environmental impacts of small industry operations.

Environmental Pollution in the Small Industry Clusters of Karnataka - Results of Analyses

Bricks & Tiles

Bricks are traditionally manufactured using different types of kilns and prominent among them are (1) Rural Clamps or Brick Clamps, which is the oldest method of firing bricks, (2) Intermittent Draught Kiln (IDK), which is a batch type kiln, (3) Bull's Trench Kiln (BTK), a continues type kiln and (4) Vertical Shaft Brick Kiln (VSBK), which represents the latest technology and the most energy efficient. In Malur, majority of the sample units used IDK technology and only a minority used conventional rural clamps technology.

The emergence of a large number of brick making units, irrespective of the kind of kilns used, is attributed to the abundant availability of Chinese clay in the region, which has got powerful plasticity and can withstand any form of weather conditions. This plasticity is the main requirement for manufacturing tiles and bricks.

All the sample units used biomass as the source of energy – while some used exclusively firewood, others used branches and leaves of eucalyptus, in addition and one unit made use of coal, apart from firewood. Brick making units engaged both skilled and unskilled labour, the former is used mainly for brick moulding and brick firing whereas the latter for transporting materials, moulded and burnt bricks.

Most of these units had poor ventilation design and building condition, house keeping and storage environment of bricks. Ash and waste bricks/tiles are dumped in the unit premises. While the former is taken away by agarbathi manufacturers, the latter by nearby villagers – once in six months.

On the whole, air pollution due to the consumption of eucalyptus leaves, firewood and coal, is the major environmental concern, identified in the brick units' cluster in Malur. On an average, one thousand bricks consumed 7,702 MJ energy and generated CO (8 kgs), TSP (4 kgs), NOx (0.78 kgs), SO_2 (0.55 kgs), CH_4 (0.23 kgs) and N_2O (0.03 kgs), apart from waste bricks (85 nos) and ash (19 kgs). The CO_2 emission is not considered because all firewood and eucalyptus leaves and twigs have been obtained in a sustainable manner.

The analysis (through ANOVA) revealed that labour skill levels and owner's qualification and technology levels are the most important factors, which determined the level of energy consumption and thereby pollution levels. Therefore, the pollution abatement measures through efficient use of energy and materials have to focus on the human resource factor, particularly labour skill levels, along with the technology factor.

The analysis showed that even the total cost per 1000 bricks reduce, as there is an increase in labour skill levels. It is observed that if a brick unit changes the ratio of skilled to unskilled labour from 1:1.6 to 1:0.47, it will realise cost savings to the extent of more than Rs. 7/- per 1000 bricks. Of course, such a shift leads to a higher labour cost but the savings due to the reduced energy costs are nearly five times the additional labour cost that a unit has to incur.

Another abatement measure that could be considered to reduce pollution through the reduction of energy consumption is through technology shifts. The technology shifts are primarily analysed for two kinds of shifts – IDK (biomass) to VSBK (coal) and IDK (coal) to VSBK (coal). It is found that the additional investments required for the shift are not very high and the savings in fuel consumption are quite significant in both kinds of shifts.

In the case of shift of IDK (biomass) to VSBK (coal) there will be substantial reduction in pollution levels due to the emissions of CO, CH_4 and TSP but at the same time there will be significant increase in the emission levels of SO_2, NOx and

CO_2. The combination of pollutants that could be reduced and those that could increase due to the shift includes both local and global pollutants. The shift from IDK (biomass) to VSBK (coal) would cause a substantial increase in CO_2 emission. Further, in the context of Malur based brick units, such a shift may not be advisable because their fuel requirements are met locally in a sustainable manner. Therefore, economically as well as environmentally, it may not be justifiable to replace the biomass based IDK technology by VSBK technology at least in Malur.

It would be appropriate that Malur based brick units should be encouraged to focus on skill upgradation of labour as that will lead to substantial reduction of energy consumption and therefore, pollution.

The pertinent question is who will bring out skill upgradation of labour and who has to bear the cost? how? Because skill improvements of labour will lead to more benefits than the costs involved, through improvements of material and energy use, the owners of the units themselves should bear the cost as it is they who realise the benefits subsequently. To achieve this, policy makers through Karnataka State Pollution Control Board can play an instrumental role first by means of communicative instruments through seminars and distribution of pamphlets in the cluster informing the entrepreneurs about the benefits that would accrue to them and to the society by going for skill upgradation of labour. If that fails, they should adopt economic instruments: 'local pollution tax' should be imposed based on the relative composition of unskilled and skilled labour. It should be progressive and should increase as the proportion of unskilled labour increases. Of course, imposition of 'pollution tax' is easier said than done because it would be virtually impossible for the authorities to get reliable figures on the composition of skilled and unskilled labour from the entrepreneurs. The other alternative could be conducting training (say once in a year) for upgrading the skills of labour in the cluster itself by the Taluk Industries Centre at a very nominal fee. The local brick makers association should be involved in conducting such training programmes. This would facilitate pollution abatement to a great extent in the cluster.

Silk Reeling

Silk reeling is the intermediate stage in the process of silk production (that links cocoons with silk weaving). Silk reeling can be done through three alternative techniques: Traditional – manual – charakha method, Semi – mechanized technique of using cottage basins, and advanced Multiend reeling machine.

Ramanagaram in Bangalore rural district is one of the well-known silk reeling clusters of Karnataka, which comprises units belonging to all the three technologies. Data is gathered from a total of 22 each charakha and cottage units and 11 multiend units.

Silk reeling units, particularly charakha and cottage units generated three kinds of pollution: water, land and air pollution. Cocoon cooking results in water pollution, dumping of cocoon & pupae waste and raw silk waste in the unit premises cause land pollution and the process of cooking cocoons with paddy husk, coal, saw dust and firewood not only causes gas emissions but generates ash and stinking smell all around.

On an average, the 55 silk reeling units in the process of producing one tonne of raw silk output, generated nearly six tonnes of pupae & cocoon waste, 116 KL of waste water, about two tonnes of ash, 3,382 kgs of CO_2, 331 kgs of CO, 173 kgs of TSP, 38 kgs of N_2O while consuming about 348 GJ energy.

Based on ANOVA results it was found that technology level and human resource factor comprising only labour skill level are the important factors explaining variations in the levels of energy consumption. However, there were no discernible patterns emerged out of this analysis to indicate the direction of the relationship between the above independent factors and energy consumption levels. Neither upgrading labour skills nor adoption of improved technology indicated the possibility of efficient energy utilisation and pollution reduction.

Therefore, the existing system is compared to an energy efficient technology, that is, the conventional wood based system with a gasifier based system, the latter as an alternative to the former. It is found that such a shift would result in enormous energy cost savings and substantial reduction in pollution levels. However, such as shift can only be realised if it is wholly financed by the government. Neither communicative and economic instruments nor CAC instruments could be successful for the simple reason that the silk reelers belong to the economically weaker sections. The only alternative is to encourage them to form a silk reelers' cooperative and adopt a gasifier-based system.

Puffed Rice Making

Puffed rice making is a labour skill based activity in Davangere and therefore, does not involve any machinery. The process of puffed rice making involves two phases: the first phase consists of conversion of paddy into rice and the second phase comprises conversion of rice, after mixing with salt water, into puffed rice.

The boiling of paddy to convert paddy into rice and the heating of sand to convert the salt water mixed rice into puffed rice require energy inputs. Puffed rice makers in the Mandakki Layout of Davangere used rice husk (which is the by-product of the conversion of paddy into rice) and scrap tyres as the energy inputs – both lead to air pollution, apart from the generation of ash, which adds to the unhygienic environment of the locality.

The use of energy inputs, particularly scrap tyres lead to significant air pollution, through the emission of gases like CO_2, NOx, SO_2 and TSP (apart from CO, CH_4 and N_2O, which are more significantly contributed by rice husk).

This is substantiated by the fact that the entire atmosphere of Mandakki Layout in Davangere is thickened with black smoke emanating from the heavily concentrated puffed rice units. The estimated pollution for the 600 units in the area would include about 3838 tonnes of CO_2 and about 144 tonnes of CO emissions in an year, apart from TSP (93 tonnes), NOx (39 tonnes), SO_2 (29 tonnes), CH_4 (4 tonnes) and N_2O (0.56 tonnes).

Within the constraints, the only way of pollution abatement is to encourage puffed rice makers to use only rice husk and not scrap tyres, which generates huge amounts of CO_2, NOx, SO_2 and TSP, apart from many carcinogenic material.

How to mitigate pollution in the Mandakki Layout is a major challenge, for which we could not come out with any easy solution. The units are tiny sized and mechanized technology is neither readily available nor a feasible alternative, given the impact it would have on employment and the investment requirements. Within the constraints, therefore, we felt, the only way of pollution abatement is to encourage puffed rice makers to use only rice husk and not scrap tyres, which generates huge amounts of CO_2, NOx, SO_2 and TSP, apart from many carcinogenic material. In this case, to mitigate pollution, particularly to avoid the use of scrap tyres, it would be appropriate to ban their use for puffed rice making through legislation.

Foundry Cluster

Foundry in Belgaum is the only relatively modern industry among the four clusters covered. A foundry is a casting manufacturing system. Casting is the process of forming objects by pouring liquid metal into prepared mould and allowing the melt to solidify. The foundry operations generate different kinds of air pollution, depending upon the kinds of furnace in use and the kinds of energy inputs that they use. The three kinds of furnaces that a foundry unit could use are cupola, blast furnace, electric arc furnace or electric induction furnace.

A total of 43 foundry units are covered in Belgaum. Majority of the foundries used cupola furnaces whereas the rest used electric arc/induction furnace, cold/divided blast furnace and crucible/OHF. The foundries are machinery oriented units much more than that of bricks, silk reeling and puffed rice, and the proportion of unskilled labour accounted for just about one-third of the total labour force.

While the raw materials used by all the 43 foundries are similar, the energy inputs and final products differed. Electric arc and induction furnaces used only electricity, cold/divided blast furnaces used only coke and firewood, cupola furnaces used in addition, coal whereas crucible/OHF furnaces used, furnace oil and diesel, apart from coke and firewood. But for six units, which produced only non-ferrous castings, all produce grey iron castings.

The pollution profile of foundry units comprised slag, ash and gases. The 46 units, on an average, generated about 76 kgs of slag, 25 kgs of ash, CO_2 (774 kgs), SO_2 (5 kgs), CO (2 kgs), NOx (1.6 kgs), among others, while consuming about 8 GJ of energy per tonne of castings.

A comparative analysis for three kinds of foundries: crucible/open hearth furnace, cupola and cold/divided blast furnaces, revealed that the cold/divided blat furnace units are the least expensive, least energy intensive and least polluting among all. It is found that the units, which are energy inefficient, are inefficient in terms of the whole production process.

It is found out through ANOVA, that human resource factors comprising labour skill, owner's qualification and value of labour are the most important factors determining the variations in the energy consumption level of a foundry unit. Technology level is the second most important factor. Therefore, for pollution abatement, the focus should be on human resource factors along with the technology factor.

A shift of units from low to high human resource quality will result in fuel savings, which will be more than the additional human resource cost that has to be incurred for improving workforce quality and a drastic reduction in pollution. Therefore, to reduce energy consumption levels and thereby pollution levels, the first and foremost activity at the foundry cluster could be to upgrade the Human Resource Quality (HRQ) set by providing appropriate training to the existing workers or hire required skill set people and arrive at a proper compensation package.

To analyse the technology shifts, two alternatives are considered – from conventional hot blast cupola to lined hot blast cupola and from cold blast furnace to divided blast furnace. In the case of both the shifts, the value of saved energy is significantly higher than the cost of saved energy indicating the economic feasibility of the shifts. Even the overall pollution reductions in both the shifts are positive and significant.

To encourage the technology shifts to reduce pollution, economic instruments should be used. As the level of education of the entrepreneurs is fairly high, mere communicative instruments will not be effective. Those foundries, which use conventional technologies and cause higher degree of pollution should be imposed ‘local pollution tax’ and those who are willing to adopt ‘more efficient technologies’ should be encouraged to do so by means of subsidised credit by the District Industries Centre.

Recommendations

The present analysis probed the scope and its feasibility for pollution reduction through economizing the consumption of energy inputs, which has a direct bearing on the cost of production and therefore, competitiveness of a small firm. As brought out in the context of bricks and foundry clusters, a reduction in the consumption of energy inputs and therefore, a reduction in cost of production as well as pollution can be achieved through not only technology shifts but more importantly an improvement in the quality of human resources comprising labour skills and entrepreneurial qualifications.

Government of India has already introduced schemes for promoting pollution prevention technologies in some of the SSIs including bricks and foundries. But they are more confined to pollution prevention than energy efficiency improvement.

The programmes launched by the Government do not contain any measure for pollution abatement in silk reeling and puffed rice units' clusters. In the former, it is found that the most inferior technology is not only less expensive but also more environment friendly. A shift towards better technology is not desirable, from the points of view of both pollution abatement and efficiency improvement.

How significant is environmental pollution generated by the four small industry clusters of Karnataka relatively? The pollution of the four SSI clusters is compared with a typical Coal Thermal Power Plant (of the capacity of 210 MW). The comparative figures for the four full clusters (not just the sample units surveyed) and the coal thermal plant reveal that but for CO and CH_4, the total pollution of the four SSI clusters are not that significant relative to that of the coal thermal plant of 210 MW.

This implies that the contribution of SSIs to global pollution may not be considerable though their operations do have significant implications for the local environment. Given this, it would be appropriate to focus on economizing the use of energy inputs through variations in labour skill composition and shifts to feasible alternative technologies, wherever possible. This would enable small firms to achieve a significant reduction in the quantum of energy input consumption as well as pollution and a consequent increase in their efficiency and competitiveness.

What is important is to propose an alternative policy framework to promote environment friendly small scale industrialisation. First and foremost, it is imperative to strengthen the infrastructure of State Pollution Control Board in terms of adequate technical personnel. This will enable them to conduct periodic surveys of pollution intensive industries, large as well as small, and to ensure that they adhere to the environmental laws and regulations of the state.

New SSI units must be allowed to come up, irrespective of the size of investment, only after obtaining consent from the State Pollution Control Board through their regional offices or even through the respective District Industries Centres/Taluk

Industries Centres. In pollution intensive industries, new entrepreneurs must be encouraged to go for environmentally sound technologies, wherever feasible.

As the nature of technology, required labour skills and environmental problems differ between industries/clusters, the State Pollution Control Board may conduct industry-wise/cluster-wise studies to suggest ways and means for pollution abatement and efficiency improvement.

In fact, two strategies are currently under promotion by the Central Pollution Control Board: (1) Clean production, and (2) Waste minimization. Clean production (CP) is the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. Clean production is relevant particularly to SSIs where the resource utilisation efficiency is very poor. The principal cleaner production technologies are: (1) Source reduction, (2) Recycling and reuse, and (3) Product reformulation or modification.

Currently, the Ministry of Environment and Forests, Government of India has been promoting a scheme for adoption of clean technologies by SSIs through the provision of interest subsidy, apart from knowledge diffusion and database development. This is a welcome step and needs to be intensively pursued at the regional level.

But, the present study has revealed that the technology up-gradation alone will not result in efficient use of material and energy. The quality of human resource available with the SSI is also equality significant in determining the level of energy use. A perfect match between the technology and quality human resource is essential to optimize the resource use and thereby reduce the environmental impacts. Any technology up-gradation in a unit should be preceded by having quality workforce in place.

Waste minimization is a new and creative way of thinking about products and processes that make them. It is achieved by the continuous application of strategies to minimize the generation of wastes and emissions. Apart form reducing pollution load, waste minimization brings in many other benefits, which include resource conservation, improvement in work environment, etc.

The Ministry of Environment and Forests has already established Waste Minimization Circles (WMCs) for SSIs in 40 different industrial sectors all over the country. There is an urgent need to involve state governments and small industry associations at the regional level in the propagation among SSIs to go for waste minimization.

The promotion of clean technologies, skill up-gradation and awareness training to the workforce and waste minimization techniques along with strengthening the State Pollution Control Board with adequate staff would go a long way in achieving the objective of pollution abatement and environment friendly small industry development.

CHAPTER 1: INTRODUCTION

1.1 Backdrop

The Small Scale Industry (SSI) plays an important role in India's socio-economic development. It contributes significantly to the overall growth of Indian economy in terms of Gross Domestic Product (GDP), employment generation and exports (Government of India, 2002). Today this sector accounts for about 95% of the industrial units, 40% of the value addition in the manufacturing sector, nearly 80% of the manufacturing employment and about 35% of the exports (Planning Commission, 2001). Therefore the performance of SSI sector has a direct impact on the growth of the overall Indian economy.

The crucial role that SSI sector could play in Indian economy was appropriately recognised by the policy makers soon after independence. Since independence, India has evolved innovative policies and programmes to protect and promote SSI, apart from institutions at the national, regional and sub-regional levels (Bala Subrahmanya, 1997). In the 1990s, the emphasis of India's small industry policy shifted, at least, implicitly from protection towards competitiveness (Bala Subrahmanya, 1998). As a result, three major concerns of the sector, namely, technology, finance and marketing gained greater attention.

In the late 90s, the Expert Committee (Ministry of Industry, 1997) made reference to the spontaneous growth of clusters of small-scale enterprises across the country. The Committee recommended among others, that the State Governments must identify the existing SSI clusters and further thrust of SSI policies must be to bolster growth in existing clusters. The recent study group on development of small-scale enterprises (Planning Commission, 2001) again viewed the development of the sector in terms of addressing its concerns related to finance, technology and marketing. In the whole process, the environmental implications and impact of small industry operations has been either ignored or sidelined.

Apparently, there is an assumption that because they are small in size, small-scale industries do not or cannot adversely affect the environment through their operations. The environmental effect of an individual small enterprise may not be significant but their aggregate impact on the environment can be considerable, particularly when they operate in clusters, in certain locations. A significant number of units existing together in a cluster consuming substantial quantity of raw material and energy (coal, firewood, etc.) will be releasing various kinds of pollutants to environment. In addition, the production efficiencies (energy and material use efficiencies) are likely to be low in small scale units because of resource constraints. This further enhances the possibility of adverse impacts on the environment. Further, if these environmental impacts are due to either human errors or infrastructural inadequacies or obsolete technologies and if appropriate abatement measures (corrective actions) are taken, it will facilitate better environmental management and may even improve the economic performance of SSI units and thereby enhance their competitiveness.

The large and growing number of small enterprises in the form of clusters in developing countries like India underlines the growing need for addressing the problems of environmental pollution, its causal factors, particularly in terms of human resource, structural and technological issues, the efficiency of SSI units in the utilisation of energy and other raw materials, and health and safety hazards that they pose.

It is with this backdrop that this study has been undertaken with reference to four clusters in Karnataka - to probe the environmental issues arising out of their operations and suggest appropriate remedial measure to address those issues.

1.2 Small Scale Industry, Clusters and Environmental Pollution: Concepts and Definitions

1.2.1 Small Scale Industry

Small-scale industry evokes different meanings for different agencies and the financial institutions (Planning Commission, 2001). In broader terms, currently, an SSI unit is defined in terms of investment ceilings on the original value of installed plant and machinery. As per the present definition, an industrial undertaking in which investment in plant and machinery, whether held on ownership terms or on lease/hire purchase basis, does not exceed Rs.10 million, is regarded as a small-scale industrial undertaking (Planning commission, 2001).

The conceptual and legal framework for small-scale undertakings is derived from the Industries (Development and Regulation) Act 1951. The IDR Act, 1951 specifically refers to only two categories of small-scale sector.

1. Small Scale Industrial Undertaking
2. Ancillary Industrial Undertaking

As of now, the investment limit for an ancillary industrial undertaking is the same as that of a small-scale industrial undertaking, i.e., Rs.10 million. Over the years, however, some sub-sectors have been identified within the overall small-scale sector (Planning commission, 2001).

These are:

- Tiny enterprises
- Women's enterprises
- Export Oriented Units (EOUs)
- Small Scale Service and Business Enterprises (SSSBEs)

While the first sub-sector refers to size, the remaining sub-sectors refer to either the nature of ownership or the nature of activity. The respective investment limit, currently, are (i) Rs. 2.5 million, (ii) Rs. 10 million with women individually or jointly, having majority share capital, (iii) Rs. 7.5 million and (iv) Rs. 1 million (Planning commission, 2001).

1.2.2 Small Industry Clusters

A cluster may be defined as a local agglomeration of enterprises (mainly SMEs, but often also including some large enterprises), which are producing and selling a range of related and complementary products and services (UNIDO, 2001). An example can be a localized leather industry which includes leather tanning units, leather finishing units, leather good producers, leather garments manufactures, designers, sub-contractors, merchant buyers and exporters, etc. The precise definition of a cluster based on quantitative parameters may vary from country to country.

Clusters can be primarily, of three kinds (UNIDO, 2001). (1) Horizontal Clusters: This type of cluster is characterized by units, which process the raw material to produce and subsequently market the finished products themselves. Majority of the clusters in India is of horizontal type (UNIDO, 2001). (2) Large Unit Based Clusters: A cluster, which is established around a large unit or a few large units, is called a large unit based cluster. The relationship that exists between the small and the large units could be based on supply of some of the critical raw materials from large enterprises or on their working as subcontractors to the large firms, which means they are either backward linked or forward linked. (3) Vertically Integrated Clusters: In vertical clusters, the operations required in producing the finished product are divided and are carried out separately by different units, most of which are essentially SMEs, in order to distinguish from the large unit based clusters.

1.2.3 Environment and Pollution

Environment comprises the biosphere, the thin skin on the earth's surface on which life exists, the atmosphere, the geosphere (that part of the earth lying below the biosphere) and all flora and fauna (Hanley, Shogren and White, 1997). The definition of the environment thus includes life forms, energy and material resources, the stratosphere (high atmosphere) and troposphere (low atmosphere) (Hanley, Shogren and White, 1997). These constituent parts of the environment interact with each other, which may have undesirable effects on the environment and in turn, on the human beings themselves. To be specific, environmental pollution is defined as the deliberate or accidental contamination of the environment by waste generated by human activities. Although environmental pollution is defined differently in different contexts such as within various legislative acts, it can be defined generally as the presence of matter or energy, whose nature, location or quantity has undesired effects on the environment (Callan and Thomas, 2000).

Pollution changes the physical, chemical and biological characteristics of air, land and water. Pollution harms human life, the life of other species, and also degrades living conditions and cultural assets, while wasting or deteriorating raw material resources (NRC, 1966).

1.2.4 Environmental Pollution: Types of Pollutants

Pollutants are of two kinds: (i) Natural pollutants, i.e., they arise from the nature, and (ii) Anthropogenic pollutants, which result from human activity.

Natural pollutants rise from non artificial processes in nature, such as gases associated with the decay of animals and plants, particles from volcanic eruptions, salt spray from the oceans, and pollen.

Anthropogenic pollutants are human induced and include all residuals associated with consumption and production. Examples include gases and particles from combustion and chemical wastes from certain manufacturing processes.

Of these two, Anthropogenic pollutants are of primary concern particularly those for which nature has little or no assimilative capacity (Callan and Thomas, 2000).

1.2.5 Environmental Pollution: Sources and Scope

Polluting sources are many and varied, ranging from automobiles to waste disposal sites. Because polluting sources are so diverse, they are generally grouped by: (1) their mobility or (2) how readily they can be identified.

Sources grouped by mobility: These are categorized as stationary sources and mobile sources. The stationary source is a fixed site producer of pollution, such as a coal-based foundry or a sewage treatment facility. A mobile source refers to any non stationary-polluting source, such as an automobile or an airplane. This distinction is commonly used to characterize air pollution sources, since each requires a different form of control measure (Callan and Thomas, 2000).

Sources grouped by identifiability: In some contexts identifiability of polluting source is an important factor, in which case a distinction is made between point sources and non point sources. A point source refers to any single identifiable source from which pollutants are released such as a factory smoke stack or a pipe. A non point source is one that cannot be identified accurately and degrades the environment in a diffused, indirect way over a relatively broad area (Callan and Thomas, 2000).

Although environmental pollution is a universal concern, some types of pollution have detrimental effects that are limited to a single community whereas others pose a risk over a large geographical region. That is, the extent of damage caused by pollution can vary considerably from local to regional and even global level.

1.3 Role of the State in Environmental Protection

The state has a major role to play in environmental protection through containing or mitigating environmental pollution caused by different economic agents such as industries, construction, mining etc. But there is considerable disagreement among the experts on the role of the state and policy prescriptions for environmental protection. This is mainly because valuation of environmental resources, particularly, their non-use values, is subject to a wide margin of error (Sankar, 2001).

However, there is some agreement that there are three broad categories of instruments available to the state for environmental protection (Kuik, et al, 1997)

1. Instruments aimed at voluntary adaptations of individual and group behavior in a more environment friendly direction. This category, referred as "communicative Instruments", includes, among others:

a) Provision of knowledge and information in all possible forms on the environmental effects of the present behaviour and on 'Cleaner' alternatives.

b) Moral suasion, i.e., campaigns to persuade people and institutions to change their behaviour.

c) Institutionalization of environmental management within firms and other organizations.

d) Voluntary commitments by trade and industry or agreements between them and the government for better environmental management.

e) Instruments, which affect the market conditions under which people and firms make their decisions. This category is commonly referred to as 'Economic Instruments'. This would comprise among others, the following:

I. Charges and taxes, which make polluting behaviour more expensive.

II. Subsidies and other types of financial support, which make environment friendly behaviour relatively economical.

III. Deposit refund systems, in which a deposit for a potential polluting product is being paid by the purchaser, which can claim a refund after returning the product or showing that the pollution did not take place.

IV. Liability legislation, requiring the polluter to compensate the environmental damage caused, and thus providing a financial incentive for pollution prevention.

Instruments, which influence the range of alternatives by means of prohibitions, restrictions, or obligations ('direct regulation'). These are called Command and Control (CAC) instruments. This can be done by introducing product, process or emission standards, by prescribing how certain activities have to be performed, demanding certain professional skills, specifying the precautionary measures to be taken, etc. Out right bans on certain activities, products or substances also belong to this category.

Thus, there are a large variety of instruments available to the policy makers of the state for the protection of the environment. However in practice, the scope of choosing between alternative instruments is limited by various factors. While the 'communicative instruments' may be the most feasible to pursue and may be the most acceptable, it may not be effective. This could be due to lack of will among the polluters as implementation of pollution abatement measures involves costs.

Even the 'economic instruments', though may be more attractive, particularly, subsidies, should fit in with the legal and institutional framework and it should be technically and administratively feasible. The information needed to apply the instrument has to be available.

Further, there should be enough support or atleast, not too much opposition against the instrument in society, to prevent sabotage and to keep enforcement costs reasonably low. This is particularly true with reference to Command And Control (CAC) instruments. Therefore, the actual mix of policy instruments chosen for environmental protection may vary from country to country depending on its goals, stage of development, institutional capabilities and political preferences (Sankar, 2001).

1.4 Trends in Environmental Policy: Developed and Developing Economies' Perspectives

Till recently, environmental policy was largely the developed world phenomenon and it generally relied almost entirely on CAC instruments. This policy proved successful to some extent, particularly in controlling air and water pollution (Kuik, et.al, 1997). However this also brought out the limitations of the policies interms of achieving the environmental objectives within a reasonable time schedule due to lengthy and detailed legislation and licensing procedures, emergence of new environmental problems, replacement of a limited number of points sources (large-scale industry, power plants, etc) by a vast amount of non-point and mobile sources (such as consumers and small scale manufacturing etc).

Therefore, these countries recognized that the target groups of environmental policy could be involved more actively in its implementation. This approach contained more responsibility and initiative from the polluters themselves, and stimulated imaginative solutions. Charges, tradable emission or production rights liability, voluntary agreements and instruments of communication formed the features of this approach larger than CAC instruments (Kuik, et.al, 1997).

More recently developed market economies have gone for an integrative approach to deal with environmental pollution problems. Integration to deal with different parts of the environment, integration of environmental policy with other government policies and integration across national borders. The degree to which these types of integration have been implemented differs from country to country.

In the developing world, environmental policy is of recent origin. The environmental problems of developing countries are not entirely the same as that of the developed world. The environment in developing countries is being threatened by deforestation, loss of fertile land, depletion and degradation of water resources and loss of bio diversity, apart from industrial pollution caused by rapid industrialization through the growth of large as well as small scale manufacturing units, emissions from households, traffic, power plants and waste dumps. But the government response to the emerging environmental challenges in these countries is rather weak due to insufficient means, as compared to developed countries and the administrative machinery is not strong enough to implement the policy effectively (Kuik, et. al, 1997).

However many developing countries have developed institutional and legislative framework for environmental policy, following the lines of developed countries. This is especially true for industrial pollution (Kuik, et.al, 1997).

1.5 Environmental Policy in India: An Overview

The origin of environmental policy in India can be traced back to the UN conference on Human Environment held at Stockholm in 1972, which exerted major influence on environmental legislation in India and other countries. The beginning was made with the enactment of Wild life (Protection), Act, 1972 followed by Water (Prevention and Control of Pollution), Act, 1974, the Air (Prevention and Control of pollution), Act, 1981, Forest (Conservation) Act, 1981, and the Environment (Protection) Act, 1986. The Water Act paved the way for the establishment of central and state pollution control boards to implement the provision of this Act and later the Environment (Protection) Act (Kuik, et. al, 1997).

India's environmental policy regime based on the legislations belongs to the CAC category. Economic instruments do not form a prominent part of the regime for environmental protection. The apex policy making body in the field of environment is the Ministry of Environment and Forests, Government of India. It acts through the central and state pollution control boards for implementing anti-pollution laws (Kuik, et.al, 1997).

Pollution is generated by point and non-point sources. For point sources, source specific effluent and emission standards have been prescribed. For non-point sources, as monitoring of pollution generation is difficult, indirect measures of pollution prevention and control are being adopted (Sankar, 2001).

The following regulatory instruments are used in pollution control or prevention mechanism: a) No Objection Certificate (NOC), b) Consent and c) Standards (Kuik, et.al, 1997).

NOC is required in the case of new industries, and is essentially a certificate of site clearance to be obtained by the entrepreneur from the concerned State Pollution

Control Board for the sponsored project. This certificate is obtained once in the life span of an industrial establishment.

Consent is required to be taken by an entrepreneur after the completion of the industrial project but before commissioning the industrial process. This is given provided the pollution level is negligible or within prescribed standards or the required pollution control equipment to abate pollution is installed. The consent has to be renewed every year.

Standards refer to specific parameters previously qualified with respect to measures for disposal, discharge and emission of solid, liquid and gaseous waste into the environment. These standards form the basis for the enforcement of any legislation for the abatement of pollution. The Government of India has prescribed standards, which are mandatory, with effect from January 1, 1994. The standard types are:

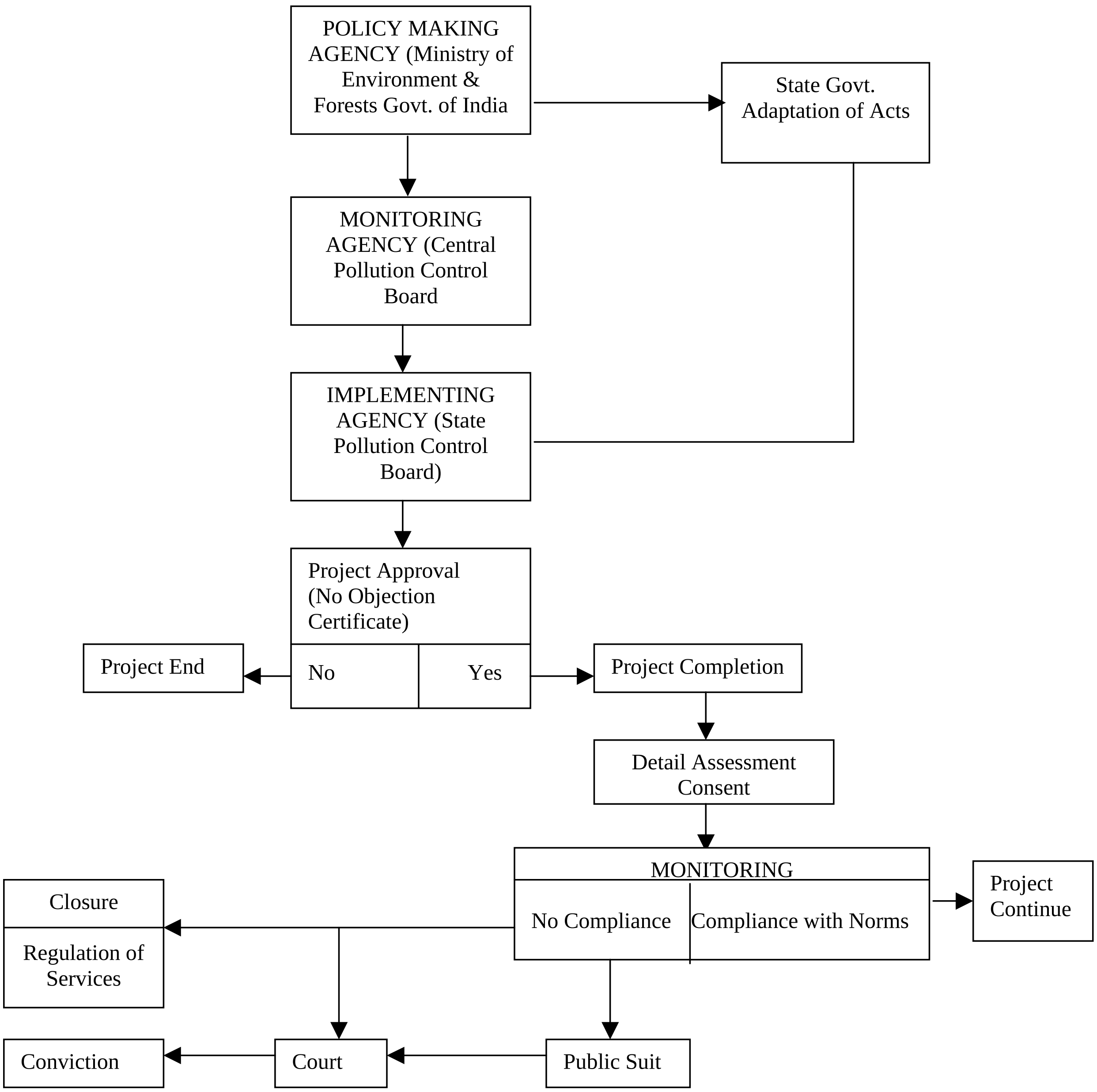
1. General standards for Discharge of environmental pollutants: effluents into
    a. Inland surface waters,
    b. Public sewers,
    c. Land for irrigation
    d. Marine coastal areas

2. Waste water generation standards
3. Load based Standards
4. Concentration based standards
5. Equipment based standards
6. Load /Mass based standards
7. Process based standards
8. Noise standards

These standards are not only a regulatory tool but also constitute a mechanism to promote technological upgradation to abate pollution and regulate waste

(Government of India, 1992). The enforcement mechanism of pollution abatement policy is presented in a simplified way in Figure 1.1.

Figure 1.1: The Pollution Abatement Enforcement Mechanism



Source: Kuik, et.al, 1997.

The environmental policy regime in India is not totally bereft of economic incentives to control pollution, though these are not prominent. The Government of India offers several incentives to ensure that industries are motivated to comply with various environmental standards prescribed under different Acts and Rules to control and prevent pollution. Some major fiscal incentives are (Karnataka State Pollution Control Board, 2000).

1. Exemption from Income Tax for contribution of corporate sector and private individuals made to programmes on conservation of nature and natural resources.
2. Depreciation allowance at 30% is allowed on devices and systems installed by Industrial units for minimizing pollution or for conservation of resources.
3. Investment Allowance at the rate of 35% of the actual costs of new machinery or plant is granted if it assists pollution control and environment protection.
4. Capital Gains Tax exemption to encourage industries to shift from congested urban areas.

The on set of economic reforms in July 1991 and the subsequent deregulation for Foreign Direct Investment (FDI) led to the apprehension that the Government might relax its environmental laws to attract more FDI and it would encourage relocation of environmentally polluting industries from the developed world into India. But pollution control laws have not been relaxed in the process of economic reforms, for large and medium-scale industries though they have been relaxed in the case of small-scale industries as it has been assumed that they do not undertake hazardous processes (Kuik, et.al, 1997).

But small industries tend to cause more pollution due to inefficient production methods, inferior equipment, poor house keeping and inability to adapt proper treatment technologies (Planning Commission, 2001). In order to encourage cleaner production, the government of India extends incentives like custom duty waiver, soft loans, etc and provides other concessions for installation of pollution control equipment in industrial units (Planning Commission, 2001).

An important decision taken by the SPCBs in the 90s is to promote common effluent treatment plants for SSIs, where they are located in clusters and recover part of the cost from them. But where SSIs are not located together, such facilities have not been available and they are allowed to release the effluent into municipal drains or streams without treatment (Kuik, et.al, 1997). On the whole, the progress made with respect to common effluent treatment plants in SSI clusters may be, at the most, minimum.

Today, SSIs have to obtain consent from the Central Pollution Control Board (CPCB) only in the case of 17 industries, which have been categorized as highly polluting:

(i) Fertilizers (Nitrogen/Phosphate)
(ii) Sugar
(iii) Cement
(iv) Fermentation and distillery
(v) Aluminum
(vi) Petrochemicals
(vii) Thermal power
(viii) Oil refining
(ix) Sulphuric acid
(x) Tanneries
(xi) Copper smelter
(xii) Zinc smelter
(xiii) Iron and steel
(xiv) Pulp and paper
(xv) Die and die intermediates
(xvi) Pesticides manufacture and formulation
(xvii) Basic drugs and pharmaceuticals

Given the national environmental policy and its focus on SSIs, it is appropriate to understand the environmental regulations prevailing in the state of Karnataka and its relevance to SSIs.

1.6 Environmental Regulation in Karnataka State: Relevance for Small Scale Industries

Karnataka has a separate ministry for Forest, Ecology and Environment under which there is the Karnataka State Pollution Control Board (KSPCB). The board is the implementing authority of the environment-related legislations in the state. It has a head office, six divisional offices and 15 regional offices across the state. One of the main functions of the board is to preserve the water quality and air quality in the state by controlling pollution from industries and local bodies (KPSCB, 2000).

To achieve this objective, the board has classified all the industries into three groups based on the potential to generate pollution by an industrial unit: Red (118 industrial categories), Orange (51 industrial categories), and Green (11 industrial categories). All new industries are required to obtain consent for establishment and consent for operation under Air and Water Acts. Consent fee varies based on 1) The category of red, orange and green for industries and 2) Size of capital investments, i.e., gross fixed assets comprising investment on land, building (including staff quarters), plant and machinery, movable and immovable assets and additions made during subsequent years. An industrial unit under the red category has to pay the highest consent fee whereas under the green category the lowest. The consent fee increases with the size of capital investment. If the assets are taken on lease, twenty times the annual lease value is to be taken as equivalent to capital investment (KSPCB, 2000).

The industries under large and medium scale red category are required to obtain consent every year. Medium scale orange and green category industries are required to obtain consent every year with an option for paying fee once in two years, by paying two years' fee. Small-scale industries (Red, Orange and Green) have to obtain consent every year with an option of paying fee once in three years, by paying three years' fee. Tiny industries have to renew consent once in ten years by paying one-year consent fee (KSPCB, 2000).

The Karnataka State Pollution Control Board has set up three common effluent treatment plants in the state and all the three are located in Bangalore. Of the three, two are for small-scale industries, one for tannery wastewater treatment and the other for electroplating wastewater treatment. The Board proposes to set up technological testing centre (cleaner technology) for demonstration of recent cleaner technologies to achieve Recycle, Reuse and Recovery concept. In addition, it has proposed to classify industrial units based on their performance in terms of pollution control measures undertaken (KSPCB, 2000):

Class A: Industrial units, which have complied with previous consent conditions and have a good track record. Consent for these will be issued across the counter.

Class B: Industrial units that have not complied some of the earlier conditions.

Class C: Industrial units whose past performance is bad.

Thus, Karnataka's environmental legislation regime operates within the national legislation framework and it covers small-scale industries as well.

1.7 Need for the Study

Environmental concern is of relatively recent origin in India. The Water (Prevention and Control of Pollution) Act, 1974 is barely three decades old as where the Air (Prevention and Control of Pollution) Act, 1981 is about two decades old now. The majority of SSI units in the country do not fall within the ambit of these pollution control laws (Planning Commission, 2001). Only SSIs in the 17 high polluting industries (referred in Section 1.5 above) have to obtain a No Objection Certificate (NOC) from CPCB prior to establishing a unit. In Karnataka, irrespective of the industrial sector, however, every SSI unit has to obtain the consent of SPCB every year.

Thus, it appears that small-scale industries in the state are appropriately covered by the environmental legislation. However, a visit to the Karnataka State Pollution Control Board (KSPCB) and discussion with concerned officials enabled us to understand that there is no systematic mechanism through which the state could ensure that SSIs comply with the environmental regulations of the state. If a SSI unit does not renew its environmental consent obtained from the SPCB, then SPCB has to send a reminder. Normally SPCB sends reminders to the concerned units two months in advance. This necessitates maintenance of detailed database containing addresses of SSI units located across the state. But currently, KSPCB database has a list of only about 6,000 units whereas the Directorate of Industries and Commerce, Government of Karnataka indicates that the population of SSI units at the end of March 31, 2001 stood at 0.25 Million. This brings out that the KSPCB database contains hardly 3% of the SSI population of Karnataka.

This implies that SSI population in Karnataka operates virtually outside the purview of environmental legislation of the State. The supervision and implementation of environmental legislation among the SSI units is further hampered by the lack of adequate supervisory staff/field officers at the regional offices of State Pollution Control Board. There are a total of 17 field officers in the SPCB for the whole state. All these bring out that the environmental status comprising the level of pollution generation, its causal factors, its variance from industry to industry or cluster to cluster, etc., with reference to SSI in Karnataka is largely an unknown issue.

This is substantiated further by the fact that there is hardly any institutional literature, which throws light on the nature and magnitude of the environmental pollution generated by SSIs. A significant feature of Small Scale Industry growth in Karnataka, like that of the Country, is the emergence of clusters, particularly traditional industry clusters such as brick manufacturers, silk reelers, puffed rice manufacturers, foundries, chemicals, plastics, wood products, etc. Not many of these clusters have been identified by the Expert Committee (Ministry of Industry, 1997). Many of these clusters have the propensity to generate environmental pollution through their activities, at least, locally.

However, it is not yet systematically probed as to how small industry clusters generate pollution? Why? What are the factors, human resource, technological, process or structural, which cause small firms to generate pollution? What abatement measures are the most feasible in the given environment? etc. It is these factors, which justify the need for the present study as it attempts to fill this information gap in the context of Karnataka State.

1.8 Objectives, Scope and Methodology

The study primarily aims at probing the nature and magnitude of environmental pollution generated by small industry clusters and suggest appropriate remedial measures for pollution abatement. The specific objectives of the study are to:

1. Identify the pollutants due to various activities in the SSI clusters and develop a pollution profile.
2. Probe the factors that influence the current level of pollution.

3. Identify appropriate abatement measures related to these factors to reduce the environmental pollution.
4. Determine the costs and benefits of pollution abatement measures.
5. Develop a policy framework to promote environment friendly small-scale industrialization.

These objectives will be studied with reference to four SSI clusters in the state of Karnataka. Karnataka is considered an industrially dynamic region in the country. It is one of the states where SSI is largely concentrated (SIDBI, 1999). The state is also known for the location of a variety of traditional as well as modern SSI clusters. To name a few, handicrafts in Bidar and Channapatna, puffed rice manufacturers in Davanagere, Harihara and Arasikere, silk reeling in Kollegal, Ramanagaram, Vijayapura, Shidlaghatta, brick making in Malur, saw milling in Tumkur, foundries in Belgaum, auto components, electronic and software units in Bangalore etc.

The problem of environmental pollution is likely to be more acute in traditional SSI clusters due to various factors such as technological obsolescence, lack of awareness among entrepreneurs about better alternatives, higher composition of unskilled labour force, etc.

Therefore, our study will be confined to four traditional SSI clusters in Karnataka, namely, foundries in Belgaum, brick units in Malur, silk reeling in Ramanagaram and puffed rice manufacturers in Davanagere. These clusters are identified in consultation with the officials of Directorate of Industries and Commerce, Government of Karnataka and District Industries Centre, apart from KSPCB. To analyze the objectives, relevant data will be gathered through a questionnaire and by conducting a field survey in each of the identified four SSI clusters. The questionnaire will comprise four sections, to cover

1. Basic information on the industrial unit/cluster: Unit characteristics entrepreneurial background, level and kinds of interaction, etc.
2. Material consumed/produced: Quantity and value of raw material used, quantity, value and range of products and value of products, energy inputs, etc.
3. Technology details: Process and technology types, equipment types, etc.

4. Human resource details: Organizational structure, education, skill levels, number of employees, etc.

Approximately 40 units each will be covered in the four identified clusters. The kinds and levels of pollution are determined by the consumption of material/energy inputs used, products, by-products and wastes generated, nature of technology in use, the skill levels of the employees and managerial style. This will enable us to identify the pollutants and develop the pollution profile.

The pollution in any industrial unit is mainly caused by the material (energy, raw material, etc) used for various kinds of production activities. The level of pollution depends directly on the quantity of materials used. We determine pollution level in the sample units based on standard parameters for emissions of various kinds of gases, using the quantity of materials used by the respective units. Subsequently pollution can be calculated either per unit of enterprise or per unit of output.

Further, the causal factors, which cause variations in the level of pollution, related to human resource, technology, industry structure and external relationship will be logically identified and to verify whether these factors really influence changes in pollution level, the analysis of variance (ANOVA) statistical technique will be used. Identification of influencing factors will also enable us to prescribe appropriate pollution abatement measures, in the given circumstances. It is based on the nature of prescriptions worked out for pollution abatement that the cost and benefits of pollution abatement will be estimated.

Finally, literature survey, discussions with experts, etc., will enable us to propose alternative policy framework to promote environmentally sound economically competitive small-scale industrialization.

1.9 Scheme of the Project Report

The project report has been structured into eight chapters. The second chapter identifies basic environmental issues related to industry and small industry and reviews existing literature, particularly with reference to clusters and environmental pollution. The third chapter describes the objectives of the study, scope and methodology in detail. The fourth chapter analyzes the objectives with reference to the brick units in Malur, Kolar district and presents the findings. The fifth chapter comprises analysis of objectives and findings for the silk reeling units in Ramanagaram, Bangalore rural district.

The sixth chapter deals with the analysis of objectives and its findings for the puffed rice manufacturers of Davanagere. The seventh chapter comprises analysis of objectives and findings on the foundry cluster of Belgaum. The eighth chapter presents the summary and findings of the study as well as alternative policy suggestions for pollution abatement in the small-scale industry clusters of Karnataka.

CHAPTER 2: SMALL SCALE INDUSTRIES AND ENVIRONMENTAL POLLUTION: REVIEW OF LITERATURE

2.1 Introduction

Small Scale Industries form part of an economic system. Both the economic system and environment are parts of the universe, and any economic activity in this system will make use of and in turn, affect the environment. That is, there will be a constant interaction between the economy and the environment. The development of economic activities will lead to a greater utilization of environmental resources and generation of wastes into the environment. Small scale industries being a vital component of economic activities of any country, they too make use of environmental resources and generate wastes.

In this context, it is appropriate to understand how economy and environment as components of the universe interact with each other and what are their implications. Given this interaction, what is the relevance of small-scale industry operations for the environment? Do small firms, either individually or collectively, affect the environment? If yes, why? How to regulate or control or mitigate the environmental impacts of small firms? These issues are discussed in this chapter, with specific reference to small industry clusters in India.

2.2 Economy-Environment Systems

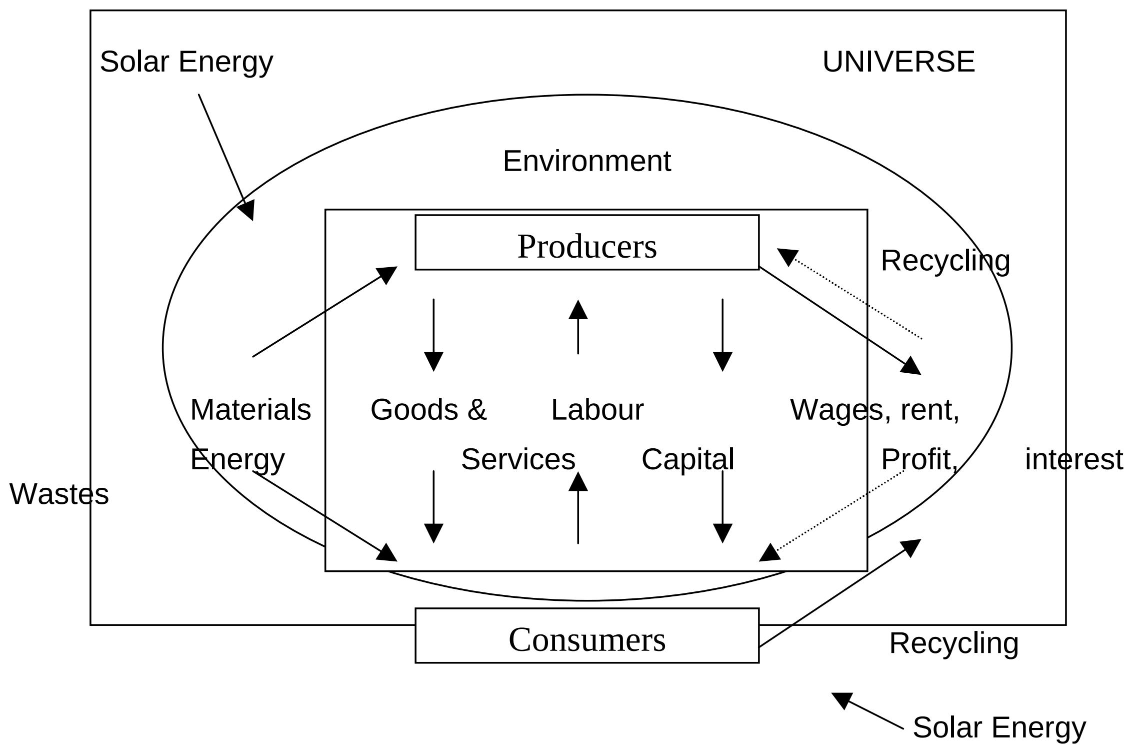
A 'system' comprises a collection of objects or entities that are bounded in terms of space and time. The entities interact with each other through various 'processes'. Both the economy and the environment are open sub-systems of larger system, the universe (Adjaye, 2000). Such a system is presented in Figure 2.1. Firms produce goods and services using raw materials such as minerals, agricultural products, timbers, fuels, water and oxygen that are extracted from the environment. These goods are sold in the market as either consumer goods or as intermediate goods for the production process. The firms would belong to either of the three sectors: Agriculture, industry-large as well as small and services.

Nearly all the material inputs to the production and consumption processes are returned to the environment as wastes (Adjaye, 2000). The wastes are mainly in the form of gases (E.g.: Carbon Monoxide, Carbon dioxide, Nitrogen dioxide, Sulphur dioxide), dry solids (E.g.: rubbish and scrap) or wet solids (E.g.: waste water). Both solid and liquid waste products from the household and production sectors may go through a further processing stage before being returned to the environment as waste.

The environment in this system (Figure 2.1) can be seen as playing three important roles:

- As a provider of raw material inputs to producers and consumers;
- As a receptacle for the waste products of producers and consumers; and
- As a provider of amenities to consumers (e.g.: recreation).

Fig 2.1: An Economy – Environment System Source: Adjaye (2000)



There are two points worth noting in this economy- environment system. Firstly, there is a strong inter-relationship between the three types of support provided by the environment. For e.g. Environment's capacity to assimilate waste is limited and when this limit to assimilate wastes is exceeded, pollution and environmental degradation begin to occur. This will result in compromising the ability of the environment to provide raw material inputs (Adjaye, 2000).

Secondly, environment has to be viewed not only as a resource but also as an asset. There is need to maintain the quality of the environment for long term sustainable development (Adjaye, 2000).

Given this, there is a need to ensure that an economic activity does not damage the environment beyond a limit, i.e., they do not generate wastes (of any kind) to exceed the assimilative capacity of the environment. Particularly, wastes, for which there are no natural processes to transform them into harmless or less harmful substances, should be curtailed or minimized. This could be done through either spreading environmental awareness or environmental legislations or a combination of economic incentives and disincentives (Sankar, 2000).

2.3 Small Industry and Environment

In most countries, small and medium sized enterprises (SMEs) makeup the majority of businesses and account for the highest proportion of employment (Fisher and Reuber, 2000). They produce about 25% of OECD exports and 35% of Asia's exports (OECD, 1997). This being the significance of the sector, it is appropriate to know the environmental implications and impact of SME operations.

But Schumaker (1989) considers that pollution from large may overwhelm environmental absorptive capacity and touts small plants as the agents of choice for sustainable development. In contrast, Beckerman (1995) argues that small factories are pollution intensive, costly to regulate and in the aggregate, far more environmentally harmful than large enterprises. Recent policy reports from the World Bank and other international institutions have tended to side with Beckerman, at least in noting the potential gravity of small enterprise pollution problem (EA2, 1997; Env, 1997).

Ghose (2001) is of the view that all industrial activities have adverse impact on the environment, but a few sectors of SMEs have major impacts and the industry has found it difficult to mitigate these adverse impacts. Some of the environmentally problematic sectors of SMEs, according to him, are given in Table 2.1.

Table 2.1: SME Industries and Pollution Potential

Industry	Environmental problem*			
	Water	Air	Odour	Solid Waste
Tanneries	3	-	3	3
Pharmaceuticals	3	3	3	3
Chemical processing	3	3	3	-
Pulp and paper	3	-	3	3
Textile dyeing and printing	3	-	-	3
Dyes and Dye intermediate	3	-	-	3
Metal Finishing	3	-	-	3
Foundries with Cupolas	-	3	-	3
Brick Kilns	-	3	-	3
Lime Kilns	-	3	-	3
Stone Crushers	-	3	-	3
Khandsari Sugar	3	-	-	3
Food and Fruit Processing	3	-	3	3
Metal Processing	-	-	-	3
Slaughter House	3	-	3	3

Note: Levels of Pollution: 1 – Low, 2 – Medium, and 3 – High

It may be true that small firms of certain industries are dynamic while those of others are stagnant; that some are environmentally benign while others are highly polluting. If small enterprises are generally clean, then environmental concerns are misplaced. If they are generating pollution but stagnant, then economic growth will diminish their role over time. But if small firms are pollution intensive and fast growing, there is cause for concern because small plants are difficult and costly to regulate.

However, Blackman and Bannister (2000) found that small-scale brick makers in Ciudad Juarez, Mexico have responded significantly to informal community pressure for improved environmental performance. Recent research has suggested that such informal regulation is common in developing countries (Pargal and Wheeler, 1996; Hettige, Haq, Pargal and Wheeler, 1996). Further, at least, some of the most pollution intensive industries- steel, paper and industrial chemicals, for instance- exhibit significant scale economies. Therefore, it is not clear whether small enterprises are likely to be pollution intensive at the aggregate, irrespective of sectors.

Some empirical research, based on data of medium-scale and large-scale industries, has suggested that plant size is inversely correlated with emissions intensity (emissions/output) in developing countries. This is attributed to private scale economies in pollution control and public scale economies in regulatory monitoring and enforcement (Blackman and Bannister, 2000).

There are not many empirical studies conducted with reference to small-scale enterprises in developing countries due to non-availability of data. This is because there are not adequate facilities for measuring and analyzing environmental data. One way of analyzing environmental effect of small-sale production is through obtaining data on materials inventory balance, which measures the principal wastes and pollutants. This might enable the identification of where any mitigation or abatement efforts should be focused. A useful measurement tool is the pollution per unit of output.

In brick making in Zimbabwe (Blackman, and Bannister, 2000), small-scale producers use mainly firewood for fuel and contribute to deforestation whereas large-scale producers, who use coal do not. In terms of green house gases, small-scale producers in Zimbabwe account for about half of the brick industry's CO_2 emissions. However, per unit of output, a small firm's emissions are lower than those of large firms. Large firms generate most of the industry's SO_2 emissions from their coal combustion but SO_2 emissions are negligible for small firms. The large brick making firms have more dust in the work place because of high volumes of materials processed.

The most significant environmental effect of small-scale gold mining stems from the use of mercury for the extraction of gold from the ore (Blackman and Bannister, 2000). Small-scale miners use two tonnes of mercury per tonne of gold, up to half of which is lost into the environment. Alluvial gold panners tend to use a greater quantity of mercury. But large-scale gold miners do not use mercury in extracting gold from the ore. The existing regulatory system in Zimbabwe is ineffective in controlling environmental damage caused by small-scale industries. Enforcement is extremely limited and is concentrated on large polluters.

2.4 Small Industry Clusters in India and Environmental Pollution

Small scale industry (SSI) is promoted through policy intervention by governments in developing countries like India to achieve multiple objectives such as employment generation, export promotion, balanced regional development, entrepreneurship creation, etc. (Ministry of Industry, 1997). Today SSI is a consistently growing sector in Indian economy (Government of India, 2002). Since SSI is growing rapidly, pollution caused by them is going to be a major problem (Kuik, et.al, 1997). This will be particularly true in the context of SSI clusters.

A significant feature of the growth of SSI in India is the spontaneous emergence of SSI clusters across the country (Ministry of Industry, 1997). It has been estimated that there exists about 350 SME clusters in India (UNIDO, 2001). These clusters are overwhelmingly predominant with small industries and the share of medium and large industries in the sales turnover, production and employment is nominal. In addition, according to an estimate, there are about 2000 rural clusters in India (UNIDO, 2001). These are mainly skill-based clusters and consist of unorganized sector tiny units with very little access to market, information and technology.

The size in terms of the number of units and the quantum of output of clusters may vary significantly. For e.g. Panipat (Haryana) produces 75% of the total blankets produced in the country, Tirupur (Tamil Nadu) contributes 80% of the country's cotton hosiery exports, and Ludhiana (Punjab) accounts for 95% of India's woolen knitwear, 85% of the sewing machines and 60% of the nations bicycles and its parts. On the other hand, there are some clusters that are very small comprising hardly 100 units, (each employing about 10 to 20 workers) like brick making units in Malur (Karnataka). Therefore, the quantum and contribution of clusters in the SME sector of India is undoubtedly, quite significant though their overall contribution has not been quantified even approximately.

Most of these clusters are natural and are traditional rather than induced and modern. SSI clusters particularly the traditional ones are likely to cause pollution at the local level due to the following factors:

- Traditional units are more likely to use obsolete technology, which necessarily generates pollution from the processes by consuming more inputs for given level of outputs.

- Low level of income and therefore, cannot go for 'better alternative' technology even if its availability is known.
- Entrepreneurs are likely to be less educated or illiterate and likely to have less environmental awareness.
- Lack of understanding on the technical specification and implications of pollution standards.
- Low level of managerial and technical ability among owners and managers, and low skill levels among workers.
- Lack of public/market pressures to improve environmental performance.

But clusters also offer certain advantages for the firms operating within the cluster as well as for policy makers. It provides ample scope for public-private ownership for the development of clusters, among others. That is why the new approach suggested for small industry development in India has focused more on clusters (Ministry of Industry, 1997). Clusters also offer scope for better enforcement of environmental regulations as well as joint action by clustered firms for setting up common effluent treatment plants or knowledge sharing etc. Joint action by small firms represents one direction of "Collective Efficiency" which has contributed to economic success associated with small firm clusters (Schmitz, 1998). This joint action could emerge due to either self-initiative by clustered firms or as a reaction to some external factor.

Kennedy (1999) has brought out that collective action by tanners located in the Palar Valley of Tamil Nadu has enabled them to meet the "Pollution Crisis" successfully. In the Palar valley alone about 45 percent of India's leather is produced by more than 200 tanneries. In 1995, the Supreme Court of India ordered the closure of hundreds of tanneries in Tamil Nadu for failing to treat their effluents. With their survival at stake, local producers of Palar valley opted overwhelmingly for a collective solution and took immediate steps to form central effluent treatment plants. Thus collective action enabled local producers to meet effectively the challenge of pollution control. But this collective action emerged due to external threat rather than internal realization.

The same is true in the case of lead smelting units in Calcutta. Lead Smelting units are considered one of the most air polluting sub sectors in Calcutta (Dasgupta, 2000a). The owners were little educated and poorly informed. They were not aware that reducing furnace inefficiency would reduce cost of pollution abatement. They did not understand the technical specifications and implications of pollution standards either. But when this cluster of units was threatened with closure and offered assistance by the local environmental agency, these units took steps to comply with the environmental standards, within one year. They improved their work practices, introduced waste management techniques and reduced furnace inefficiency with the assistance got from the State Pollution Control Board.

Thus, mere technological approach will not be sufficient to alleviate environmental pollution in small-scale industries. Along with identification of constraints and incentives to adopt environmental pollution abatement measures, or development of cleaner technology, it is essential to investigate the socio-economic and regulatory environments in which small firms operate.

Bartone and Benavides (1997) through their four case studies pertaining to Mexico, Peru, India and Zimbabwe ascertained the problems associated with hazardous waste management in SSI. They suggested that steps to improve environmental management in SSI must include a combination of information and educational campaign to address the limited knowledge base and low environmental awareness in the sector.

Industrial air pollution is a matter of concern and in India SMEs cause considerable air pollution (Padma Rao, 1996). This could be due to adoption of primitive technology, use of low-grade fuel, and hence inefficient combustion. The foundries in general and cupola in particular are such units used as the most economic unit for manufacturing iron. In India there are more than 6000 cupola based foundry units located mostly in clusters. The energy intensity of these units is quite high. Even after the strict imposition of emission standards, most small-scale foundry units find it extremely difficult to comply, primarily due to the lack of availability of any ready-made gas cleaning systems.

The Howrah belt of West Bengal has the largest concentration of foundry units in India and accounts for over 20 percent of the country’s production of grey cast Iron

(TERI, 1999). Tata Energy Research Institute's (TERI) Action Research Programme in the Foundry Sector, initiated with the support of the Swiss Development and Cooperation (SDC) found that there is scope for improving the energy and environmental performance as there is scope for energy saving and carbon dioxide abatement in small-scale foundries in India. The project demonstrated and diffused energy efficient Cupola Furnace and appropriate pollution control system. The Project demonstrated that an appropriate design of the cupola and pollution control system would not only help to improve ambient conditions but also facilitate reduction of global emissions. TERI implemented similar programmes for improving environmental performance of small-scale foundry units in Agra as well.

According to Central Pollution Control Board (CPCB) (CPCB, 2001a), the share of small-scale industries in generating wastewater among different classes of industries is estimated to be about 40%. The total volume of wastewater generated from small-scale industries is 3881 mld; the contributors being engineering industries (2125 mld), paper and board mills (1087 mld), textile industries (450 mld), organic chemicals (60 mld), tanneries (50 mld), pharmaceuticals (40 mld), dye and dye intermediates (32 mld), soaps and detergents, paints and varnishes and petrochemicals (10 mld each).

According to CPCB (2001a), the level of pollution caused by SSI sector in India is higher than their counterparts in developed countries due to: (i) Usage of outdated and inefficient technologies, (ii) Unplanned industrial conglomeration, (iii) Lack of resources for enforcement and implementation of pollution control programmes, (iv) Lack of public/market pressure for improving environmental performance, (v) Lack of guidance, funds, space and facilities for SSI units for setting up pollution control systems, etc.

According to an estimate of CPCB, even if a meagre 10% of the total SSI units are polluting in nature, there are more than 0.3 million units causing adverse impact on the environment. This would amount to nearly the same impact as all the large and medium industries put together. The situation, therefore, is grave especially because SSIs are mostly located in the non-confirming areas; be it residential or commercial (CPCB, 2001b).

All these bring out that small firms of certain industries in India do cause environmental damage through air or water pollution, particularly those located in clusters. SSI clusters, in general, lack the knowledge base and also the awareness to implement pollution prevention plans. Even if a particular small firm is interested in implementing any of the changes required to become more environment friendly, it lacks the capital resources to do the same. But clusters provide scope for collective action for pollution abatement as demonstrated in many a cluster in India.

However, in none of the clusters, small firms on their own have initiated joint-action to reduce pollution. It is either due to the threat of legal action towards closure or assistance offered by some external agency for improvements or a combination of both that small firms in clusters have joined together to incur costs to counter environmental pollution and realized 'benefits' subsequently.

The task is arduous. This is because the problem is not simply technological. It has socio-cultural dimensions as well, as there is a need to convince the SSI entrepreneurs about the need to go for environmental protection. Therefore, the problem of environmental pollution abatement in SSI clusters may differ from region to region, industry to industry and cluster to cluster.

2.5 Environmental Pollution and Small Industry Clusters in Karnataka: Current Status

Though Karnataka has been in the forefront of high technology industries, in particular, electronics, communication and informatics (Government of Karnataka, 2001), it is also known for its concentration of traditional industries such as raw silk, handicrafts, bricks and tiles, handlooms, etc (Government of Karnataka, 1996). Most of these traditional industries predominantly comprise small-scale industrial units and operate in clusters. What is disturbing is that in the 80s, the highly polluting industries (18 industries referred in section 1.5) registered a relatively high growth as compared to less polluting industries in Karnataka (Kuik et.al, 1997).

However, current statistics does not throw light on the growth of highly polluting SSIs vis-à-vis less polluting SSIs in Karnataka. Even the officials of Karnataka State Pollution Control Board (KSPCB) do not have figures on the exact number of polluting SSIs or pollution intensive SSI clusters in the state. Though they have knowledge about the kind of SSIs causing pollution, the inadequate staff strength

(Kuik, et.al, 1997) is a major obstacle, which prevents them from carrying out an appropriate assessment of pollution intensive SSI units and SSI clusters. This being the case, ensuring the implementation of environmental legislation or pollution control and pollution abatement among the vast and growing SSI sector by the administrative machinery is a far cry in the state.

It is in the light of the above that we have undertaken our study to probe the variety and magnitude of environmental pollution generated in small industry clusters, its causal factors and appropriate and economically viable measures of pollution abatement in Karnataka. This would enable us to prescribe policy measures for environmentally sound small-scale industrial development in the State.

CHAPTER 3: OBJECTIVES, SCOPE & METHODOLOGY AND BACKGROUND OF CLUSTERS

Based on the review of literature and identification of research gaps, we have formulated our research objectives, determined its scope and developed the methodology. This chapter describes the objectives, scope and methodology of the study and provides an over view of the four small industry clusters in Karnataka chosen for the study.

3.1 Objectives

The primary goal of our study is to probe the nature and magnitude of environmental pollution in small industry clusters of Karnataka. The specific objectives of our study are to:

1) Identify the pollutants due to various activities in the SSI clusters and develop a pollution profile.
2) Probe the factors that influence the current level of pollution.
3) Identify appropriate abatement measures related to these factors to reduce the environmental pollution.
4) Determine the costs and benefits of pollution abatement measures.
5) Develop a policy framework to promote environment friendly small scale industrialization.

Thus, the study is an attempt to understand environmental pollution of small-scale industry clusters and come out with appropriate abatement measures.

3.2 Scope and Methodology

The study is confined to environmentally polluting four small industry clusters in Karnataka. Initially, we chose 1) Chemical units cluster in Nanjangud, Mysore district, 2) Brick and tiles cluster in Malur, Kolar district, 3) Foundry cluster in Belgaum, Belgaum district and 4) Silk reeling cluster in Ramanagaram, Bangalore rural district. These clusters were identified in consultation with the officials of Directorate of Industries & Commerce (D.I&C), Government of Karnataka and Karnataka State Pollution Control Board (KSPCB).

To ascertain the feasibility of data collection and to gain familiarity with the clusters chosen for the study, we visited Nanjangud, Malur, Belgaum and Ramanagaram during February- April 2001. This enabled us to gather preliminary information about the origin and nature of clusters, number of SSI units functioning in the respective clusters, etc. Our visit to Nanjangud and discussion with the officials of Taluk Industries Center (T.I.C), Nanjangud revealed that there was not enough number of chemical industry units functioning for conducting the study. Most of the units listed with the T.I.C were closed down due to various reasons. There were only 13 units functioning, which forced us to look for an alternative cluster having more number of chemical units.

After discussing with the officials of D.I&C, we found that Bykampady Industrial Area in Mangalore had a significant number of chemical industries. The project team then visited the Bykampady Industrial Area in order to determine the exact number of chemical industrial units functioning in the area. The team had discussions with the officials of the District Industries Centre (D.I.C) at Mangalore and obtained the list of chemical units located in Bykampady industrial area. The list contained 63 chemical units producing a variety of chemical products such as industrial grease, printing ink, perfumery compounds, electroplating, mixed fertilizer and other related products.

To ascertain facts about the cluster and gather preliminary information regarding the product and process details, a pilot study was conducted in the third week of July 2001. We found that most of the listed 63 units were either closed down or manufacture an altogether different product and not chemicals. Some of the units were chemical mixing units and paint mixing units whereas the rest manufactured plastic bags. The officials of KSPCB agreed with the observation made by us and informed that all these industrial units come under green category, which is considered non-polluting. This made us to conclude that not enough number of chemical units is available for our study in Bykampady Industrial Area. Our search for a new cluster resulted in the identification of puffed rice manufacturing cluster in Davanagere town, Davanagere district.

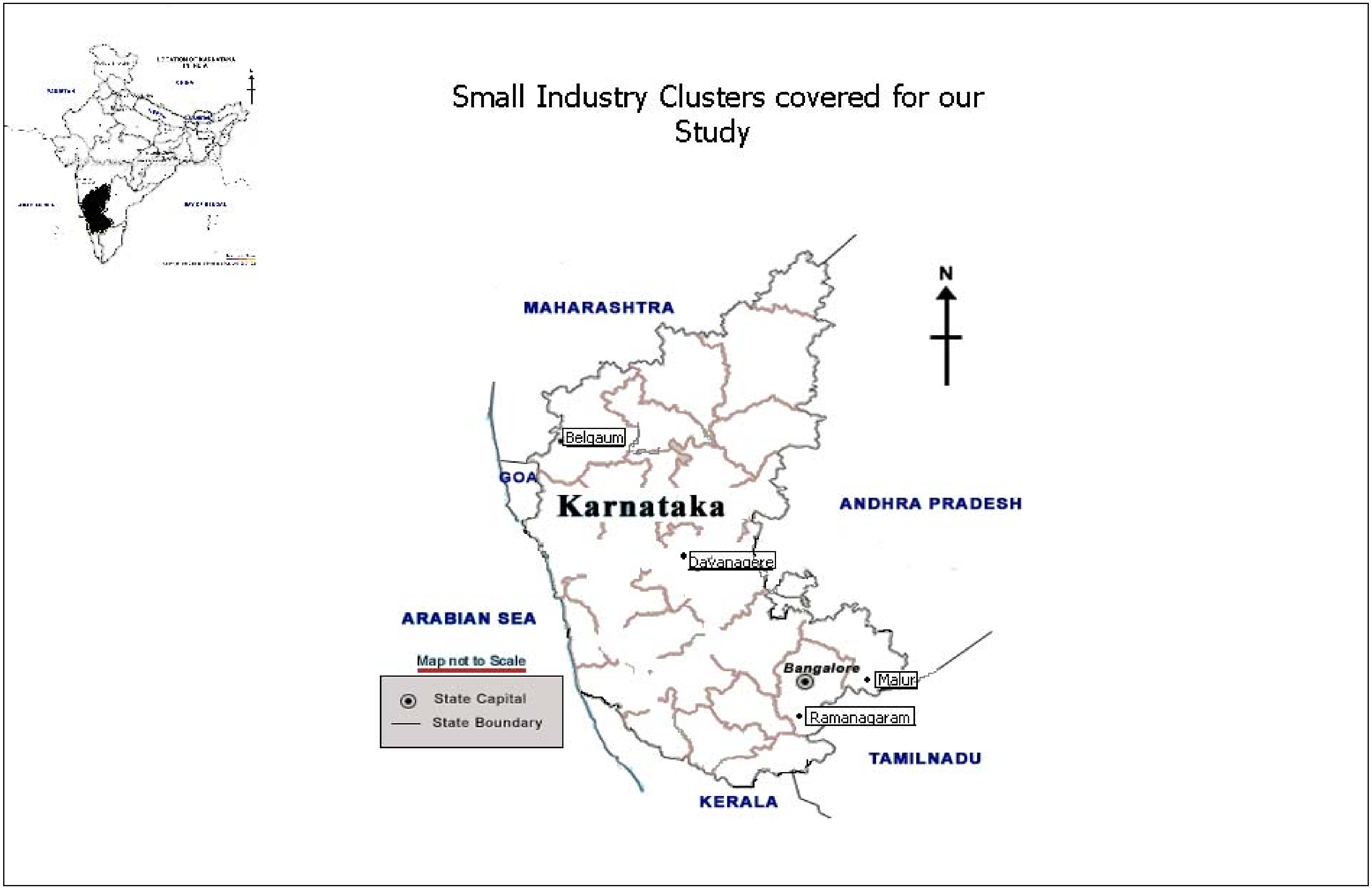
Thus the scope of our study is confined to bricks & tiles in Malur, foundries in Belgaum, silk reeling in Ramanagaram and puffed rice making in Davanagere (See Map). The initial visits to these clusters proved useful in getting all basic information pertaining to these clusters and enabled us to find out the feasibility of data collection as well as details on the manufacturing process of industrial units in the clusters, apart from establishing sufficient contacts for primary data collection. It is based on this information, among others, that questionnaires are developed subsequently for data collection. The data collection exercise was started with the target of covering at least 40 units each in the four clusters.

3.2.1 Questionnaire Development

As the nature of product and nature of manufacturing are different in the four clusters chosen for our study, we decided to develop separate questionnaires to take into account the special features of each cluster. The process of questionnaire development began with a detailed review of literature (internet, journals and books) on the selected cluster specific industries. This helped us to gather information related to manufacturing process, kind of technology employed, type of raw material and energy used, possible type of emission and waste generated, etc. In addition, we had detailed interaction with the experts of State Pollution Control Board, Central Silk Board, Directorate of Industries and Commerce, Taluk Industry Centers (TICs), the industry specific manufacturing associations and a few progressive manufacturing units. This activity made us to realize the need for cluster specific questionnaires for data collection. The secondary information thus gathered used for developing four cluster specific and structured questionnaires for data collection.

The questionnaires developed had four sections-

i) <u>Basic information on the industry</u>: unit characteristics, entrepreneurial background,etc.



Small Industry Clusters covered for our Study

ii) Materials Consumed/Produced: raw material use, product range, energy use, etc.

iii) Technology Details: process and technology types, equipment types, etc.

iv) Human Resource Details: organizational structure, education, skill levels, number of employees, etc.

Further, we sent the first draft of the questionnaires to all the above experts to elicit their opinion. Their feedback enabled us to refine the questionnaires.

3.2.2 Data Collection

For the purpose of survey, our project team members (three of them) visited all the four clusters from the first week of July 2001 to the end of October 2001. The team members were able to gather information from 45 units of brick and tile cluster, Malur, 43 units of foundry cluster, Belgaum, 46 units of puffed rice cluster, Davanagere and 55 units of silk reeling cluster, Ramanagaram.

3.2.3 Tabulation of Survey Data

Subsequently, a simple Database Management System (DBMS) was developed using MS Access to facilitate easy data entry and retrieval. The cluster specific questionnaire was exactly replicated into FORMS of DBMS. Separate forms were prepared for each cluster and the data was entered into it. This has enabled us to produce reports depending on the requirements.

3.2.4 Estimation of Pollution Levels

The pollution levels are determined by the consumption of material/energy inputs used, nature of technology in use and the skill levels of the employees and managerial style. (Figure 3.1). Therefore, we intend to estimate pollution generated in the clusters based on the data gathered from the sample units on the above-referred variables. For this purpose, we will make use of standard pollution coefficients (emission factors) worked out based on material and energy specific. Also, wherever applicable the various kinds of wastes generated during the production process will be estimated.

The direct environmental impacts would be studied in terms of pollution intensity for a given type of pollution. A useful measurement tool for this purpose is the pollution per unit of output (physical output as well as value added), which allows comparisons between production units. In addition, the pollution intensities may be studied in terms of effluents, solid waste, various kinds of air pollution per unit of enterprise, per unit of output and investment. The pollution intensities would be estimated with respect to water, air and land pollution caused by the units in the chosen SSI sectors wherever applicable.

3.2.4.1 Estimation of Air Pollution

The direct energy use for combustion process is the single most important cause of air pollution in the industrial sector. The small industry clusters included in the study mainly use firewood, other biomass, coal, fuel oil as combustion fuel for the production process. In some cases, diesel and kerosene are being used for power generation through captive generation mode. One could adopt one of the two approaches to determine the level of emissions from energy use (Figure 3.1) –

1. Using appropriate pollution measurement devices, the emission levels could be measured at the point of exhaust. This typically needs recording of observations over a period of time and known level of fuel use during this period.
2. Using standard emission factors for different types of pollutants per unit of fuel used for combustion process.

The estimates of emission levels obtained from the above two processes will be approximately equal if there are no emission control devices installed in the industrial units. Also, the standard emission factors have been obtained assuming complete combustion of the fuel used. However, this may not be always true in the real life where incomplete combustion is a possibility. This also may cause some differences between the measured and estimated pollution levels.

The preliminary survey conducted by us in all the four selected small industry clusters (prior to the actual survey) revealed that no industry uses any emission control devices (except for very few in the foundry cluster of Belgaum). Since our approach was basically a survey based, and for the kind of information that we are expected to collect, we felt that we could adopt only the second approach to estimate the pollution levels. Also, the overall objective of the study is not to measure the pollution level but to develop indicative pollution levels and then use the variability in these estimates to establish some relationships with the identified factors.

3.2.4.2 Land Pollution

The information on land pollution in our study is limited to the quantum of solid wastes generated during the production process. This information we have gathered through our questionnaire based survey. In a few cases, it would be possible to estimate the extent of land degradation due to extraction of raw material (e.g. clay extraction for brick making).

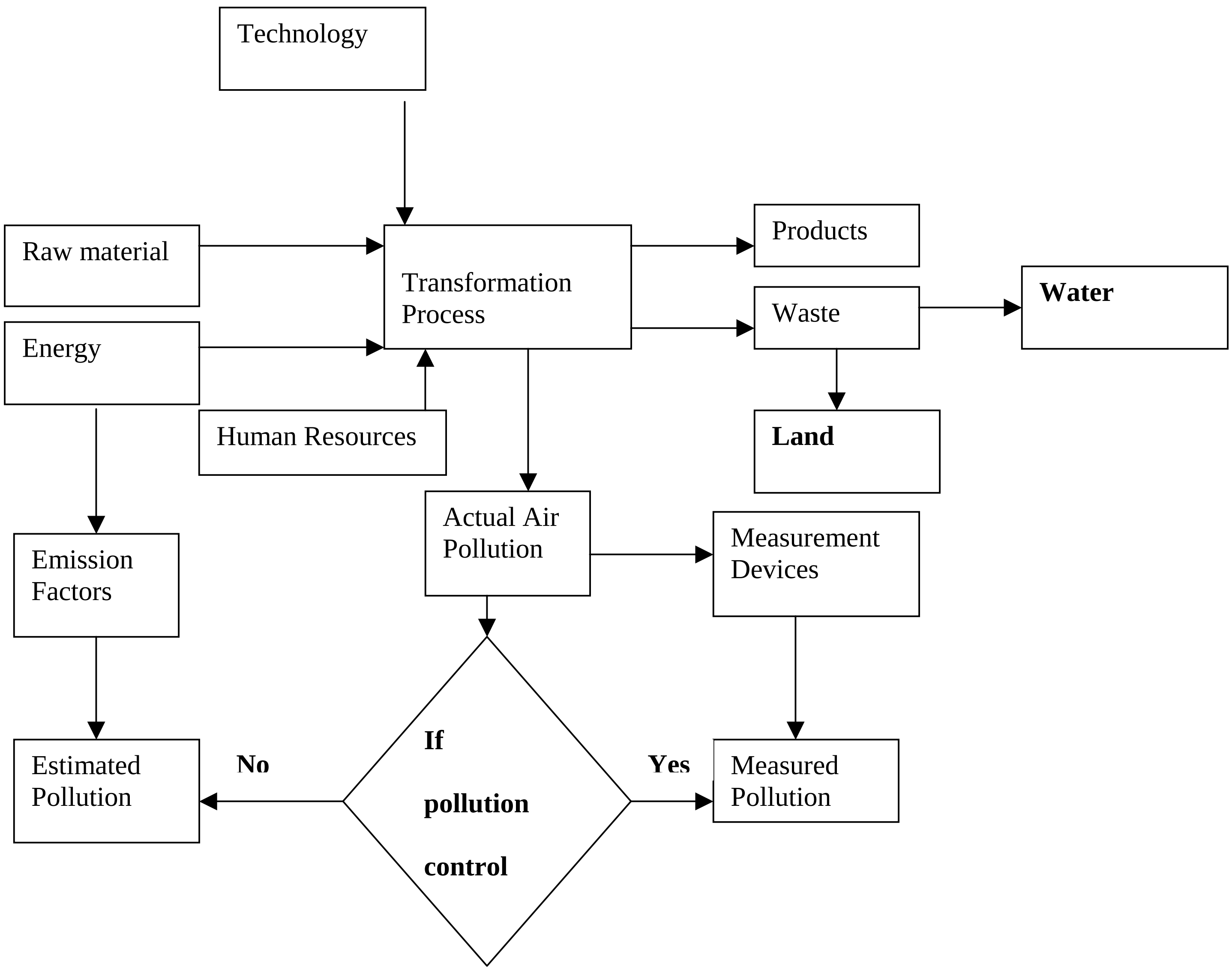
3.2.4.3 Water Pollution

Our attempts to gather information on small industries causing water pollution failed due to the non-availability of chemical industries cluster. Only the silk reeling cluster to a certain extent causes water pollution by generating significant amount of wastewater.In our survey we could gather information on the quantum of wastewater generated by each of the units.

3.2.5 Analysis of Factors responsible for Pollution

The pollution in any industrial unit is mainly caused by the material (energy, raw material, etc.) use for various kinds of production activities. Again, the level of pollution depends directly on the quantity of material used. In other words, the level of efficiency with which the material is consumed determines the quantity of material input and the resulting pollution levels. The efficiency levels in a typical industrial unit are influenced by many factors. These factors could be related to human resource, technology, material quality, external and internal infrastructure, production process, etc. Analysis of the influence of these factors on the efficiency of material use would help in identifying the most important factors. This would further facilitate in the development of appropriate abatement measures to reduce pollution levels.

Figure 3.1: METHOD OF POLLUTION ESTIMATION



In the present study, we have collected data on entrepreneurial and managerial background, skill levels of work force, type of organization of the unit, type of products and processes, the kind of technology in use, the infrastructural environment in which the unit functions, etc., which has enabled us in the identification of external, technological, structural and human resource factors, which influence the level of material use. Thus we have included following factors to study the relationship between material use and the resulting environmental pollution and the considered factors. Each of these factors has been arrived at by using more than one-scaled variables.

3.2.5.1 Human Resource Factor

In the case of human resource factor, we have included three variables, which we feel are important from the point of view of determining the overall effectiveness of the human resource involved in the production process.

Managerial/Owner/Supervisor qualification levels

The influence of education on the managerial capabilities in terms of awareness, planning and decision making, implementing, innovating, etc., with respect to various issues is very significant. Thus one could argue that the qualification levels of the owner (or manager) especially in a small-scale industry have significant influence on the performance of the unit as a whole.

Skill set of labour

It is an established fact that the skill levels of the labour (worker) involved in any given activity are directly reflected in the quality of the final product. The skill level of the whole workforce can also influence the quantum of material used and waste generated.

Value of Labour

If in case, the skill levels are difficult to identify, the value of labour (labour cost per labour for different activities) can act as a proxy for determining the skill set of the workforce. This is used with an assumption that the value of labour increases with the skill level. Second objective of including this variable is that there is a possibility of increased motivation and thereby increased performance level on the part of workforce with the increase in the compensation package (measured in terms of value of labour).

3.2.5.2 Technology Factor

We have included three variables, production technology levels, age of plant and machinery, and other innovations and modifications to capture the technology status of a given unit.

Production Technology Levels

The kind of technology use determines the level of material and energy use depending on the efficiency levels. The variations could be caused by the type of machines, process technology, etc.

Age of plant and machinery

The efficiency levels of the plant and machinery employed tend to get worse with the age. The performance level of the newer machines tends to be relatively better compared to the older machines.

Other innovations/modifications

This variable is included with an assumption that the various kinds of innovations and modifications attempted at various stages of production cycle will have influence on the overall performance level of the unit.

3.2.5.3 Structural and External Factor

We have attempted to capture the structural and external factor by establishing the facts on how long the unit is involved in the production activities, the general environmental conditions prevailing both inside and outside the factory premises, the openness of the entrepreneur in terms of external interactions.

Age of the unit

The age of the unit can have both positive and negative impact on the overall performance level. In the case of older units, the long experience of involving in the production activities can have a positive impact on the efficiency of material use and quality of production, provided they regularly update their knowledge and technology. On the other hand, relatively new units may have to overcome their inexperience in the field, by adopting modern technologies and trained labour force.

General environmental conditions

We believe that the overall performance of the unit as a whole in terms of efficiency of production and material use, quality of workforce, entrepreneurial capabilities and quality of products are reflected in the maintenance of the factory premises. To gather information on these aspects, we developed a set of questions to be answered by the project team members who conducted the survey. The questions are related to general environmental grading of the unit, factory layout, building design features, ventilation, lighting, house keeping, storage conditions, environmental hazards, overall plant appearance & maintenance, etc.

Interaction Levels

External interactions with the fellow units and industry associations; participating in seminars, exhibitions, conferences, etc.; discussions with professionals and consultants; training for the workers; and referring journals and books may have significant influence on the performance of a unit. These kinds of interactions help in upgrading knowledge, increasing awareness, upgrading the skill levels of employees and thereby resulting in improved performance.

To find out how significantly these factors explain the variations in demand, multifactor ANOVA (Analysis of Variance) technique has been used. This analysis is expected to answer the following questions: which factors explain the maximum variations in the considered dependent variables, are they significant to include in the model, how much variations could be accounted through these factors, etc.

3.2.6 Multifactor Analysis of Variance

Analysis of variance (ANOVA) models are versatile statistical tools for studying the relation between a dependent variable and one or more independent variables. They neither require making assumptions about the nature of the statistical relation nor assume the independent variables to be quantitative. The ANOVA models are employed to determine whether different factors interact or not, which are the key factors, which factor combinations are “best”, and so on. As with regression analysis, the method of least squares is used to fit the ANOVA model and provide estimators of the model parameters.

There are three regression-based least-squares methods - unique sum of squares, experimental-design and sequential sums of squares - available for the analysis of experimental or observational data (Overall and Klett, 1972). They yield identical results when applied to equal-cell-frequency or balanced design problems but different results in other cases. According to Overall and Klett (1972), the first method, unique sum of squares, is not appropriate when the problem is unbalanced while the second one, experimental-design method, is the proper generalization of traditional experimental design analysis of variance. The authors state that whenever all the main effects precede interaction terms and lower-order interactions precede higher-order interactions, the only differences between second and third method will be found in the within-levels adjustments. It is especially important to note that the component sums of squares always add up to the total sum of squares when third method is used. This is not generally true for the first two methods if disproportionate cell frequencies are present. In using first and second methods, care should be exercised not to include classification variables that are highly related. The third method can be used with less concern over dependencies among the classification variables.

In the present analysis of finding out the influence of various factors on the considered dependent variables, we propose to use sequential sums of squares method for the analysis of variance. This method can be used if a logical *a priori* ordering exists among the hypotheses to be tested. For example, if certain classification variables have logical priority in a theoretical or causal sense, their effects can be tested disregarding secondary factors and then the effects of secondary factors tested after adjustment for the primary factors. One may wish to order the effects to be tested in terms of *a priori* probabilities of significance, testing first the effects, which are expected to be the strongest and subsequently the weaker effects to determine whether they add anything.

The method has a pronounced advantage in minimizing the possibility that significant effects will cancel one another. Because of the following reasons this method has been used. The designs proposed to be developed in the present work are expected to be unbalanced ones, i.e., the factors will have unequal number of observations in each of the factor levels. Since the number of observations in each class intervals are to be obtained from the data of sample units surveyed, it is difficult to obtain equal number of units in each class. For example, if the class intervals are to be based on technology level, it becomes practically difficult to ensure equal representation of units in all the groups. Also, we expect it to be possible to arrive at an *a priori* ordering of the various factors influencing the variations in the dependent variables based on the relative importance of the factors.

3.2.7 ANOVA Model

In the present analysis, for simplification, the ANOVA model is explained for a two-factor study. Let A and B be the two factors and the model is given by

$$X = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

Where,

X = Dependent variable

μ = Grand mean

α_i = The main effect of factor A at the i^{th} level (deviations of row means about the grand mean), subject to the restriction $\sum\alpha_i = 0$

β_j = The main effect of factor B at the j^{th} level (deviations of column means about the grand mean), subject to the restriction $\sum\beta_j = 0$

$\alpha\beta_{ij}$ = The interaction effect when factor A is at the i^{th} level and factor B is at the j^{th} level (deviations of the cell means about row and column effects), subject to the restrictions $\sum_i \alpha\beta_{ij} = 0$ and $\sum_j \alpha\beta_{ij}$

ε_{ijk} = Random error: n $(0,\sigma^2)$ and independent

$i = 1, \ldots\ldots, a; j = 1,\ldots\ldots\ldots\ldots, b; k = 1,\ldots\ldots\ldots\ldots,n$

3.2.8 Identification of Abatement Measures and Estimation of Cost Implications

The third objective deals with the exploration of opportunities and identification of appropriate measures to reduce environmental pollution and estimate its cost. The abatement measures encompass five generally applicable prevention practices: product modification, technology modification, input substitution, good housekeeping and on-site recycling. This is to be done through the information gathered through the questionnaire, literature review and discussions with the experts.

The fourth objective deals with the development of an appropriate methodology to evaluate the cost and benefits of the measures taken to minimize the environmental impacts. Estimated costs will be in terms of cost of abatement measures (capital and operating), cost of existing and proposed scenarios, cost of externalities, etc. The benefits will be cost savings if any, reduced energy and production costs, societal benefits due to reduced environmental damages, etc. Using this information, ranking of these measures will be done.

3.2.9 Policy Framework

The results of previous analyses along with literature survey, discussions with experts, etc., will enable us to propose alternative policy framework to reduce the impacts of environmental emissions. This may facilitate the policy makers to formulate an appropriate strategy to promote environmentally sound, economically competitive small-scale industrialization.

3.3 Background of Small Industry Clusters

It is essential and appropriate to understand the background of the four small industry clusters chosen for the study. The background is presented particularly in terms of its origin, nature and size and its importance in the region.

3.3.1 Brick and Tile Industry Cluster, Malur, Kolar District

Malur is one of the eleven taluks in Kolar district. Kolar district is located in south east Karnataka bordering Andhra Pradesh in the north and east, Tamil Nadu in the south and Tumkur and Bangalore rural districts of Karnataka in the west.

Malur is well known for the availability of abundant amount of clay. Clay is excavated from a number of irrigated tank beds in the area. These tanks hold ample reserves of clay highly suitable for tile and brick industries. This clay is also known as Chinese clay, which has got powerful plasticity and it can withstand any form of weather conditions. This plasticity is the main requirement for the manufacturing of the tiles and bricks. This is the main reason for the emergence of bricks and tiles cluster in and around Malur. Today, Malur has more than 150 units engaged in the manufacturing of bricks and tiles. Thus, it is a horizontal medium sized cluster and most of the units market their products in/through Bangalore city, which is hardly 50 Kilometers away from Malur.

3.3.2 Silk Reeling Cluster, Ramanagaram

Sericulture industry, which comprises silk reeling, among others, is one of the most important traditional industries of Karnataka (Government of Karnataka, 1996). Karnataka is the leading centre of sericulture in the country. Silk reeling activity in sericulture inter links cocoon production with production of raw silk. There are several centres of silk reeling and weaving in Karnataka. Ramanagaram in Bangalore rural district is one of the important centres of silk reeling in the state.

Silk reeling units are of three kinds (i) Charakha units-the most traditional one, (ii) Cottage units and (iii) Multi-end units-the most sophisticated machinery based unit. There are about 1500 silk reeling units in Ramanagaram, out of which 27 units are multi-end and the rest are accounted, approximately equally, by charakha and cottage units (About 700 each). Ramanagaram is also the centre for many raw silk weaving units having links with silk reelers. Thus, Ramanagaram is a large sized vertically integrated small industry cluster.

3.3.3 Puffed Rice Industry Cluster, Davangere

Davangere city is the head quarters of the newly created Davangere District and is a major commercial centre in central Karnataka. It was known for the concentration of textile mills in the post independence era. However, due to various factors, these textile mills declined gradually and steadily. But it is found that the city is also known for the concentration of puffed rice manufacturing units particularly in a single location on its outskirts. There are about 600 puffed rice-manufacturing units situated in a single cluster, which is the largest of its kind in Karnataka.

According to the officials of the District Industries Centre, Davangere, this cluster alone meets 90% of the demand for puffed rice in the state. The units are, more or less, of uniform size and could be categorized as a horizontal, large sized small industry cluster.

3.3.4 Foundry Industry Cluster, Belgaum

Belgaum city is the headquarters of the Belgaum district, located in northwest Karnataka bordering Goa in the west, Maharashtra in the north, and surrounded by Bijapur, Bagalkot, Gadag, Dharwad and Uttar Kannada districts of Karnataka in the east and south. Belgaum is one of the industrial centres in the northern Karnataka. The region is particularly known for the location of foundry industry. It has a history of more than 50 years old. The foundries of Belgaum are known all over India and even abroad for their quality casting and competitive pricing. Belgaum has about 150 foundries ranging in capacity from a few tons/month to 2000 tons/month, producing both ferrous and non-ferrous castings. Thus, it is a medium sized horizontal cluster. Out of the 150 foundries, about 60 units are clustered in a radius of half a kilometer in Udyambag industrial area on the outskirts of Belgaum.

The castings produced are for a very wide range of applications and weighing from a few grams to few tons per piece. The specialty of foundries is their ability to promise castings as per the customer requirements at a very competitive price. This is the reason for Belgaum foundries having a special status in foundry industry. Major portion of castings is supplied to Bangalore, Chennai, Pune, Mumbai, Delhi and many other places. The Belgaum foundries are all in small-scale sector except one unit, Ashok Iron Works Ltd., which is the biggest foundry in Belgaum and in fact, in Karnataka.

The Belgaum foundries produce about 6000t/month of castings. They employ about 10,000 workers directly and provide employment to an equal number indirectly. This industry is one of the mainstays of economy of this region. The work force available in and around is highly skilled and this is the main reason for foundry industry coming to this region. The foundry industry in Belgaum has its problems, which hinders its further growth. The problem of infrastructure is very much evident. There is shortage of electricity, water, good roads, industrial plots and so on. The foundry industry here is in a peculiar situation. Most of the units, being in the small-scale sector, have limited resources. They are on the lower-end of technological development. Very few foundries have the technical expertise to achieve the technical specification being now demanded by the customers.

Thus, of the four small industry clusters chosen for the study, three are horizontal clusters and only one is a vertically integrated cluster. Of the three horizontal clusters, two are medium sized and one is a large sized cluster. But for foundries, all are traditional clusters and use primarily labour intensive techniques in its manufacturing processes. Given this, it is pertinent to understand the pollution profile, causal factors, viable measures for pollution abatement, etc. in the case of each of these clusters.

CHAPTER 4: BRICKS AND TILES INDUSTRY CLUSTER – MALUR, KOLAR

4.1 Introduction

The ever-growing population along with rapid industrialization and urbanization process necessarily demands millions of new buildings and houses every near. This has made the construction activity as one of the most flourishing businesses in India. It is being said that currently India has a shortage of 18 million houses (Kumar, *et al*, 1999). Because of these reasons building materials industry is a rapidly growing sector in India. The building materials industry in India is a major user of natural resources, energy, labour and capital. The construction sector is responsible for 22 per cent of all India's CO_2 emissions. The major energy users in the building materials industry are the producers of cement, bricks, steel, and lime, which together contribute 80 per cent of the construction sector's total CO_2 emissions. Current demand for these four materials requires 743 PJ of energy, which translates into 81 million tones of CO_2 emissions per year (Kumar, *et al*, 1999).

Burnt bricks remain one of the most important building materials in India. Brick making is a traditional industry, generally confined to rural and semi-urban areas. According to one source, there are around 30,000-50,000 brick making units in the country producing about 50 billion bricks per year (Climate Change-India, 2001). The same source points out that the production of burnt bricks account for 27% of the total national energy consumption for the production of construction materials. However, according to Pandey (2001) about 60 billion bricks are used every year for housing purposes alone. According to him, this would consume 160 million tonnes of topsoil, rendering barren about 3,050 hectares of fertile land. Further, he writes that currently, the brick kilns consume about 15 million tonnes of coal per year. In addition, brick production in the traditional sector consumes about 10-12 million tonnes of biomass, mainly firewood. The fuel cost alone accounts for about 37 per cent of the total cost in brick making.

The above discussion clearly indicates that brick making is an energy and pollution intensive manufacturing process. Brick making involves three main processes of shaping the bricks from soil, drying and firing in kilns. Firing in kilns is the main energy intensive process during brick making. The most conventional types of kilns are rural clamps, which use energy in the range 5 – 11 MJ/brick. The Bull trench kilns, which are found in the organized sector require on an average 4.2 MJ/brick of energy. The latest technology for firing bricks is Vertical Shaft Brick Kiln (VSBK) where the energy consumption norm is 1.98 MJ/brick (Kumar, *et al*, 1999). Except for the VSBK technology, the other two types of technologies are being used in the brick and tile cluster in Malur.

4.2 Technologies of Brick and Tile Manufacturing (Firing)

In the Malur cluster, majority of the units use Intermittent Downdraught Kiln (IDK) technology for firing bricks. Locally, these kilns are referred to as Arch Kilns because they resemble arch type of structure. A small minority still uses the conventional rural clamps technology. But no unit in Malur uses the latest Vertical Shaft Brick Kiln (VSBK) or continuous type Bull's trench kiln (BTK) technology for bricks manufacturing. These four technologies are briefly reviewed in the following sections (Brick Clamps, 1995; IDK, 2002; BTK, 1995; VSBK, 1995).

4.2.1 Rural clamps or Brick clamps

The use of brick clamps is by far the oldest and most rudimentary method of firing bricks. As a method of firing bricks it is still used all over the world because it still has several advantages over more modern and sophisticated methods. The main advantages are because of their versatility and low cost, especially where labour is cheap. This is despite the clamp being potentially the least energy efficient method of firing. This is because so much of heat is allowed into the atmosphere during both firing and cooling, and fuel combustion is both uncontrollable and inefficient.

Rural clamps are usually constructed on a level surface of pre-fired bricks, laid side by side for a wood fired clamp, or with spaces between them for a coal, agri-waste or fuel inclusion fired clamp. These Spaces around the bricks are 2 to 2.5 cm wide. Bricks are set up to 40 layers high. The bricks are placed on top of each other for the first 8 to 12 layers, above which each layer is inset by 2 to 3 cm, so that clamp tapers towards the top. The tapering produces greater clamp stability, which is important as the whole structure will move with the expansion firing. For greater stacking stability, clamps can be built on ground with the center of the site has been scooped out to a depth of 30 cm.

Advantages

- They are cheap and straightforward to build. There is no permanent structure to install and maintain.
- They can be built next to the supply of clay and fuel, so that transport costs can be kept at the minimum.
- They can be of any size ranging from 5000 to 100000 bricks at a time, which would enable them to accommodate fluctuations in brick production.
- Clamps can be fired with a large variety of fuels, including agriculture waste such as rice husk, coffee husk, sawdust, coconut husk as well as fossil fuels.

Disadvantages

- They are very labour intensive, being assembled and disassembled by hand and if not built correctly and fired badly, can result in a very high percentage of incompletely fired bricks.
- They are very slow to fire, taking several days to heat up and cool down and there is a little or no control over firing once it has started.
- They are highly susceptible to the prevailing weather conditions, especially strong winds which result in a very uneven firing, with many more under fired and over fired bricks.

4.2.2 Intermittent Downdraught Kiln (IDK)

This is a conventional batch process type of kiln used for brick/tile firing. In this technology a vault is made to hold and fire the bricks. There is a Chimney to create draught. The typical Chimney height is between 40 –70 feet. Coal or biomass is typically used for firing the kiln. The capacity per batch is between 20000 to 40000 bricks.

The downdraught kiln is far more efficient than the updraught or clamp type of kilns. Firing is much easier to control. They are often arch type in structure with multiple fire holes. Inside the fire holes are baffles or 'bag' of firebricks. It had a domed roof and a perforated floor under which ran a flue leading to the chimney stack. Depending on the size of the kiln the capacity varies from 20,000-40,000 green bricks per batch. Coal or biomass is lit inside the fire hole grates and hot gases are directed upward from the baffles and then downwards from the underside of the dome and through the stacked bricks by the draught from the chimney. Altogether it takes fourteen days or so to operate, with two days for loading or setting, three days for 'curing', two days for heating to full temperature, one day at full heat, then another three or four days to cool down and a further day to unload or draw.

In the case of a downdraught design the chimney serves a more specific function. The hot gases rise naturally to the crown of the chamber from which point they must be drawn back down through the setting to the exit flue in the kiln floor. To create the necessary pull a chimney is required. The relevant areas of fire boxes to chamber floor and exit flue, together with chamber height, flue length and chimney height are critical factors in the performance of a downdraught kiln. Although the chimney must be tall enough to create the necessary pull, if it is too tall it will increase the gas velocity inside the chamber lowering rather than increasing the temperature.

Advantages

- Low initial investment and medium capacity
- Far more energy efficient compared to updraught type kilns
- Firing is easy to control

Disadvantages

- Since they are produced in batch mode, they take significant time to heat up and cool down.

4.2.3 Bull's trench kiln (BTK)

These kilns are made either circular or elliptical in shape. They are constructed on dry land, by digging a trench of the size of 6 to 9 m wide, 2- 2.5m deep and 100-150m long. The green bricks to be fired are set in rows, two to three bricks wide, with holes in between that allow feeding of coal or biomass and sufficient flow of air through the setting. On top of the bricks, two layers of bricks are covered with ash or brick dust to seal the whole setting. The trench normally contains 200 to 300000 bricks at a time.

Traditionally, BTKs were used to fit with moving metallic chimneys. However due to the unacceptably very high emission levels from these moving chimneys, the environment standards of 1996 banned their use and stipulated that they be replaced with fixed chimneys (TERI, 2001).

The firing in a Bull's trench kiln is continuous, day and night. Green bricks are loaded and finished bricks are drawn all the time. The fuel saving is achieved mainly by reusing part of the energy which is going to be wasted in other types of kilns.

Advantages

- Low initial investment and high capacity
- More fuel efficiency compared to rural clamps

Disadvantages

- The kiln is fired continuously and has to be loaded with a constant number of bricks every day. This demands a good organization of the brick production, which cannot be easily adjusted to fluctuations in the brick market.
- The firing crew needs long time experience.

4.2.4 Vertical Shaft Brick Kiln (VSBK)

This technology, which originated in China, is expected to dominate small-scale brick manufacturing in the future. It is a revolutionary type of brick kiln, combining the simplicity and low cost of updraft firing with very impressive fuel economy plus the benefits of continuous operation.

With a roofed and buttressed rectangular support building, VSBK is a well-insulated firebrick lined firing shaft, which is open at the bottom. This shaft is approximately 6.5 meters in height with the central four meters being lined with a single layer of firebrick. Bricks and coal, in a batch at a time are loaded at the top of the shaft, with coal fines being sprinkled among the green bricks one layer at a time.

In a single wider shaft kiln, each batch of bricks is made up of four layers making a total of 320 bricks and the shaft holds twelve batches to give a firing capacity of 3840 bricks every 12 hours. The bottom layer of bricks in each batch which is the first loaded, consists of 68 bricks, arranged in 7 rows to provide six open channels running across the firing shaft. These channels are provided to allow the placement of the steel beams that support the bricks in the kiln. The second layer of 84 bricks is placed in right angles to the first layer bridging the channels. The third and fourth layers, each of 84 bricks, are added at alternating right angles to make up a complete batch. The bricks in each layer are carefully spaced apart to provide a gap of 1 to 1.5 cm around each brick. Coal is spread evenly on top of each layer of bricks, except the first layer with cross channels.

The kiln is started by lighting a fire with wood among the bricks at the bottom of the shaft. The fire moves up the bricks and coal in the shaft until it reaches the middle. At this point a batch of fired bricks is removed from the base of the shaft and fresh batch of green bricks and coal is loaded at the top.

Advantages

- Highly energy-efficient method for firing bricks. This technology results in an energy saving of more than 50% compared to clamps and 30% compared to BTKs.
- The kiln is very compact for the same production capacity, VSBKs need only a quarter of the land required by BTKs.
- Easy to operate and does not require electricity for functioning.
- VSBK is not affected by variations in weather. It can be operated during monsoon because, unlike other traditional kilns, VSBK has a roof, which affords protection from rain and allows year-round operations.

Disadvantages

- It is a new type of kiln and method of firing bricks that has only recently been introduced to countries outside China. Despite there being thousands of this type of kilns operating in China, the technology has not yet been adopted anywhere else on a large scale.
- The kiln requires good quality green bricks because they have to be able to withstand being stacked 5 metres high in the firing shaft.

4.3 Brick Making Units in Malur, Kolar District: Characteristics

A total of 45 brick making units in Malur have been covered for the study. Brick making is one of the traditional industries in rural India. However, majority of the sample units (36 out of 45 units) are newly started ones, either individually or as a partnership, by their owners. Only the remaining 9 units are the inherited ones by their owners from their elders. Because majority of the 45 units are newly started units, most of these units, i.e., 25 of them have come up in the 90s or thereafter.

The very fact that it is a traditional industry, the level of education of the entrepreneurs is quite moderate. Owner entrepreneurs of 10 of the 45 units are either uneducated or had only primary school education. Owners of another 13 units had educational qualification ranging from secondary school up to intermediate education. The owners of the remaining 20 units are either diploma holders (4 units) or graduates (14 units)/double graduates (2 units) or post graduate (one unit).

One major advantage of clustering of enterprises is that it gives scope for interaction and even joint action. However, interaction is a pre-requisite for any kind of joint action. Further, interaction helps in the flow of information related to different issues concerning a unit such as technological, marketing, finance, etc. Interaction can take place horizontally among the brick manufacturers themselves or vertically, i.e., between brick manufacturers and material suppliers/ agents who supply the manufactured bricks to the market. Majority (60 percent of the 45 units) has interaction of one kind or the other.

Owners of eight units interact only with the fellow brick manufacturers whereas those of 19 units do interact not only with other brick unit owners but also with material suppliers/ agents who supply bricks to markets. Surprisingly, owners of the remaining 18 units (40 percent) do not have any interaction of any kind.

Irrespective of the level of education of owners and the nature of origin of units, 40 of the 45 units use exclusively IDK technology for bricks and tiles making, two units have only rural clamps and other three units use a combination of IDK along with rural clamps and intermediate technologies respectively. The only unit, which has BTK technology along with IDK has not yet started production through BTK mode. Thus, by and large, IDK technology is the technology in use in this brick manufacturing cluster.

The sources of energy used by these units include branches and leaves of eucalyptus trees, firewood and coal. While rural clamps (in three of the 45 units) use only firewood, IDK technology based units use both eucalyptus and firewood as fuel. One of the units based on rural clamp, in addition to firewood, used coal as fuel.

Brick making is one of those economic activities, which absorbs both skilled and unskilled labour force, more or less, in an equal proportion. The 45 units together, have employed 527 skilled workers, including supervisors and 463 unskilled workers. The initial investment in plant and machinery ranged from Rs.5000/- for a unit started in 1962 to Rs.12,75,000/- for a unit started in 2001. Therefore, all these units come under the category of 'tiny units' as their initial investment did not exceed the current investment limit of Rs.2.5 million.

What is equally important is the general environment of a brick-making unit as it has environmental implications. This comprises layout of the unit, ventilation design and condition, plant condition and house keeping, condition of the building, and storage environment of the bricks. When we ranked the 45 units on a scale ranging from 1 (for very good) to 5 (for very bad implying threat to health and safety), (based on the physical observation of the units) we found that, on an average, as many as 60 percent of the units could be ranked 3 (average, i.e., no immediate problem as far as safety is concerned). About 30 to 35 percent of the units have been ranked 4 (accidents may happen). Only about 5 percent of the units had a reasonably safe condition in the units. However, as far as emissions are concerned, we have observed it in all the 45 units and dust pollution in 43 of the 45 units. Water contamination is observed in 29 of the 45 units. Ash and waste bricks/ tiles are dumped in one of the corners of the units. But ash is generally taken away by farmers and/ or agarbathi manufacturers whereas broken bricks/ tiles by villagers for some nominal amounts, once in six months. Thus, on the whole, it is 'air pollution' that is caused by brick making units in Malur.

4.4 Brick Making Units: Extent and Dimensions of Environmental Pollution

The summary data for the quantity of raw materials, energy inputs and outputs for the 45 brick units in Malur is presented in Table 4.1. The raw materials are clay and sand, energy inputs are eucalyptus, firewood and coal, and outputs are bricks and tiles.

The total cost of transportation of material inputs, total costs of lubricants, energy inputs, labour, electricity and administration are presented in Table 4.2. On an average, cost of energy inputs (excluding that of coal) account for more than 40 percent of the total production cost, excluding cost of capital and depreciation. This brings out that brick and tile manufacturing is an energy intensive industry.

Given the energy inputs and energy intensity of the units, the possible emissions that would emerge from the different energy inputs per tonne, from these units in the process of brick and tile manufacturing are given in Table 4.3. While coal usage results in the generation of relatively more SO_2, NOx and N_2O, firewood and eucalyptus usage causes CO, CH_4 and TSP. Environmental pollution per tonne is more in the case of firewood as compared to eucalyptus. The usage of coal, in addition to others, causes CO_2 emission (but this is not significant, because only one unit uses coal). The figures of Table 4.3 are standard parameters. It is based on these parameters that we tried to estimate the pollution generated by the brick and tile units in Malur in one year. In absolute figures, it is Carbon Monoxide (CO), which will be generated the most by using one tonne each of firewood and eucalyptus whereas carbon dioxide will be the maximum if coal is used. CO_2 emissions from biomass (firewood and eucalyptus) are not accounted in our analysis. This is done with an assumption that equal amount of CO_2 has been absorbed by the trees from which this biomass has come. One more implicit assumption is that both firewood and eucalyptus leaves are produced in a sustainable manner.

The estimated pollution in terms of generation of wastes such as broken tiles and bricks and ash as well as the different kinds of gases can be seen in Table 4.4. As firewood and eucalyptus are the prominent energy inputs used by majority units, and CO is the highest generated gas per tonne of each of these inputs, followed by TSP, NOx, SO_2, CH_4 and N_2O, the total pollution generated by all the 45 units in terms of these gases also follow the same sequence. The same holds good for the average emissions per unit of output (Table 4.4) as well as emissions per 1000 bricks (Table 4.5). On the whole, CO and TSP are the major forms of environmental pollution generated by the brick and tile units in Malur in the process of consumption of firewood and eucalyptus trees. The raw material and fuel consumption per 1000 bricks is presented in Table 4.6.

Table 4.1: Summary Data for the Sample Units of the Cluster (For 45 Units)

	No. of Units	Total	Average/Unit	Standard Deviation
Clay (Loads/Year)	45	23,331	518.47	325.81
Sand (Loads/year)	45	2,246	49.91	44.69
Eucalyptus (Tonnes)	38	18,888	497.05	317.32
Firewood (Tonnes)	24	9,963	415.13	280.21
Coal (Tonnes)	1	70	70	0
Total Fuel (GJ)	45	343,501	7,633	4884.53
Bricks (Thousands)	42	36,900	879	640.23
Tiles (Thousands)	12	9,650	804	354.5

Table 4.2: Production Cost Details per Year (Rs.)

	Total	Average/Unit	Standard Deviation
Cost of Clay (Transportation)	6,532,680	145,171	91,226
Cost of Sand (Transportation)	786,100	17,866	15,592
Lubricant Cost	741,250	61,771	34,528
Eucalyptus	6,610,800	497,053	317,315
Firewood	5,977,800	249,075	168,123
Coal	224,000	224,000	0
Labour	11,029,579	245,102	178,206
Electricity	1,603,000	38,167	31,255
Administration	1,723,200	43,080	85,682
Total	35,228,409	1,521,285	

Table 4.3: Emission Factors (kg/Tonne)

	Firewood	Eucalyptus	Coal
CO	15	10.2	0.71
CH_4	0.45	0.306	0.059
N_20	0.06	0.0408	0.088
SO_2	0.8	0.8	7.83
NOx	1.5	1.02	5.72
TSP	7.8	5.304	1.42
CO_2			1337.4

Note: Climate Change-India (2001), EM-1.4 (1999), IIASA (2001), IPCC (1996)

Table 4.4: Summary of Environmental Pollution Details

	Total	Average/Unit	Standard Deviation
Wastage – Bricks & Tiles (Thousands)	3826	85.02	75.08
Ash (Tonnes)	787.7	17.5	12.32
CO (kg)	342,152	7603.38	4910.79
CH_4 (kg)	10,267	228.16	147.26
N_20 (kg)	1,375	30.55	19.53
SO_2 (kg))	23,629	525.09	311.41
NOx (kg)	34,611	769.13	485.7
TSP (kg)	177,993	3955.39	2551.98
CO_2 (kg)	93,618	93,618	0

Table 4.5: Pollution Generated and Energy use per 1000 Bricks

	Average	Standard Deviation	Minimum	Maximum
Wastage – Bricks & Tiles (No.)	85.29	32.46	25.00	135.00
Ash (Kg)	19.22	10.00	5.00	50.00
CO (kg)	7.672	1.932	2.750	9.925
CH_4 (kg)	0.230	0.058	0.085	0.298
N_20 (kg)	0.031	0.007	0.013	0.040
SO_2 (kg))	0.553	0.151	0.193	0.773
NOx (kg)	0.776	0.179	0.317	0.993
TSP (kg)	3.991	1.000	1.503	5.161
CO_2 (kg)	93.618	0.000	93.618	93.618
Energy (MJ)	7702.20	1863.25	3165.88	9925.00

Table 4.6: Raw Material and Fuel use per 1000 Bricks

	Average	Standard Deviation	Minimum	Maximum
Clay (loads)	0.532	0.127	0.067	1.000
Sand (loads)	0.058	0.040	0.005	0.167
Eucalyptus (Tonnes)	0.608	0.245	0.094	0.967
Firewood (Tonnes)	0.305	0.139	0.125	0.607
Coal (Tonnes)	0.070	0.000	0.070	0.070

4.4.1 Factory and Non-Factory Brick Units: Energy Consumption and Environmental Pollution

What is important to know is that when technology-in-use is largely similar and so is the composition of labour force, whether scale of production has any implication for energy consumption/ conservation and environmental pollution. The 45 units can be classified into two groups based on Indian Factories Act, 1948:

- Units having 20 or more workers, without power, are factories: 30 units
- Units having less than 20 workers, without power, are non-factories: 15 units.

The average values for number of workers, both skilled and unskilled, output, labour cost, fuel consumption and cost, raw material consumption and cost, generation of wastes and emissions per 1000 bricks are presented in Table 4.7.

The factory sector units (having 20 or more workers) used more labour force, both skilled and unskilled and therefore, incurred more expenditure in terms of wages and salaries as compared to non-factory units. Even the raw material cost is marginally higher. What is significantly higher for factory units is “other costs” comprising administration and office maintenance costs.

However, as far as energy consumption is concerned, factory units consumed less eucalyptus but marginally more firewood. The average energy consumption is also higher in factory units than in non-factory units. The emissions in terms of CO, TSP, and CH_4 are higher in factory units whereas NOx and SO_2 are higher in non-factory units. The overall value of output (per 1000 bricks) is however, higher in factory units than in non-factory units.

These figures indicate that though factory units have larger scale of production and generate higher value of output, they consumed more clay and more energy and therefore, generated more emissions, in terms of CO, CH_4 and TSP. Of course, factory units generated less waste, in terms of ash and waste bricks/tiles.

But to understand whether scale factor can contribute to pollution abatement, another way of classifying the units is based on the value of output. This is done and the comparative figures on different variables are given in Table 4.8. The units having output value up to Rs.14 lakh (17 units) are grouped separately from (28) units having value of output more than Rs 14 lakh, which is the average value of output for the 45 units.

Table 4.7: Factory and Non-Factory Sectors - A Comparison (For 1000 Bricks)

	Average	Standard Deviation	Average	Standard Deviation
Group	**Labour (< 20) – 15 Units**		**Labour (> 20) – 30 Units**	
Average Labour/Unit (No.)	12.87	3.85	27.63	13.66
Average Skilled Labour/Unit (No.)	7.13	3.40	14.57	9.05
Average Unskilled Labour/Unit (No.)	5.73	3.15	13.07	6.42
Total Labour (No.)	0.020	0.009	0.031	0.020
Skilled Labour (No.)	0.012	0.009	0.015	0.009
Unskilled Labour (No.)	0.009	0.006	0.015	0.012
Value of Output (Rs.)	1296.26	319.25	1620.56	641.22
Labour Cost (Rs.)	202.09	74.09	228.59	65.26
Fuel Costs (Rs.)	279.78	67.02	276.59	77.95
Raw Material Cost (Rs.)	168.49	21.62	170.38	46.40
Other Costs (Rs.)	58.67	36.36	102.46	140.22
Total Cost (Rs.)	709.02	111.78	778.02	212.68
Eucalyptus (tonnes)	0.645	0.197	0.498	0.244
Firewood (tonnes)	0.248	0.093	0.285	0.141
Coal (tonnes)	0.070	0.000	0.000	0.000
CO (kg)	7.340	2.289	7.565	2.095
CH_4 (Kg)	0.220	0.068	0.227	0.063
N_20 (kg)	0.030	0.008	0.030	0.008
SO_2 (kg)	0.591	0.124	0.518	0.157
NOx (kg)	0.770	0.174	0.757	0.209
TSP (kg)	3.824	1.176	3.934	1.089
CO_2 (kg)	93.62	0.00	0.00	0.00
Total Fuel (MJ)	7462.77	2041.39	7565.12	2094.70
Ash (kg)	19.52	5.84	18.55	9.91

	Average	Standard Deviation	Average	Standard Deviation
Waste Bricks/Tiles (No.)	93.30	34.33	79.52	31.69
Clay (Loads)	0.526	0.045	0.540	0.142
Sand (Loads)	0.061	0.045	0.054	0.041

It is clear that units of larger output group used less labour, skilled as well as unskilled and therefore, incurred less expenditure, in terms of wages and salaries. These units consumed less eucalyptus but more firewood than the units of smaller output group. Further, larger units consumed less raw materials and less energy per 1000 bricks. Therefore, their total cost is lower than that of smaller units, even though other costs are higher. The wastes generated in the form of broken bricks/ tiles and ash as well as emissions such as SO_2, NOx and TSP and lower in larger output units. CO is marginally higher in larger units. But the value of output is significantly higher for larger units than the smaller units.

On the whole, it brings out that the size of brick units, as reflected in the value of output, has some implications for environmental pollution abatement. The larger units consumed less labour, less raw materials and less fuel and therefore, incurred less cost per 1000 bricks, but realized more value of output. What is more important is that the emissions emerging out of larger units, on an average, appeared less.

To further ascertain whether there is any negative relationship between size of output and energy consumption per unit of output, which, inturn, causes pollution, we conducted correlation analysis. The correlation co-efficient value is –0.208. Of course, the value is not statistically significant but it does indicate that energy consumption and environmental pollution are likely to be less, if a unit produces more output by expanding the scale of production, provided the technology-in-use is similar.

Thus, our analysis on brick and tile units cluster in Malur bring out that the cluster does cause environmental pollution in the local region. The technology-in-use is similar and the educational background of entrepreneurs did not exceed graduation, in general. The general environment of the unit premises did not appear clean and the owners have not taken any concrete measures to keep the premises clean nor to control the pollution in the local region. The owners are aware of superior VSBK technology, which is said to be ‘more energy efficient’ and causes ‘less pollution’.

Table 4.8: A Comparison with Size of Value of Output (For 1000 Bricks)

	Average	Standard Deviation	Average	Standard Deviation
Group	**Value of Output (> 14 Lakh) – 17 Units**		**Value of Output (< 14 Lakh) – 28 Units**	
Average Value of Output/Unit (Rs.)	3,007,059	1,019,312	789,643	275,325
Total Labour (No.)	0.019	0.008	0.032	0.017
Skilled Labour (No.)	0.010	0.006	0.017	0.009
Unskilled Labour (No.)	0.009	0.005	0.016	0.010
Value of Output (Rs.)	1886.47	656.67	1289.01	359.91
Labour Cost (Rs.)	235.62	89.21	249.32	84.14
Fuel Costs (Rs.)	290.03	69.86	277.23	62.65
Raw Material Cost (Rs.)	150.70	51.31	179.14	31.14
Other Costs (Rs.)	108.82	108.84	88.04	115.40
Total Cost (Rs.)	785.17	142.37	793.73	196.45
Eucalyptus (tonnes)	0.413	0.250	0.697	0.188
Firewood (tonnes)	0.355	0.146	0.221	0.073
Coal (tonnes)	0.000	0.000	0.070	0.000
CO (kg)	7.674	1.879	7.671	1.998
CH_4 (Kg)	0.230	0.056	0.230	0.060
N_20 (kg)	0.031	0.008	0.031	0.008
SO_2 (kg)	0.484	0.146	0.594	0.140
NOx (kg)	0.767	0.188	0.781	0.176
TSP (kg)	3.990	0.977	3.992	1.032
CO_2 (kg)	0.000	0.000	93.618	0.000
Total Fuel (MJ)	7673.71	1879.04	7719.50	1887.98
Ash (kg)	14.02	6.93	22.38	10.35
Waste Bricks/Tiles (No.)	70.08	32.05	94.84	29.36
Clay (Loads)	0.488	0.156	0.559	0.101
Sand (Loads)	0.040	0.037	0.067	0.039

But, except one, none of the owners are keen to shift to this superior technology, as the investment requirements are substantially high. Therefore, given the circumstances, the one feasible way to go for pollution abatement is to encourage the expansion of existing units rather than permitting the establishment of new units in the region.

4.5 Comparison of Various Estimated Parameters Across Groups Based on Energy Consumption Level

To study how the different parameters vary on an average with the change in energy consumption levels, we equally grouped the 45 brick and tile units into low, medium and high energy consumption per brick groups. This resulted in 15 units in each of the three groups. Table 4.9 contains the details of various estimated parameters for a production level of 1000 bricks. The average fuel required for producing 1000 bricks for the three groups respectively is 5500 MJ, 8150 MJ and 9457 MJ. This clearly shows that, the brick and tile cluster in Malur exhibit significant variations in energy consumption norm. From the table, it may be observed that most of the parameters tend to get worse with the increase in the level of energy consumption. This may be an indication that the unit, which is energy inefficient, is also inefficient in terms of the whole production process. The share of skilled labour in total labour, decreases with the increase in energy consumption. The opposite is the case with the unskilled labour. Only in the case of number of waste bricks per 1000 bricks, the trend is opposite where it is decreasing with increase in energy consumption. One possible reason could be that over use of fuel has resulted in better burning of bricks and thereby resulting in reduced wastages.

Even this comparative analysis suggests that there may be factors other than technology, causing variations in the energy consumption. This is because majority of the units in Malur use IDK technology, which should not have resulted in this kind of variation. Therefore, to study whether there is any influence of other factors on the level of energy consumption, we have carried out analysis using ANOVA technique.

Table 4.9: Comparison of Various Parameters for Different Group of Units based on Energy Consumption Levels (For 1000 Bricks)

	Low Energy	Medium Energy	High Energy
Total Fuel (MJ)	5499.83	8149.86	9456.90
Skilled Labour (No.)	0.0122	0.0127	0.0160
Unskilled Labour (No.)	0.0082	0.0144	0.0179
Labour Cost (Rs.)	243.74	249.32	263.50
Total Cost (Rs.)	681.76	816.47	897.39
Ash (kg)	14.87	21.13	21.67
Waste Bricks/Tiles (No.)	97.75	82.49	76.22
Fuel Cost (Rs.)	212.92	291.48	341.81
Eucalyptus (kg)	429.81	686.72	673.62
Firewood (kg)	273.95	297.04	338.23
Coal (kg)	70	0	0
CO (kgs)	5.41	8.15	9.46
CH_4 (Kgs)	0.16	0.24	0.28
N_20 (kgs)	0.022	0.033	0.038
SO_2 (kg))	0.41	0.59	0.67
NOx (kg)	0.57	0.81	0.95
TSP (kg)	2.82	4.24	4.92
CO_2 (kg)	93.62	0	0

4.6 Factors for ANOVA Analysis in Bricks and Tiles Cluster

From the discussions presented in the methodology, it is clear that, we are attempting to model the variations in energy consumption and thereby pollution level through its relationship with human resource, technology and external & structural factors. This relationship is being established using ANOVA method.

4.6.1 Human Resource Factors

As described in the methodology, we considered three variables, Owner/Manager/ Supervisor qualification levels, labour set skill levels and value of labour.

i) *Owner/Manager/Supervisor Qualification Level:* In brick industry cluster at Malur, it has been observed that it is a common practice that the owner himself manages the whole unit. The units have been grouped into three levels based on the qualification of owners. The units with owner having education up to primary level, secondary and pre-university level and graduation level have been grouped respectively as low, medium and high qualification groups.

ii) *Labour Skill Level:* Three levels – low, medium and high – are used in the ANOVA analysis. The ratio of number of skilled labourers to the unskilled labourers has been used as a basis for arriving at these skill levels. We grouped the units having a ratio of below 1 in the low, between 1 and 1.25 in the medium and above 1.25 in the high skill level class interval.

iii) *Value of Labour*: The value of labour has been estimated using the annual cost per labour. Again three levels are identified with the units where the value of labour is up to Rs. 8,000/year are grouped into low, between Rs. 8,000 to Rs. 12,000/year into medium and above Rs. 12,000/year into high level of value of labour.

Further, to ascertain the importance of each of the variables in explaining the variations in the dependent variable (energy consumption per brick), we performed simple One-way ANOVA. This resulted in the variable labour skill level to be the most important variable in explaining the variations in the dependent variable. The owner/manager qualification level found to be the second most significant variable. However, the variable on value of labour found to be not significant and therefore not considered for further analysis. Since both the labour skill level and owner qualification level variables are found to be significant, we decided to include them separately in the overall model for explaining the variations in the dependent variable rather than merging them into single human resource factor.

4.6.2 Technology Factors

Under technology factor, we have considered three factors based on Production Technology (Technology Level) being used, Age of Plant and Machinery and other Innovations and Modifications carried out in the unit.

i) *Technology Level*: Technology levels are identified based on the kind of moulding technology in use, type of kilns used (rural clamps, intermittent downdraught kilns and mixed) and product types (only bricks or both bricks and tiles). Each of these variables is assigned with scores ranging from 1 to 4. These individual scores have been summed up to obtain the total score for the technology factor for each unit. Then the individual units are grouped into three technology factor levels. The units having a total score in the range of 2-4 as low, of 5 to 6 as medium and of above 6 as high technology level group.

ii) *Age of Plant and Machinery*: The units are classified into three groups, the first one with plant & machinery of above 10 years old, second with plant & machinery of 5 to 10 years old and third group with plant & machinery of up to 5 years old.

iii) *Other Innovations/Modifications*: Since the units are not doing any kind of innovations we did not include this variable in the analysis of brick and tile cluster.

The simple one-way ANOVA analysis between each of these variables and the energy consumption per brick variable resulted in only technology level variable to be significant in explaining the variations. The other variable, age of plant and machinery found to be not significant therefore excluded from further analysis.

4.6.3 Structural and External Factors

i) *Age of the unit*: Here the units are classified into three groups based on the year of inception. Units with an age of 16 years and above, between 10 and 16 years and up to 10 years have been classified into groups 1, 2 and 3 respectively.

ii) *General Environmental conditions*: The project team members' observation on each of the items in the general environment related questionnaire enabled us to generate unit-wise total scores indicating the level of environmental conditions. Based on the total scores obtained, each unit has been categorized into good, average and bad in terms of general environmental conditions.

iii) *Interaction Levels*: Based on the responses given by the units to the different types of interaction related questions, the total score for each unit is obtained.

Using these total scores, the units have been grouped into high, medium and low interaction level categories.

All the three variables in combination, reflect the unit's overall ability to accept challenges, gather information, willingness to innovate and implement, present a modern outlook and express concern for the environment. Therefore, we decided to combine these variables into one external and structural factor for including in the model. The original groupings of the units based on the individual variables have been aggregated to form the combine groupings. In other words, the units have been grouped into high, medium, and low levels based on the total scores under a single external and structural factor.

4.7 Results and Discussion

To study the influence of the above factors on the energy consumption levels forms the basic purpose of ANOVA. The dependent variable considered here is energy consumption per brick. Even though, the brick & tile industry in Malur produces tiles along with bricks, we have combined the two and reported it as total bricks produced. This is because, both tile and bricks are approximately similar in terms of weight (around 3 kg), material and energy use and cost requirements. Only difference is the sales price per unit where a brick is priced at Rs. 1.2 per unit whereas a tile is priced at Rs. 3.0 per unit. Also, we could not separate most of the information in relation to brick and tiles. In addition, we have also attempted to study the ability of considered factors in explaining the variations in value of output per 1000 bricks and total cost per 1000 bricks across.

i) Relationship between Factors and Energy Consumption

As proposed in the methodology, we have used *sequential sums of squares method* for the analysis of variance to explain the relationship between the considered factors and dependent variables. This method is appropriate because the design used here is an unbalanced one. First condition of this method is *a priori* ordering of the factors. The preliminary analysis attempted revealed that in terms of technology levels there is not much to differentiate among various units. Majority of the units use IDK technology except for a few which use rural clamps. The only thing we could observe is that many of the units have attempted one or the other kinds of minor technology alternatives in the production process. However, the analysis clearly showed that variations in energy consumption per brick is significant even among the units which use the same IDK technology. This shows that the factor effecting this variation has to be other than the technology factor. Therefore, we felt that labour skill levels may be the most significant factor causing this variation. To prove this we ran one-way ANOVA (one factor and one dependent variable) with each of the factors and energy per brick as dependent variable. Then the factors are ordered according to the level of each factor explaining the variations in the energy consumption. This resulted in the ranking of factors in order of labour skill level, technology level, structural and external factor and owner qualification. In the same order, the factors have been used for ANOVA with different dependent variables.

The details of the final factors/variables considered for the analysis and the type of classifications made and the number of units in each of the groups are presented in Table 4.10. From the table one could observe that the analysis design is an unbalanced one because the cell frequencies (number of units in each group) are unequal. Using the SPSS (Statistical Package for Social Sciences) software, the ANOVA has been carried out.

Table 4.10: Factors Considered for Univariate ANOVA

Factors	**Levels**	**Classes**	**No. of Units in each Class Intervals**
Labour Skill Level	Low	1.00	14
	Medium	2.00	16
	High	3.00	15
Technology Level	Low	1.00	5
	Medium	2.00	25
	High	3.00	15
Structural and External Factor	Low	1.00	15
	Medium	2.00	18
	High	3.00	12
Owner Qualification Level	Low	1.00	12
	Medium	2.00	19
	High	3.00	14

As described earlier, the pollution in the brick and tiles industry is mainly due to the energy use for brick burning. Therefore we started with the analysis of variation in energy consumption with the above factors. Thus, the dependent variable for the model is energy consumption per brick produced. The results of this analysis are presented in Table 4.11. The table mainly contains the information on the total sum of squares (total variance in the dependent variable), how much of sum of squares is accounted by the main effects of the considered factors, the sum of squares accounted by the interaction among the variables, unaccounted variance (error term) and R-square (percentage variance explained by the model).

From Table 4.11, it appears that all the four factors significantly explain the variations in the energy/brick variable. However, the variable labour skill level explains maximum amount of variation, followed by technology level. The other two factors structural & external and owner's qualification explain relatively less amount of variations but they are significant to include in the model. It appears from this analysis that the labour skill levels and technology levels are the most important factors, which determine the level of energy consumption.

Further, the interaction effects appear to provide some useful insights into the relationship with energy consumption. The interaction effects of labour skill and technology level by structural and external factor are significant in explaining the variance in energy consumption. The interaction effects are difficult to interpret. However, in the present case, we may interpret them as higher labour skill and technology levels, might have partially compensated for lower performance of unit in terms of general environmental conditions and interactions with the outside world. Similarly, the interaction effects of labour skill, technology level and structural and external factor by owner's qualification level significantly account for variations in energy use per brick. With respect to these interaction effects, we may explain that the lower levels of owner's qualification might have been compensated with higher labour skills and better technology. The high value of R-square indicates that the model is able to explain the significant amount of variation in the dependent variable. Overall, one may arrive at a conclusion that though changes in technology levels might have caused variations in energy consumption it is the contribution of the other factors, which is more significant compared to technology level alone.

Table 4.11: Univariate ANOVA Results for the Relationship Between Fuel/Brick and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	39.382	2	19.691	32.380	.000
Technology Level	28.692	2	14.346	23.591	.000
Structural and External Factor	6.163	2	3.082	5.068	.024
Owner Qualification Level	5.676	2	2.838	4.667	.030
Labour Skill by Structural and External Factor	11.732	4	2.933	4.823	.013
Technology Level by Structural and External Factor	6.781	3	2.260	3.717	.040
Labour Skill by Technology Level by Structural and External Factor	6.524	5	1.305	2.146	.124
Labour Skill by Owner Qualification	8.246	4	2.061	3.390	.042
Technology Level by Owner Qualification	15.359	3	5.120	8.419	.002
Structural and External Factor by Owner Qualification	16.295	4	4.074	6.699	.004
Sum of Squares due to Factors	144.850	31	4.673	7.684	.000
Sum of Squares due to Error	7.905	13	.608		
Total Sum of Squares	152.755	44			
R Squared	0.948				
Adjusted R Squared	0.825				

It appears from this analysis that adopting the efficient technology alone may not result in reduced energy consumption levels. However, along with this, if the unit concentrates on having an appropriate mix of skilled and unskilled labour forces, better interaction with the outside world and good house keeping, the energy consumption levels and thereby pollution levels could be significantly reduced. The analysis of essential differences among the various groups of units formed based on the above factors will be discussed in latter sections.

ii) Relationship between Factors and Value of Output

Table 4.12: Univariate ANOVA Results for the Relationship Between Value of Output per 1000 Bricks and Considered Factors

Source of Variation	**Sum of Squares**	**DF**	**Mean Sum of Squares**	**F**	**Significance of F**
Labour Skill Level	1335203.162	2	667601.581	9.232	.001
Technology Level	4065565.413	2	2032782.706	28.109	.000
Structural and External Factor	837186.428	2	418593.214	5.788	.010
Owner Qualification Level	1112131.647	2	556065.823	7.689	.003
Labour Skill by Technology Level	1246767.073	4	311691.768	4.310	.011
Labour Skill by Technology Level by Structural and External Factor	1929397.279	8	241174.660	3.335	.014
Structural and External Factor by Owner Qualification	2200110.190	4	550027.547	7.606	.001
Sum of Squares due to Factors	12726361.192	24	530265.050	7.333	.000
Sum of Squares due to Error	1446338.602	20	72316.930		
Total Sum of Squares	14172699.794	44			
R Squared	0.898				
Adjusted R Squared	0.775				

The analysis of the relationship between the considered factors and value of output per 1000 bricks serves limited purpose. The value of output/1000 bricks remains the same across units if the production is restricted only to bricks. Only if the unit produces tiles in addition to bricks then the value of output/1000 bricks changes because of the price differences. Thus, the value of output/1000 bricks for a given unit depends on the composition of the production (i.e., mix of bricks and tiles). In other words, the variations in value of output/1000 bricks are caused mainly by the relative share of tile production. The results of the ANOVA analysis may be used to explain the differences among units with respect to relative share in tile production (Table 4.12). From the table, it may be observed that, all the considered factors, namely, labour skill level, technology level, structural and external factor and owner's qualification level significantly explain the variations in value of output per 1000 bricks. Technology level has main effect and as well as in interaction with labour skill and structural & external factor explains the most in variations in value of output/1000 bricks. This can be interpreted as the need for better technological initiatives with regard to production of tiles compared to only brick production. Also, it supports the need for higher skill level for tile production. The high R-square indicates the suitability of the considered model in explaining the variations in the value of output.

iii) Relationship between Factors and Cost of Production

The ANOVA attempted with respect to the considered factors and total cost per 1000 bricks is basically aims to test the hypothesis whether higher levels of labour skill, technology, owner's qualification and structural & external factor tend to reduce the overall cost of production. However, the results presented in Table 4.13 show that only the labour skill levels significantly explain the variations in the total cost per 1000 bricks. Other factors are found to be insignificant. Even in terms of interaction effects, only two – technology level by owner's qualification and Labour Skill by Technology Level by Owner Qualification – effects are found to be significant. The only conclusion one may arrive at is that the human resource factors to a certain extent influence the variations in total cost per 1000 bricks.

From the ANOVA performed with three different dependent variables, we may arrive at the following conclusions with respect to brick and tiles cluster.

I. Human resource factor, constituting labour skill level and owner's qualification, is the most important factor determining the level of energy consumption and to a certain extent the level of value of output and total cost.

II. Technology level is the second most important factor explaining variations in the level of energy consumption and value of output.

III. General appearance of the units, environmental conditions and interaction levels also to a certain extent indicate the overall performance of the units in terms of efficiency of material and energy use, levels of labour skill, owner's qualification and technology.

Table 4.13: Univariate ANOVA Results for the Relationship Between Total Cost per 1000 Bricks and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	278487.838	2	139243.919	8.966	.004
Technology Level	59399.929	2	29699.964	1.912	.190
Structural and External Factor	81781.750	2	40890.875	2.633	.113
Owner Qualification Level	37728.001	2	18864.000	1.215	.331
Labour Skill by Technology Level	60782.905	4	15195.726	.978	.455
Technology Level by Structural and External Factor	21376.452	2	10688.226	.688	.521
Labour Skill by Technology Level by Structural and External Factor	19811.979	2	9905.990	.638	.545
Labour Skill by Owner Qualification	149366.585	4	37341.646	2.405	.107
Technology Level by Owner Qualification	199558.621	3	66519.540	4.283	.028
Labour Skill by Technology Level by Owner Qualification	176261.591	2	88130.795	5.675	.018
Structural and External Factor by Owner Qualification	24800.359	3	8266.786	.532	.669
Sum of Squares due to Factors	1116440.989	32	34888.781	2.247	.069
Sum of Squares due to Error	186356.837	12	15529.736		
Total Sum of Squares	1302797.827	44			
R Squared	0.857				
Adjusted R Squared	0.476				

The results of the above analysis indicate that the abatement measures need to be adopted to reduce the level of pollution through efficient use of energy and material has to focus more importantly on the human resource factor along with the technology factor.

4.8 Comparison of Various Estimated Parameters Across Groups Based on the Factors

4.8.1 Labour Skill Level Based Groups

The analysis presented earlier indicated that changes in the levels of labour skill, owner's qualification, technology, etc., result in significant variations in dependent variables like energy consumption, value of output and cost. It would be interesting to know how some of the important parameters varies across groups formed on the basis of these factors. Table 4.14 contains the average estimates of various parameters for the brick and tile units falling under the groups of low, medium and high labour skill levels. It is clear from the table that the average number of skilled labour per unit increases with the skill levels, starting from 9 in low, 12 in medium and 15 in high skilled groups. On the other hand, the average number of unskilled labour per unit is 15 for low, 11 for medium and 7 in high skilled groups. Even in terms of labour requirement per 1000 bricks, the skilled labour requirement increases with skill level and it is opposite in the case of unskilled labour. The average fuel consumption per brick ranges from a high of 8.95 MJ/brick in the low to 7.63 MJ/brick in the medium and 6.62 MJ/brick in the high skilled groups. This shows that the energy consumption comes with the increase in labour skill levels. The same trend is observed in the case of ash produced per 1000 bricks. However, the average number of waste bricks per 1000 bricks reduces from 83.46 in the low skill to 78.42 in the medium skilled group but increases to 94.81 in the case of high skilled group.

On an average the units in the lower labour skill group spend about Rs. 8,034 per labour per year. To achieve the above savings, the units in the lower skill group have to spend on an average Rs. 3,486 per labour per year extra to move into medium skill group and to move into higher labour skill group the extra expenditure is of the order of Rs. 7,174 per labour per year.

Table 4.14: Comparison of Various Parameters for Different Group of Units based on Labour Skill Levels

	Low	Medium	High
Skilled Labour (No. per Unit)	9	12	15
Unskilled Labour (No. per Unit)	15	11	7
Skilled Labour (No./1000 Bricks)	0.0135	0.0131	0.0143
Unskilled Labour (No./1000 Bricks)	0.0224	0.0125	0.0062
Brick Production/year/unit (Million)	0.89	0.88	1.34
Fuel/Brick (MJ)	8.95	7.63	6.62
Ash (kg/1000 Bricks)	22.23	18.35	17.35
Waste Bricks (No./1000 Bricks)	83.46	78.52	94.81
Total Cost (Rs./1000 Bricks)	913.88	762.12	729.74
Labour Cost (Rs./1000 Bricks)	239.33	248.49	268.12
Additional Labour Cost (Rs./1000 Bricks)	0.00	9.16	28.78
Labour Cost per Labour per year (Rs.)	8034.18	11520.10	15208.29
Fuel Cost (Rs./1000 Bricks)	322.24	275.48	251.60
Savings in Fuel Cost (Rs./1000 Bricks)	0.00	46.76	70.65
Eucalyptus (tonnes/1000 Bricks)	0.50	0.43	0.33
Firewood (tonnes/1000 Bricks)	0.23	0.22	0.20
Coal (tonnes/1000 Bricks)	0.00	0.00	0.07
CO (kg/1000 Bricks)	8.63	7.70	6.31
CH_4 (kg/1000 Bricks)	0.26	0.23	0.19
N_20 (kg/1000 Bricks)	0.035	0.031	0.026
SO_2 (kg/1000 Bricks)	0.59	0.52	0.45
NOx (kg/1000 Bricks)	0.86	0.77	0.65
TSP (kg/1000 Bricks)	4.49	4.00	3.29
CO_2 (kg/1000 Bricks)	0	0	93.62

The estimated average consumption of various fuel types per 1000 bricks for the units in different groups are also presented in Table 4.14. Though the dominating source of fuel is eucalyptus, its relative share appears to be decreasing with the increase in the labour skill levels. The coal consumption is restricted to only one unit and the energy consumption norm is calculated using the bricks production details of that unit. The table also contains average estimates of various types of pollutants for different group of units.

4.8.2 Owner's Qualification Based Groups

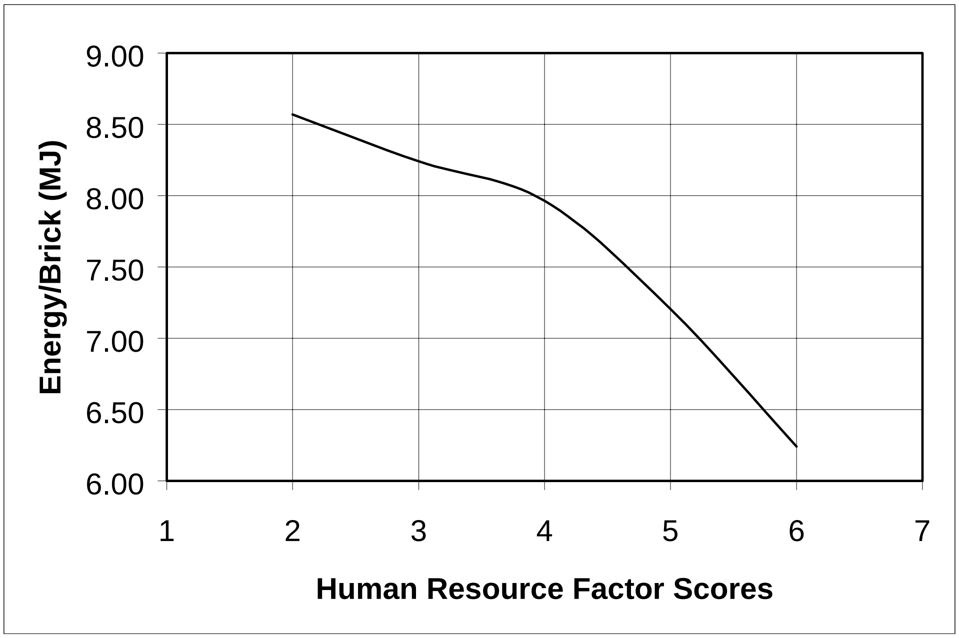
Table 4.15 contains the various estimated parameters for the groups of units formed on the basis of owner's qualification level. Comparison between average number of skilled and unskilled labour per unit does not show any interesting feature. However, when we compare the skilled and unskilled labour requirement per 1000 bricks, it appears lower owner's qualification level is compensated by having higher share of skilled labourers. This becomes clear when we compare the ratio of skilled to unskilled labourers of the units grouped under low and medium level of owner's qualification. However, this is not the case with the group of units with high owner's qualification where the ratio is higher than the earlier two groups. The lack of initiatives in terms of hiring skilled labour by the units owned by medium qualified entrepreneurs are reflected in terms of higher energy consumption per brick by these units compared to other two groups of units. The total cost of production and labour cost per 1000 bricks reduces with the increase in qualification levels. The higher level of energy consumption and higher fuel costs in the medium group may be due to the higher share of eucalyptus leaves (in the wet form) which are relatively less efficient compared to dried firewood. The table also contains group-wise average estimates of various pollutant types.

The labour skill level and owner's qualification level variables are combined to form a common human resource factor with six classification levels. The lowest level has a group of units with low labour skill and owner's qualification level and moving in the order to highest level of skill and qualification level. This has been done basically to study the relationship between fuel consumption and the human resource factor. Figure 4.1 shows a plot of human resource factor groups versus the average fuel consumption per brick for the units belonging to these groups. From the figure, we may observe that the fuel use decreases with the increase in the human resource quality.

Table 4.15: Comparison of Various Parameters for Different Group of Units based on Owner's Qualification Levels

	Low	Medium	High
Skilled Labour (No. per Unit)	11	13	11
Unskilled Labour (No. per Unit)	11	12	9
Skilled Labour (No./1000 Bricks)	0.0145	0.0141	0.0123
Unskilled Labour (No./1000 Bricks)	0.0135	0.0154	0.0108
Fuel/Brick (MJ)	6.97	8.56	7.17
Ash (kg/1000 Bricks)	18.76	21.83	16.07
Waste Bricks (No./1000 Bricks)	86.60	85.16	84.98
Total Cost (Rs./1000 Bricks)	824.91	801.42	772.03
Labour Cost (Rs./1000 Bricks)	256.69	251.07	249.83
Fuel Cost (Rs./1000 Bricks)	253.69	303.47	277.34
Eucalyptus (tonnes/1000 Bricks)	0.28	0.55	0.30
Firewood (tonnes/1000 Bricks)	0.26	0.16	0.26
Coal (tonnes/1000 Bricks)	0.00	0.00	0.07
CO (kg/1000 Bricks)	6.78	7.95	6.94
CH_4 (kg/1000 Bricks)	0.20	0.24	0.21
N_20 (kg/1000 Bricks)	0.027	0.032	0.028
SO_2 (kg/1000 Bricks)	0.43	0.56	0.49
NOx (kg/1000 Bricks)	0.68	0.79	0.72
TSP (kg/1000 Bricks)	3.53	4.13	3.62
CO_2 (kg/1000 Bricks)	0	0	93.62

Figure 4.1: Relationship Between Human Resource Factor and Energy



Consumption

4.8.3 Technology Level Based Groups

The average parameters estimated for units coming under different groups formed based on technology levels are presented in Table 4.16. From the table it may be observed that the average energy consumption per brick is the lowest in the case of units in the low technology group and it is the highest for medium technology group. The units (five units) falling under the low technology group mainly use rural clamps for firing the bricks. The energy consumption norm for rural clamps is lower than the IDK technology. By design the rural clamps require less energy. But, this results in inadequate firing of bricks and thereby lower quality bricks. However, the influence of some incremental innovation in technology could be seen in the reduction in energy use per brick for units in the high technology group compared with medium group. Ash produced per 1000 bricks follows the same trend of energy use but the quantity of waste bricks/1000 bricks decreases with the increase in the technology level. The total cost of production shows an increasing trend with the technology level, while the labour cost per 1000 bricks is lowest in low technology group because of the low skill requirements. The labour cost is highest for the medium group but it reduces with the impact of technology playing a role on the efficiency of the production.

We have used investment on plant and machinery to reflect on the cost of technology. Since, the information on investment in plant and machinery was incomplete with respect to the units of low technology group we did not use it for comparison. The average investment on plant and machinery is higher in the case of units in high technology group compared to medium group. Based on the analysis presented for this cluster, on an average the additional investment required is Rs. 83,750 if a unit wishes to move from medium to high technology group (Table 4.16). But this additional investment results in the overall improvement in the production process and thereby the productivity. This becomes clear when we compare the investment on plant and machinery per 1000 bricks for the two groups. It is about Rs. 880 and Rs. 610 for the medium and high technology groups respectively (a saving of Rs. 270 per 1000 bricks). This can be viewed as a savings opportunity for additional investment on plant and machinery. The table also contains information on quantum of fuel used from different sources and different types of pollutants for a production of 1000 bricks.

Table 4.16: Comparison of Various Parameters for Different Group of Units based on Technology Levels

	Low	Medium	High
Fuel/Brick (MJ)	5.52	8.10	7.77
Ash (kg/1000 Bricks)	16.97	20.07	18.56
Waste Bricks (No./1000 Bricks)	99.33	89.16	74.75
Total Cost (Rs./1000 Bricks)	687.64	797.58	837.12
Labour Cost (Rs./1000 Bricks)	195.70	272.37	237.37
Average Investment on Plant & Machinery (Rs./Unit)	----	535250	619000
Additional Investment on Plant & Machinery (Rs./Unit)	----	0.00	83750
Investment on Plant & Machinery (Rs./1000 Bricks)	----	880.51	609.91
Savings in Investment on Plant & Machinery (Rs./1000 Bricks)	----	0.00	270.60
Fuel Cost (Rs./1000 Bricks)	241.07	285.20	290.52
Eucalyptus (tonnes/1000 Bricks)	0.14	0.62	0.26

	Low	Medium	High
Firewood (tonnes/1000 Bricks)	0.27	0.12	0.29
Coal (tonnes/1000 Bricks)	0.07	0.00	0.00
CO (kg/1000 Bricks)	5.39	8.11	7.10
CH_4 (kg/1000 Bricks)	0.16	0.24	0.21
N_20 (kg/1000 Bricks)	0.023	0.032	0.028
SO_2 (kg/1000 Bricks)	0.43	0.59	0.45
NOx (kg/1000 Bricks)	0.62	0.81	0.71
TSP (kg/1000 Bricks)	2.82	4.21	3.69
CO_2 (kg/1000 Bricks)	93.62	0	0

4.8.4 Structural and External Factor Based Groups

The average estimates of various parameters for production of 1000 bricks for units falling under the three different groups formed on the basis of structural and external factor are presented in Table 4.17. The fuel consumption per brick shows a slight decreasing trend with the increase in the factor levels. Similar is the case with the total cost of production per 1000 bricks. If we compare the various parameters, the difference between the lower and medium group is not much significant. However, with relatively high level of interaction and better environmental performance, and in the case of relatively newer units, the comparison shows that the units perform well in terms of most of the parameters.

Overall the analysis presented earlier has clearly indicated that the higher grouped units in terms of labour skill level, owner’s qualification, technology level and structural & external factor tend to excel in comparison with units in the lower groups.

Table 4.17: Comparison of Various Parameters for Different Group of Units based on Structural and External Factor Levels

	Low	Medium	High
Fuel/Brick (MJ)	7.96	7.64	7.47
Ash (kg/1000 Bricks)	19.65	20.26	17.13
Waste Bricks (No./1000 Bricks)	83.66	83.85	90.23
Total Cost (Rs./1000 Bricks)	849.62	784.12	756.32
Labour Cost (Rs./1000 Bricks)	271.93	237.62	249.35
Fuel Cost (Rs./1000 Bricks)	286.15	287.55	268.74
Eucalyptus (tonnes/1000 Bricks)	0.53	0.35	0.36
Firewood (tonnes/1000 Bricks)	0.18	0.24	0.21
Coal (tonnes/1000 Bricks)	0.00	0.07	0.00
CO (kg/1000 Bricks)	8.11	7.22	6.81
CH_4 (kg/1000 Bricks)	0.24	0.22	0.20
N_20 (kg/1000 Bricks)	0.032	0.029	0.027
SO_2 (kg/1000 Bricks)	0.57	0.50	0.46
NOx (kg/1000 Bricks)	0.81	0.74	0.68
TSP (kg/1000 Bricks)	4.22	3.76	3.54
CO_2 (kg/1000 Bricks)	0	93.62	0

4.9 Abatement Measures to Reduce Pollution Levels in the Bricks and Tile Cluster

From the results of the previous analysis we may be able to come up with the following abatement measures that are likely to influence in reducing the pollution levels –

I. Improvements in the ratio of skilled and unskilled labourers. In other words, having an appropriate skill set of labour force.

II. Appropriate compensation of lower owner's qualification levels with a better skill set of labour force.

III. Adoption of efficient technology for the production of bricks and tiles. One of the technologies could be VSBK for this purpose.

IV. Encouragement of incremental innovations at different stages of production process. These could be in terms better methods of brick moulding, proper drying of green bricks, better firing practices, use of waste heat for pre-heating of bricks, etc.

V. Higher interaction with the external world.

To implement some of the above measures, the brick & tile units need to incur additional cost. If the unit decides either to hire skilled labourers or provide necessary training to the existing labourers to upgrade their skills, this requires additional cost. Similarly, technology up-gradation involves substantial new investment. Implementation of any of these measures needs to be justified in terms of corresponding benefits to the units. Pollution reduction alone cannot be the only resulting benefit and this need not enthuse the unit owners to incur additional cost to implement the abatement measures. It is the financial benefit what they may look for this purpose. However, some of the other measures like incremental innovations and higher external interaction may not result in any significant additional cost and the units can implement them easily.

4.9.1 Labour Skill Set Up-gradation

As discussed above, we have considered labour skill set up-gradation as one of the abatement measures to reduce pollution levels. To estimate the cost and benefits of this option we have considered two cases. In the first instance, we have attempted to analyse the shifts from low to medium, low to high and medium to high levels of labour skill sets in the case of a typical brick manufacturing unit. The typical brick unit has a capacity of producing one million bricks per annum and exhibits similar characteristics of brick units in the Malur cluster. In the Malur cluster, the average wage rate for a skilled labourer is Rs. 160 per 1000 bricks and that for an unskilled labourer is Rs. 65 per 1000 bricks.

The analysis results are presented in Table 4.18. The total labour cost, fuel cost and fuel consumption are estimated using the norms obtained for each of the labour skilled groups. From the table it may be observed that the proposed shifting from lower skill set to upper skill set provides very good returns in terms of cost saved due to reduced energy consumption. The cost of energy saved is estimated by dividing the additional labour cost

Table 4.18: Cost and Benefits of Labour Skill Set Up-gradation for a Typical Brick & Tile Unit

	Low Labour Skill	**Medium Labour Skill**	**High Labour Skill**
Skilled Labour Wage Rate (Rs./1000 Bricks)	160	160	160
Unskilled Labour Wage Rate (Rs./1000 Bricks)	65	65	65
Brick Production/Year	1000000	1000000	1000000
Skilled Labour (No.)	10	12	14
Unskilled Labour (No.)	17	11	6
Total Labour Cost (Rs./Year)	239334.7	248494.64	268115.54
Total Fuel Cost (Rs./Year)	322243.7	275480.26	251595.69
Fuel Consumption (GJ/Year)	8945.71	7631.14	6617.38
Shifting of Skill Set →	**Low to Medium**	**Low to High**	**Medium to High**
Additional Labour Cost (Rs.)	9159.97	28780.86	19620.90
Savings in Fuel Cost (Rs.)	46763.45	70648.02	23884.57
Savings in Fuel Consumption (GJ/Year)	1314.56	2328.33	1013.77
Cost of Saved Energy (Rs./GJ)	6.97	12.36	19.35
Value of Saved Energy (Rs./GJ)	35.57	30.34	23.56
Savings in Eucalyptus (tonnes)	72.74	170.63	97.90
Savings in Firewood (tonnes)	12.67	38.37	25.70
Reduction in Waste Bricks (No.)	4942	-11354	-16296
Reduction in Ash (tonnes)	3877.7	4883.3	1005.6
Reduction in Pollution Levels			
CO (kg)	931.94	2313.47	1381.54
CH_4 (kg)	27.96	69.27	41.31
N_20 (kg)	3.73	8.96	5.23
SO_2 (kg)	68.32	139.86	71.54
NOx (kg)	93.19	211.63	118.43
TSP (kg)	484.61	1199.34	714.73

by the quantum of energy saved due to the shift. The value of energy saved is estimated using the ratio of cost of energy saved to quantum of energy saved. Shifting from low to medium labour skill set, results in lowest cost of saved energy of Rs. 6.97/GJ and highest value of saved energy of Rs. 35.57/GJ compared to any other shifts. The cost and value of energy saved for low to high and medium to high labour skill sets are Rs. 12.36/GJ and Rs. 30.34/GJ, Rs. 19.35/GJ and Rs. 23.56/GJ respectively. The table also contains the information on the possible reduction in pollution levels due to the three kinds of shifts described above. These shifts also result in reduced burden of ash disposal. In the case of reduction in the number of waste bricks, the positive reduction is achievable only in the case of shift from low to medium skill set. In other instances, the shift results in the increase of number of waste bricks. One possible explanation for this is that the increased labour skill set becoming more quality sensitive and thereby increasing the rejection rates.

The analysis has been extended to study the impacts of the above kind of labour skill set shifts on the 45 sample units of the Malur cluster of brick and tiles units. To estimate the total labour requirement for the sample units, we have used the average number of skilled and unskilled labourers per unit obtained from the units grouped under low, medium and high labour skill class intervals (refer Table 4.14). The average unit grouped under low labour skill set with 9 skilled and 15 unskilled labourers can produce approximately 0.9 million bricks per year. The unit with 12 skilled and 11 unskilled labourers has an approximate capacity of 0.9 million and that with 15 skilled and 7 unskilled labourers has a capacity of 1.3 million bricks per year. For comparison, we have taken the total bricks produced per year by the sample units as 40.5 million, for which either 45 units with low or 45 units with medium or 31 units with high labour skill sets are required (Table 4.19). The table presents the total required skilled and unskilled labourers estimated using the above method for all the units to produce 40.5 million bricks per year. From the table, one could observe a contradiction that the medium labour skilled units have more skilled labourers but less production capability compared to high labour skilled units where the number of skilled labourers is low but have higher production capability. However, from our earlier analysis it is clear that it is the composition of skilled and unskilled labourers per unit, which determines the labour productivity and not the total numbers in all the units.

The estimates of additional labour cost, fuel cost saved, cost of energy saved and value of energy saved for different kinds of shifts are presented in Table 4.19. The results are similar to that discussed with respect to the typical unit earlier. Only difference is that these estimates give a total picture for the considered sample units of Malur cluster. Similarly, the table contains information on reductions that one could achieve by shifting from lower to upper labour skill levels in terms of fuels, ash and pollution levels. Overall from the table we may observe that these reductions are quite significant. Therefore, to reduce energy consumption levels and thereby pollution levels, the first and foremost activity at the Malur cluster is to upgrade the labour skill set by providing appropriate training to the labourers. The analysis has clearly showed that the benefits to the entrepreneurs are significant and will be able to more than compensate the cost involved for training and higher wages to skilled labourers.

The improvements in the efficiency of material and energy use due to skill set up-gradation could be due to the following –

I. Quality of bricks is mostly dependent on the clay preparation, brick moulding and proper drying of the green bricks. Skilled people can ensure better performance in all these aspects.

II. Firing practices determine the level of fuel consumption and the quality of final burnt bricks. Proper arrangement of bricks in the kiln, feeding of fuel and circulation of fumes around the stacked bricks require skilled work force.

Table 4.19: Cost and Benefits of Labour Skill Set Up-gradation for Sample Units in the Brick & Tile Cluster

	Low Labour Skill	**Medium Labour Skill**	**High Labour Skill**
Skilled Labour Wage Rate (Rs./1000 Bricks)	160	160	160
Unskilled Labour Wage Rate (Rs./1000 Bricks)	65	65	65
Average Brick Production Capacity (Million/unit/year)	0.9	0.9	1.3
No. of Units	45	45	31
Brick Production (Million per Year)	40.5	40.5	40.5
Skilled Labour (No.)	405	540	465
Unskilled Labour (No.)	675	495	217
Total Labour Cost (Rs. Million/Year)	9.69	10.06	10.86
Total Fuel Cost (Rs. Million/Year)	13.05	11.16	10.19
Fuel Consumption (GJ/Year)	362301	309061	268004
Shifting of Skill Set →	**Low to Medium**	**Low to High**	**Medium to High**
Additional Labour Cost (Rs.Million)	0.37	1.17	0.79
Savings in Fuel Cost (Rs.Million)	1.89	2.86	0.97
Savings in Fuel Consumption (GJ/Year)	53240	94297	41057
Cost of Saved Energy (Rs./GJ)	6.97	12.36	19.35
Value of Saved Energy (Rs./GJ)	35.57	30.34	23.56
Savings in Eucalyptus (tonnes)	2945.77	6910.57	3964.80
Savings in Firewood (tonnes)	513.11	1553.89	1040.78
Reduction in Waste Bricks (Lakh)	2.00	-4.60	-6.60
Reduction in Ash (tonnes)	157.0	197.8	40.7
Reduction in Pollution Levels			
CO (kg)	37743.47	93695.66	55952.18
CH_4 (kg)	1132.30	2805.54	1673.23
N_20 (kg)	150.97	362.74	211.77
SO_2 (kg)	2767.10	5664.43	2897.32
NOx (kg)	3774.35	8570.82	4796.47
TSP (kg)	19626.61	48573.16	28946.56

4.10 Technology Shift – Intermittent Downdraught Kiln to Vertical Shaft Brick Kiln

One of the abatement measures considered to reduce pollution by reducing the energy consumption level is through technology shifts. Here we have made an attempt to analyse the shift from IDK to VSBK technology for brick firing. In the Malur cluster almost all the brick and tile units use biomass (firewood and eucalyptus leaves) as a fuel in the IDK kilns for firing the bricks. Predominantly, this biomass is obtained in a sustainable manner. However, in the VSBK technology coal is used as a fuel for firing the bricks. Therefore, in the present analysis, for comparison we have used two types of IDK alternatives – one with biomass and the other with coal as a fuel – to be replaced by VSBK with coal as fuel. For, IDK with biomass as a fuel, the information on investment required for setting up a new IDK kiln is obtained from the project proposal prepared by an entrepreneur from Malur. The fuel (biomass) cost is the estimated average fuel cost for the sample units of Malur cluster. Same investment cost is used for the IDK with coal as a fuel alternative. The information on cost of coal is obtained from Climate Change-India (2001). The information for VSBK technology is obtained from various secondary sources (TERI, 2001; VSBKINDIA, 2002; VSBK, 2001). For the purpose of analysis a discount rate of 10% is assumed. The lifespan of kilns has been taken to be equal for both the kilns at 15 years. For this analysis, we have not considered all other capital costs because they will be the same for both the technologies and the results will not get affected. The results of the analysis of cost and benefits of shifting of IDK (biomass) and IDK (coal) to VSBK (coal) technology are presented in Table 4.20.

The comparative analysis is made for typical brick units with a capacity of three million bricks per year. From the table, we may observe that the initial investment required for VSBK technology is slightly higher compared to IDK. The IDK (biomass) technology is the representative technology of the process practiced in the Malur cluster. Here the fuel used is a combination of firewood and eucalyptus leaves. Therefore the fuel price used is the average price of firewood and eucalyptus leaves. Similarly for IDK (biomass), the energy consumption norm is the average of sample units of Malur cluster and for other two alternatives, it is from secondary sources quoted above.

From the Table 4.20, the annual energy consumption levels (in GJ) are highest for the brick unit with IDK (biomass) technology and lowest for unit with VSBK (coal). However, the total fuel cost per year is the highest for unit with IDK (coal) technology and lowest for VSBK unit. The IDK (biomass) unit has to spend slightly more on fuel compared to VSBK unit. The changes in order in fuel consumption and fuel cost levels are due to the low price of biomass. In terms of pollution level, the CO, CH_4 and TSP emissions are significantly higher in the case of IDK (biomass) compared to IDK (coal) and VSBK (coal) and N_2O emissions of IDK (biomass) are slightly higher compared to the other two. These high levels are mainly due to the type of fuel used, i.e., biomass, which is the major source of these pollutants when burnt. Since, the biomass is obtained in a sustainable manner, there are no CO_2 emissions with respect to IDK (biomass) where as CO_2 emissions are significant in the case of other two alternatives. Also, the levels of SO_2 and NOx emissions are very high in the case coal based IDK and VSBK technologies compared to biomass based IDK technology. The reduction in pollution levels in the case of VSBK (coal) compared to IDK (coal) is mainly due to the higher efficiency of fuel use achieved in the case of former technology.

The technology shifts are primarily analysed for two kinds of shifts – IDK (biomass) to VSBK (coal) and IDK (coal) to VSBK (coal). The results are presented in Table 4.20. From the table, we may observe that the additional investments required for the shift are not very high. The savings in fuel consumption are quite significant in both kinds of shifts. However, the savings in fuel costs are more than 12 times higher in the case of IDK (coal) → VSBK (coal) compared to IDK (biomass) → VSBK (coal) shift. This gets clearer when we compare the cost of saved energy and value of saved energy for the two shifts. The cost of saved energy for IDK (coal) → VSBK (coal) shift is slightly higher at Rs. 1.65 per GJ compared to Rs. 1.04 per GJ for IDK (biomass) → VSBK (coal) whereas the value of saved energy is more than 19 times higher in the case of the former shift compared to IDK (biomass) → VSBK (coal). In other words, it is economically not that attractive for the units with IDK technology using biomass as a fuel to shift to VSBK (coal) technology at the prevailing prices of biomass. This is true for all the units in Malur cluster. However, for the units with IDK technology with coal as a fuel, the shift to VSBK provides very high returns at very low cost. Even in the literature, the economic comparison of the shift from IDK to

VSBK has been done only for the units with coal as a fuel (TERI, 2001; VSBKINDIA, 2002; VSBK, 2001).

Table 4.20: Cost and Benefits of Technology Change for a Typical Brick & Tile Unit

	IDK (Biomass)	IDK (Coal)	VSBK (Coal)
Kiln Investment	696000	696000	786000
Brick Production/Year	3000000	3000000	3000000
Discount Rate (%)	10	10	10
Estimated Life (Years)	15	15	15
Annualised Capital Cost (Rs./Year)	91505.75	91505.75	103338.39
Fuel Price (Rs./MJ)	0.037	0.073	0.073
Energy Consumption (MJ/Brick)	7.380	5.994	3.596
Fuel Consumption (GJ/Year)	22140	17982	10789.2
Total Fuel Cost (Rs./Year)	825822	1305000	783000
CO (kg)	22053.06	639.00	383.40
CH_4 (kg)	661.76	53.10	31.86
N_20 (kg)	88.60	79.20	47.52
SO_2 (kg)	1522.98	7047.00	4228.20
NOx (kg)	2230.79	5148.00	3088.80
TSP (kg)	11472.33	1278.00	766.80
CO_2 (kg)	0.00	1203660	722196

Changing of Technology →	**IDK (Biomass) to VSBK (Coal)**	**IDK (Coal) to VSBK (Coal)**
Additional Investment (Rs.)	90000	90000
Additional Annualised Capital (Rs.)	11832.64	11832.64
Savings in Fuel Cost (Rs./Year)	42822	522000
Savings in Fuel Consumption (GJ/Year)	11350.80	7192.8
Cost of Saved Energy (Rs./GJ)	1.04	1.65
Value of Saved Energy (Rs./GJ)	3.77	72.57
Reduction in Pollution Levels		
CO (kg)	21669.66	255.60
CH_4 (kg)	629.90	21.24
N_20 (kg)	41.08	31.68
SO_2 (kg)	-2705.22	2818.80
NOx (kg)	-858.01	2059.20
TSP (kg)	10705.53	511.20
CO_2 (kg)	-722200	481460

Further, the reductions in the emission levels of various kinds of pollutants that could be achieved by these two technology shifts are not consistent (Table 4.20). In the case of shift of IDK (biomass) → VSBK (coal), there will be substantial reduction in pollution levels due to the emissions of CO, CH_4 and TSP and at the same time there will be significant increase in the emission levels of SO_2, NOx and CO_2. The combination of pollutant types that are likely to be reduced as well as increased due to the shift includes both the local and global pollutants. However, with the shift, the emission of CO_2 is likely to increase substantially. Therefore, the shift from IDK (biomass) to VSBK (coal) depends on the priority of what kind of pollutants needs to be reduced. However, it may not be a desired shift to VSBK (coal), though it is energy efficient, for the units in Malur cluster because they are meeting their fuel requirements in a sustainable manner. But, the scenario will be different, if the shift is from IDK (coal) to VSBK (coal). The reduction in pollution levels is significant for all kinds of pollutants (Table 20). Therefore, it is both economically as well as environmentally attractive to shift from IDK (coal) to VSBK (coal).

In the above analysis of cost and benefits of shifting from IDK to VSBK, we have assumed that the additional investment required for VSBK is the net of investment on IDK. However, this scenario is applicable only to a new entrepreneur or to an existing owner of the unit, who wants to completely scrap the old kiln and go for a new one, for whom the choice is between IDK and VSBK technology. This is not applicable to the owners of the brick units having kilns under working condition, for whom the additional investment required for VSBK will be the net of current value (depreciated value) of IDK. Therefore, the economic benefit of the shift depends on the current value of the existing kiln. We have analysed this aspect by varying the current value of the existing IDK kiln as a percentage of the investment on new IDK and comparing the cost and value of saved energy. The Figures 4.2 and 4.3 show the cost and benefits of shifts of IDK (biomass) → VSBK (coal) and IDK (coal) → VSBK (coal) respectively for different levels of value of replacement. From the Figure 4.2, for IDK (biomass) to VSBK (coal), we may observe that the shift is beneficial for the units having kilns with a current value of less than 35% of the investment on the new IDK. In other words, the cost of energy saved is less than the value of energy saved when the current value of the existing kilns is less than 35% of the investment. However, the shift from IDK (coal) to VSBK (coal) is beneficial irrespective of the changes in the current value of the kilns as a percentage of investment on new IDK (coal) (Figure 4.3). The value of saved energy is significantly higher than the cost of saved energy at all levels of current value of the existing kiln.

Overall, the analysis with respect to the changing of IDK with VSBK technology has shown that it is both economically and environmentally not justifiable to replace the biomass based IDKs with VSBKs. This technology shift is advisable only for IDKs, which use coal as a fuel for firing bricks.

Figure 4.2: Cost and Benefits of IDK (Biomass) shift to VSBK (Coal) at different levels of Current Value (Depreciated Value) of IDK

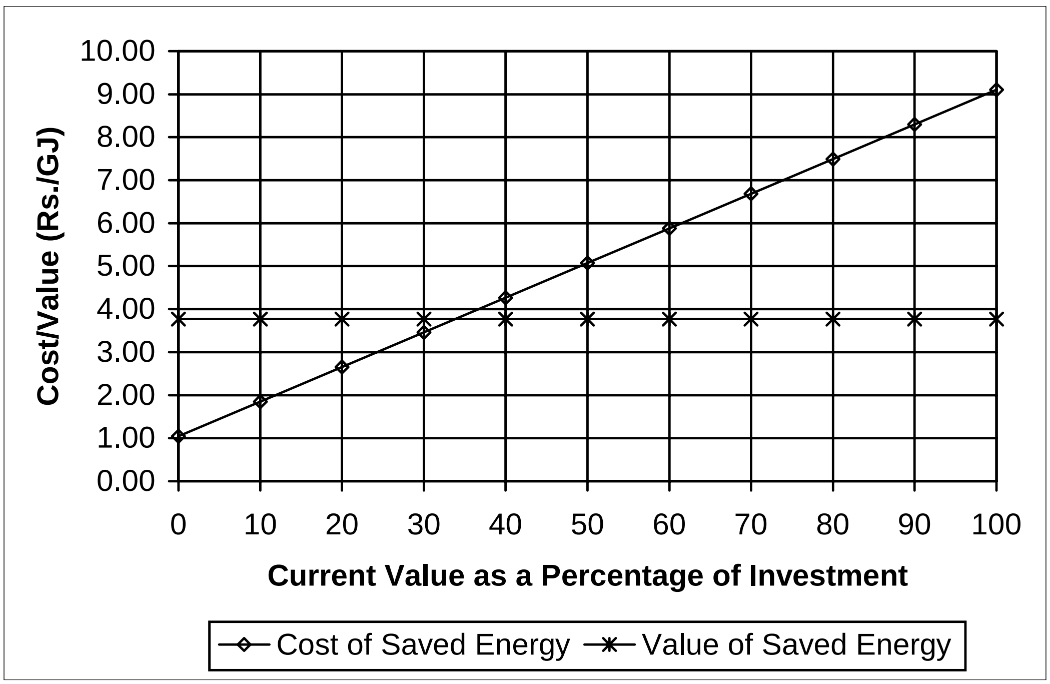
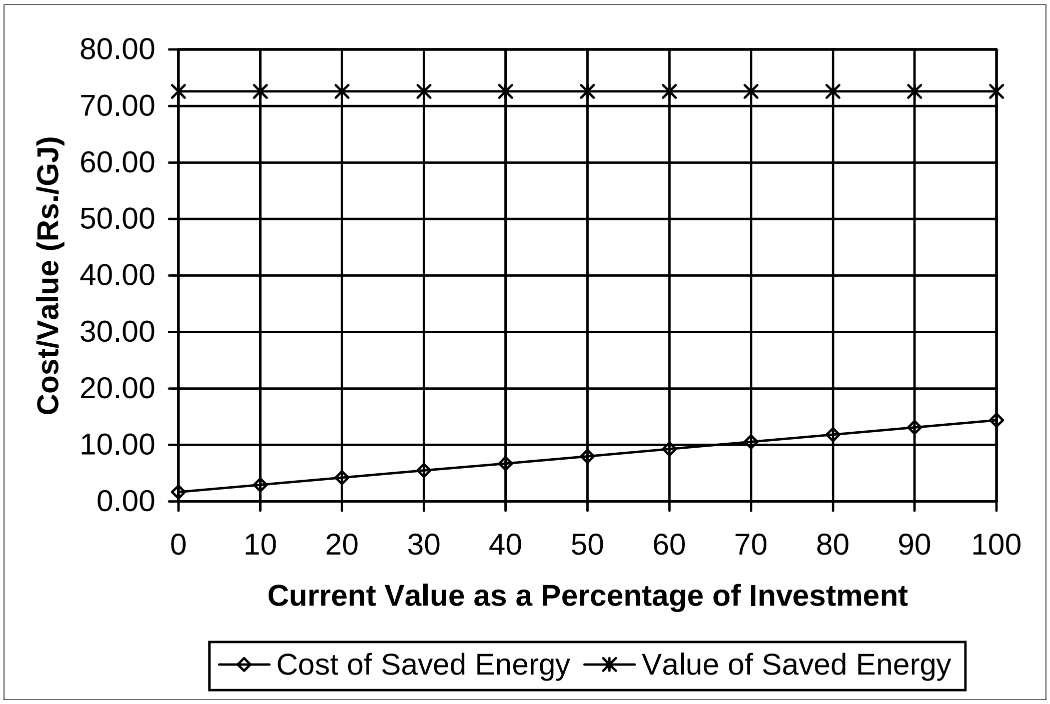


Figure 4.3: Cost and Benefits of IDK (Coal) shift to VSBK (Coal) at different levels of Current Value (Depreciated Value) of IDK



CHAPTER 5: SILK REELING CLUSTER – RAMANAGARAM, BANGALORE RURAL

5.1 Introduction

India is the second largest silk manufacturer in the World after China (Raghavendra, 1993). The overall process of silk manufacturing involves broadly, two phases (Fig 5.1). The first one, which involves the growing of mulberry and rearing of cocoons is predominantly agriculture oriented and is generally known as sericulture. The other phase involves the reeling of raw silk yarn, silk twisting and weaving operations, which are normally grouped under cottage industry or small-scale industry sector (Raghavendra, 1993). These two phases are popularly categorized as pre-cocoon (sericulture) and post-cocoon (silk) segments of the industry respectively.

India produces all the known commercial varieties of silk, namely, Mulberry, Tasar, Muga and Eri. Of these, Mulberry silk is the predominant one, accounting for more than 90 percent of the total silk production in the country. Karnataka is the premier Mulberry silk producing state in India, as it accounts for about 70 percent of the country’s total Mulberry silk production (UNDP, 2001). The main silk regions in the state are the four talukas of Channapatna, Ramanagaram, Kanakapura and Magadi in Bangalore Rural district and Kollegal taluka of Chamrajnagar district.

5.2 Reeling of Cocoons

Reeling of cocoons to produce the raw silk is the beginning of the second phase in silk manufacturing (refer Figure 5.1). The silk worm spins the cocoon by spitting out the silk fluid through a spinneral at its mouth and this fluid hardens to form a fine silk filament (bave) on coming into contact with the air. This bave comprises two distinct filaments or brins composed of fibroin and stuck together and covered by silk gum or sericin. When the cocoons are treated with hot water, the gum (sericin) being readily soluble in hot water facilitates the unwinding process. This operation of unwinding the bave (silk filament) from the cocoon is called reeling.

The process of reeling cocoons comprises cocoon drying/stifling, boiling, brushing, reeling, re-reeling, finishing and testing. Silk reeling consists of essentially two operations, i.e., cooking the cocoons to separate the thread from the cocoon and combining 8-12 single threads into a single yarn on to a reel.

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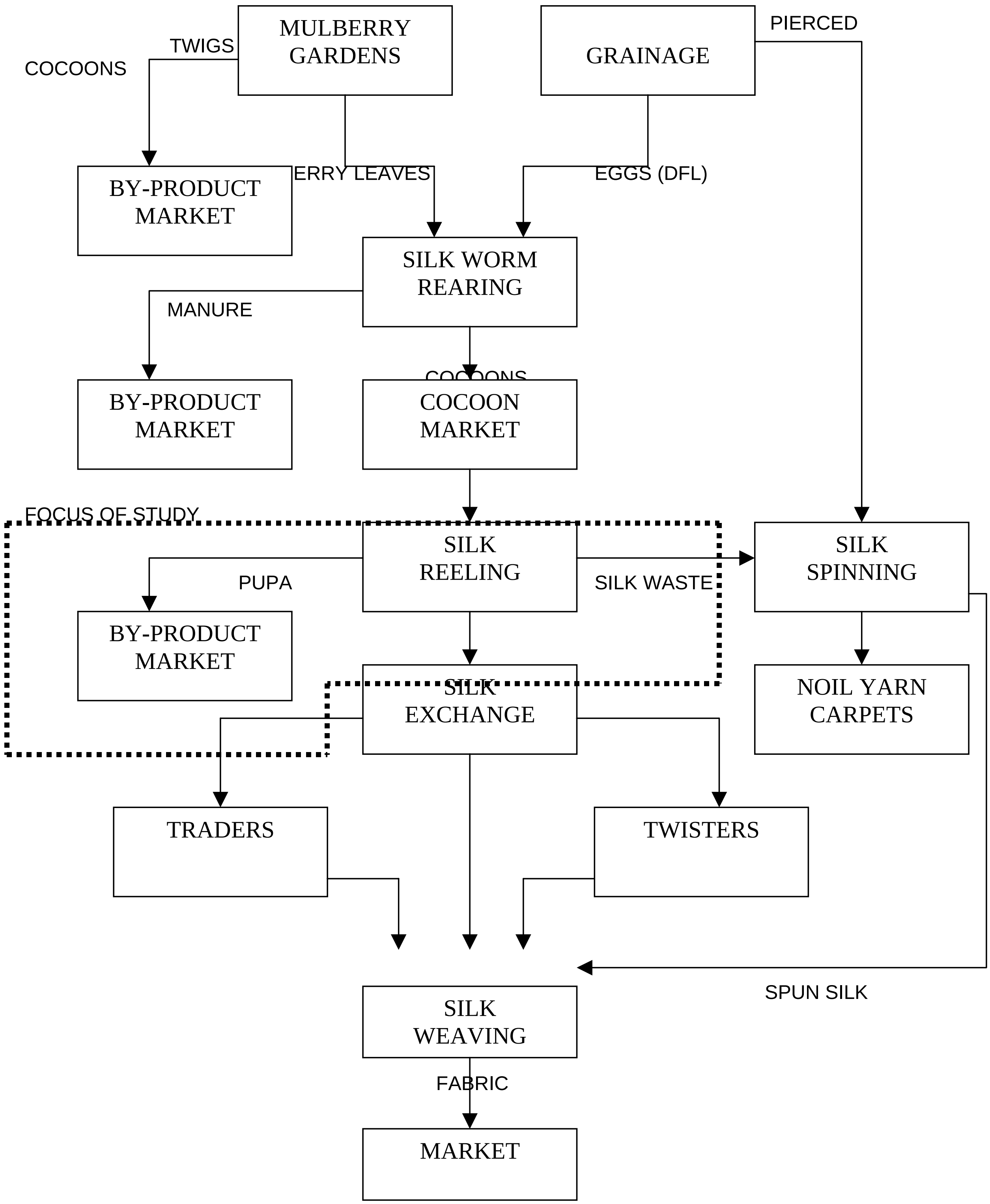
Figure 5.1 A Schematic Diagram of Silk Production Process



There are three principal techniques of silk reeling, though it is predominantly a cottage industry

5.2.1 Traditional Manual Charakha Method

This method has been existing in the state since the last 200 years. In the Charakha process, cocoons are cooked in a simple kettle over saw dust and the cocoons fed manually to a large manually operated Charakhas connected to cycle wheels fitted with ball bearings, driven by a chain and a manual turning mechanism. Sometimes, the Charakhas are directly driven through a large wheel operated by hand with/ without ball bearings.

5.2.2 The Semi-mechanized Technique of using Cottage Basins

Cottage basin reeling enables better control over the uniformity of the yarn. It involves reeling the cocoons in power operated Cottage basins, mostly of smaller size and with one or two tables (i.e., two to four basins) operated by a single turner.

5.2.3 The Multi-end Reeling Machine

The Multi-end reeling machine uses 10 ends per basin. The machine requires a large shed area. It is difficult to reel lower quality cocoons using the multi-end machine because wastage is much higher and therefore, it is more uneconomical. The price of a multi-end machine is exorbitantly high for an ordinary farm family. Its price is about Rs. 6,50,000/- per machine.

5.3 Silk Reeling Industry in Ramanagaram

Ramanagaram is known for its cluster of silk reeling units. There are about 1500 silk reeling units in Ramanagaram. Majority of these units are Charakha and Cottage units – numbering more than 700 each. There are only 27 multi-end units.

The silk reelers procure cocoons on a daily basis – from the local farmers as well as from the Government cocoon market located in Ramanagaram. The procured cocoons are then cooked, which unwinds the cocoon filament spun by the silk worm. The process of silk reeling generates raw silk, which is the main product, pupae, which is the bye-product and, cocoon and silk wastes. The silk reeling units do generate revenue by selling not only raw silk but also pupae and silk waste. However, these units do not have a systematic method of storing and disposing pupae, cocoon and silk wastes. Therefore, silk reeling units, particularly the Charakha and Cottage units, generate three kinds of pollution:

1. The process of cocoon cooking with water results in water pollution. Such polluted water is simply thrown in the unit premises.

2. The main sources of fuel used for cooking are neem, tamarind and jungle wood. In addition, paddy husk, sawdust and wooden pieces are used. The process of cooking cocoons generates stinking smell all around and usage of energy inputs add to the air pollution.

3. As there is no proper way of storing pupae, cocoon and silk wastes, they are simply dumped in the unit premises, before its sale. This results in land pollution.

As a result of all these, the working conditions in these units are very unhygienic, particularly in Charakha units.

5.4 Silk Reeling Units in Ramanagaram: Characteristics

The cluster of silk reeling units in Ramanagaram is a traditional one. There is no source of secondary data available on the exact number and addresses of silk reeling units of Ramanagaram. Therefore, scientific random sampling is not possible. We have covered a total of 55 units across Ramanagaram randomly, covering all the three kinds of silk reeling units, i.e., Charakha (22 units), Cottage (22 units) and Multi-end units (11 units). As described earlier, Charakha units are the most traditional ones as they are manually operated, Cottage units are operated with power whereas Multi-end units are mechanized and are the relatively recent ones. Among the 55 units, all the 11 Multi-end units have come up in the 80s or 90s whereas the origin of 22 Cottage as well as 22 Charakha units ranges from the 60s to the 90s.

The educational background of entrepreneurs of the 55 units reveals that majority of them had only school education (Table 5.1). Though majority of the Charakha owners (about 60%) had school education, a considerable number of them (about 40%) are uneducated. The proportion of owners who had school education in the Cottage sector is relatively more (almost 90%) whereas the rest are uneducated. But all the Multi-end unit owners are educated – they had mostly school education, and one each had intermediate and degree education, respectively.

Table 5.1: Educational Background of Entrepreneurs in Silk Reeling Units

Category of Units	Educational Level				
	Nil	School Education (upto SSLC)	Intermediate	Graduation	Total
Charakha	9	13	-	-	22
Cottage	3	19	-	-	22
Multi-end	-	9	1	1	11
Total	**12**	**41**	**1**	**1**	**55**

In terms of investment, Charakha units are the least capital intensive ones followed by cottage units, whereas multi-end units are the most capital intensive (Table 5.2). The classification is done based on the current replacement value of plant and machinery.

In terms of size of units, on an average, a charakha unit has about three basins, a cottage unit has about eight basins whereas a multi-end unit has about 10 basins for silk reeling (Table 5.3). The average number of workers, cost of raw materials, consumption of water and energy inputs are presented in Table 5.4. The average size of workforce is the largest in multi-end units whereas it is the lowest in the charakha units. On an average, a cottage unit consumes more raw materials and water as compared to multi-end and charakha units.

Table 5.2: Size of Investment in Silk Reeling Units

Category of Units	Investment Level				
	Up to Rs 2000	Rs 2000 – 10,000	Rs 10,000 – 25,000	> Rs 25,000	Total No of Units
Charakha	18	-	-	-	18
Cottage	1	10	8	-	19
Multi-end	-	1	-	6	7

Note: All units did not give data on the size of investment.

Table 5.3: Number of Basins in Silk Reeling Units

Category of Units	No of Units	Average No of Basins	Total No of Basins
Charakha	22	3	56
Cottage	22	8	180
Multi-end	11	10	108
Average for Total	55	6	344

Table 5.4: Labour, Raw materials, Water and Energy Inputs

Category and number of units	Workers	Average Cost of Raw materials/ day	Quantity of Water/ day (Litres)	Firewood kg/ day	Coal Bags/ day	Bags of Saw Dust/ day
Charakha (22)	4	4708	400	-	-	2.24
Cottage (22)	14	12735	1370	330	1	-
Multi-end (11)	17	12437	650	375	-	-

As far as energy inputs are concerned, charakha units use only saw dust whereas multi-end units use firewood and electricity. The cottage units consume both firewood and coal to cook cocoons. On an average, a charakha unit consumes two and a quarter bag of saw dust per day. A cottage unit consumes about 330 kg of firewood and a bag of coal whereas a multi-end consumes 375 kg of firewood per day for cooking cocoons.

In terms of output, a multi-end unit, on an average, generates more output and less bye-products than cottage units (Table 5.5). The rate of output is the lowest in charakha units. As the quality of raw silk produced in charakha units is of inferior quality, such units do not generate any raw silk waste. The raw silk, cocoon and pupae wastes generated are relatively high in cottage units compared to multi-end units. It is the consumption of water and energy inputs for cooking cocoons and generation of wastes, particularly cocoon and pupae waste, which affect the environment through water, air and land pollution.

Table 5.5: Product and Bye Products

Category and number of units	Value of Raw Silk Output (Rs./ day)	Cocoon + Pupae Waste (kg/day)	Raw silk Waste (kg/day)
Charakha (22)	4900	52	-
Cottage (22)	10846	103	3.5
Multi-end (11)	12750	96	2.4

5.5 Silk Reeling Units: Extent and Dimensions of Environmental Pollution

The summary data for the 55 silk reeling units for the quantity of raw materials and energy inputs and outputs is presented in Table 5.6. The raw materials are multivoltine, bivoltine and dupion cocoons and water, the energy inputs are firewood, coal and sawdust, and outputs are raw silk (main product) and raw silk waste, pupae (bye-products) and cocoon waste.

The corresponding cost details including that of diesel and electricity are given in Table 5.7. Silk reeling industry is a raw material intensive industry, as raw materials account for almost 90% of the total cost of production whereas labour accounts for about 7% and energy inputs (including diesel and electricity) formed only about 3% of the total cost.

Table 5.6: Summary Data (per Year) for the Sample Units of the Cluster (For 55 Units)

	No. of Units	Total	Average/Unit	Standard Deviation
Multivoltine Cocoons (Tonnes)	10	195.47	19.55	6.20
Bivoltine Cocoons (Tonnes)	25	363.73	14.55	4.22
Dupion Cocoons (Tonnes)	21	193.20	9.20	2.44
Water (Kilo Litres)	55	11952.00	217.31	185.67
Firewood (Tonnes)	34	2002.33	58.89	21.61
Coal (Tonnes)	19	89.96	4.73	2.04
Saw Dust (Tonnes)	21	370.80	17.66	5.21
Total Fuel (GJ)	55	37394.38	679.90	412.14
Diesel for Power Generation (Litres)	28	8580.00	306.43	263.51
Raw Silk (Tonnes)	55	102.12	1.86	0.65
Raw Silk Waste (Tonnes)	34	27.00	0.79	0.31
Pupae &Cocoon Waste (Tonnes)	55	623.28	11.33	5.05

Table 5.7: Production Cost Details per Year (Rs.)

	Total	Average/Unit	Standard Deviation
Multivoltine Cocoons	23,456,000	2,345,600	744,576
Bivoltine Cocoons	65,472,000	2,618,880	759,083
Dupion Cocoons	21,150,000	1,007,143	281,657
Water	248,969	4,527	3,533
Firewood	2,320,939	68,263	23,832
Coal	515,340	27,123	14,114
Saw Dust	864,000	41,143	11,953
Diesel for Power Gen.	127,750	4,563	4,362
Labour	8,696,880	158,125	94,800
Electricity	334,646	9,843	8,097
Total	123,186,524	2,239,755	1,147,538

Table 5.8 provides the information on value of output from both the main product (raw silk) and the wastes. A Comparison of the production costs and the value of

output makes it clear that the margins are very small. The revenues from the wastes actually increase the margins. It may be observed from this comparison that the silk reeling operation just about manages to breakeven. The general opinion expressed by the reelers is that more than the profits, it is the employment opportunity, which is the main reason for the functioning of the sector.

Table 5.8: Value of Output Details per Year (Rs.)

	Total	Average/Unit	Standard Deviation
Raw Silk	124,464,000	2,262,982	1,149,940
Raw Silk Waste	4,748,400	139,659	57,545
Pupae &Cocoon Waste	1,069,200	19,440	13,546
Total	130,281,600	2,368,756	1,221,048

Though silk reeling is not energy intensive, it causes environmental pollution through the generation of foul smell (emanating from the process of boiling cocoons), which cannot be measured by any means, and consumption of energy inputs, i.e., firewood, coal and saw dust which together result in air pollution. The usage of water for boiling cocoons results in wastewater and therefore, water pollution. The generation of ash and bye-products such as pupae and cocoon wastes and their dumping in unit premises causes land pollution. The summary of environmental pollution details is presented in Table 5.10. These details are estimated based on standard emission factors (Table 5.9). The emission coefficients of sawdust are assumed to be equal to firewood. Unlike in the case of brick making units in Malur, in absolute figures, Carbon dioxide (CO_2) is the highest generated gas followed by Carbon monoxide (CO), TSP, NOx, SO_2, CH_4 and N_2O. We have assumed that whatever water used for boiling cocoons is converted into wastewater.

Table 5.9: Emission Factors (kg/Tonne)

	Firewood	Sawdust	Coal
CO	15	15	0.71
CH_4	0.45	0.45	0.059
N_20	0.06	0.06	0.088
SO_2	0.8	0.8	7.83
NOx	1.5	1.5	5.72
TSP	7.8	7.8	1.42
CO_2			1337.4

Note: Climate Change-India (2001), EM-1.4 (1999), IIASA (2001), IPCC (1996)

Table 5.10: Summary of Environmental Pollution Details

	Total	Average/Unit	Standard Deviation
Pupae &Cocoon Waste (Tonnes)	623.28	11.33	5.05
Ash (Tonnes)	182.16	3.31	1.85
Waste Water (KL)	11952	217.31	185.67
CO (kg)	35660.77	648.38	398.46
CH_4 (kg)	1073.21	19.51	11.98
N_20 (kg)	150.30	2.73	1.66
SO_2 (kg)	2602.92	47.33	32.19
NOx (kg)	4074.28	74.08	45.28
TSP (kg)	18638.14	338.88	207.81
CO_2 (kg)	120317.85	6332.52	2730.11

The average emissions per tonne of raw silk output are given in Table 5.11. The largest amount of gas generated is that of CO_2 followed by CO, TSP, NOx, SO_2 and N_2O. The larger amount of CO_2 emission is attributed to the consumption of coal. Whereas the remaining pattern of gas emissions are comparable to that of brick making cluster in Malur as the energy inputs are largely similar – they are wood and wood related materials. The raw material and fuel consumption per tonne of raw silk is presented in Table 5.12.

Table 5.11: Pollution Generated and Energy use per tonne of Raw Silk Output

	Average	Standard Deviation	Minimum	Maximum
Pupae &Cocoon Waste (Tonnes)	5.99	1.02	4.50	8.60
Waste Water (KL)	115.58	86.01	28.57	333.33
Ash (Tonnes)	1.89	1.17	0.56	6.00
CO (kg)	330.78	132.20	150.00	590.63
CH_4 (kg)	9.96	3.98	4.50	17.72
N_20 (kg)	1.40	0.58	0.60	2.38
SO_2 (kg)	24.45	14.75	8.00	68.44
NOx (kg)	38.01	17.35	15.00	75.63
TSP (kg)	172.92	69.19	78.00	307.13
CO_2 (kg)	3382.99	1706.68	1228.74	7863.91
Energy (GJ)	347.62	142.61	150.00	590.63

Table 5.12: Raw Material and Fuel use per tonne of Raw Silk

	Average	Standard Deviation	Minimum	Maximum
Multivoltine Cocoons (Tonnes)	8.63	1.67	4.34	10.00
Bivoltine Cocoons (Tonnes)	7.17	0.88	3.47	8.00
Dupion Cocoons (Tonnes)	6.29	0.69	5.56	8.33
Water (Kilo Litres)	115.58	86.01	28.57	333.33
Firewood (Tonnes)	28.11	4.88	18.85	39.38
Coal (Tonnes)	2.53	1.28	0.92	5.88
Saw Dust (Tonnes)	12.14	2.02	10.00	17.14

5.5.1 Technology/Scale Specific Groups: Energy Consumption and Environmental Pollution

The silk reeling process is clearly distinguished in terms of scale of production, starting from traditional Charakha to the latest multiend, the cottage industry being in between. The technology level of silk reeling process also moves along the same lines. The consumption and cost of energy, material and factor inputs and quantity and value of output for the three groups are presented in Table 5.13. On an average,

Table 5.13: Technology/Scale Specific Groups - A Comparison (Per Tonne of Silk per year)

	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Groups	Multiend		Cottage		Charakha	
Avg. Labour/Unit (No.)	17.91	5.68	13.96	3.36	3.67	1.59
Avg. Skilled Labour/Unit (No.)	13.00	4.29	10.13	2.67	2.24	1.04
Avg. Unskilled Labour/Unit (No.)	4.91	1.70	3.83	0.94	1.43	1.43
Total Labour (No.)	7.81	1.32	7.37	1.78	2.55	1.12
Skilled Labour (No.)	5.67	1.15	5.36	1.40	1.53	0.64
Unskilled Labour (No.)	2.14	0.46	2.01	0.52	1.02	1.15
Value of Output (Rs.)	1464676	21861	1490739	28590	807891	5151
Labour Cost (Rs.)	115212	27074	103539	27495	42371	11851
Fuel Costs (Rs.)	38990	7703	41855	10640	28558	7038
Raw Material Cost (Rs.)	1229834	128817	1264314	132143	686032	54326
Other Costs (Rs.)	9200.7	3288.0	9735.3	3330.8	1479.6	549.4
Total Cost (Rs.)	1393237	154599	1419444	133837	758440	56326
Firewood (Tonnes)	31.21	3.96	26.62	4.63	0	0
Coal (Tonnes)	0	0	2.53	1.28	0	0
Saw Dust (Tonnes)	0	0	0	0	12.14	2.02
CO (kg)	468.21	59.34	400.79	69.25	182.11	30.29
CH_4 (Kg)	14.05	1.78	12.10	2.07	5.46	0.91
N_20 (kg)	1.87	0.24	1.78	0.28	0.73	0.12
SO_2 (kg)	24.97	3.16	37.66	11.73	9.71	1.62
NOx (kg)	46.82	5.93	51.88	10.02	18.21	3.03
TSP (kg)	243.47	30.86	210.61	35.77	94.70	15.75
CO_2 (kg)	0	0	3382.99	1706.68	0	0
Total Fuel (GJ)	468.21	59.34	441.05	70.27	182.11	30.29
Ash (Tonnes)	1.48	0.47	2.39	1.43	1.56	0.92
Pupae &Cocoon Waste (Tonnes)	6.47	0.96	6.39	0.97	5.29	0.69
Multivoltine Cocoons (Tonnes)	7.86	2.48	9.14	0.75	0	0
Bivoltine Cocoons (Tonnes)	6.78	1.38	7.35	0.47	0	0
Dupion Cocoons (Tonnes)	0	0	0	0	6.29	0.69
Water (KL)	79.69	47.10	170.76	97.89	73.94	47.91

multi-end units use more labour compared to cottage and charakha units. This is true both in terms of skilled and unskilled labourers. That is why the labour cost is the highest in multi-end units relative to cottage and charakha units. However, the average value of output is marginally high in cottage units compared to that of multi-end units and both are substantially high compared to that of charakha units.

What is more significant to note is that keeping aside CO_2 emissions, the average emissions of other gases particularly CO, TSP and N_2O are the highest in multi-end units followed by cottage and charakha units respectively. The multi-end units consumed the highest amount of fuel, on an average. The same holds good for generation of ash, and pupae and cocoon wastes. On the whole, it appears that among all it is the traditional charakha units which are causing the least environmental pollution.

From Table 5.13, we may observe that both the cost of production (including fuel costs) and value of output per tonne of raw silk are significantly higher in the case of multiend and cottage industries compared to Charakha. However, in the case of information on number of labour and labour cost is partial in the case of Charakha units, which are basically household units. In these units the family members perform most of the activities. The labour related information provided by the majority of the units is restricted to hired labourers. If we assume family member participation in the range of four to six in numbers, the labour requirement becomes comparable with that of other two groups. Even in terms of energy use, the Charakha units turn out to be more efficient compared to other types of units. Also, they use sawdust as a fuel whereas cottage units use both firewood and coal and the multiend units use only firewood. From the sustainability point of view Charakha fares the best, then the multi end and last is the cottage.

The ranking of units in terms of level of pollution also follows the same pattern. The Charakha units mainly depend on the cheaper variety raw material (dupion cocoons) and produce low quality raw silk using primitive technologies for boiling cocoons (saw dust in conventional wood stoves) and reeling (Charakha). This results in low cost, low energy use and low value of output.

This analysis has clearly indicated that the variations in energy consumption cannot be studied across the sample units comprising all the three types of units. Therefore there is a need for studying the variations in energy consumption in units in the same group.

5.6 Comparison of Various Estimated Parameters Across Groups Based on Energy Consumption Level

As described earlier, the sample units belong to distinctly different technology and size groups. Therefore the comparison of parameters across different energy consumption levels has been done separately for multiend, cottage and Charakha units. Since the number of units in each category is small, we grouped the units into low and high energy consumption groups. Table 5.14 contains the details of various estimated parameters for a production level of one tonne of raw silk. The units grouped under low energy consumption level in the multiend category on an average consume 422.4 GJ of energy compared to 506.4 GJ for units grouped under high energy consumption level. Similarly, the units under low and high energy consumption level groups in the cottage industry consume 386.8 GJ and 490.8 GJ respectively, and that in Charakha consume 161.1 GJ and 205.2 GJ respectively. This shows that there are significant variations in energy consumption levels both within and across groups to produce one tonne of raw silk. Also, the pollution levels change with the increase in the energy consumption levels.

From the table, it may be observed that the total labour requirement per tonne of silk goes up with the increase in the level of energy consumption in the case of multiend units, but this increase is very small in the case of cottage units. The reduction in labour requirements showed in the case of Charakha units may not be realistic because this excludes the family members. The ratio of skilled to unskilled labour does not have any pattern to show the influence of skill level changes on the energy consumption level. This ratio is higher for high energy use units in the case of multiend but lower in the cases of cottage and Charakha units compared to low energy use units. This indicates that the skill level changes have only a marginal influence on energy consumption levels. Further, from the table we may observe that the cost of production increases with the energy consumption level. The pattern of changes in the level of labour and raw material inputs with the increase in energy consumption level indicates the very marginal level of influence of these parameters. However, it is difficult to pinpoint the exact reason for this. One possible reason could be the involvement of unskilled people in energy using activities. The owners also feel unconcerned because the energy cost is negligible compared to the total cost of production. Therefore one possible solution could be promotion of energy efficient technology to reduce the energy consumption level and thereby pollution impacts.

Table 5.14: Comparison of Various Parameters for Different Group of Units based on Energy Consumption Levels (Per Tonne of Silk Output per year)

Groups	Multiend		Cottage		Charakha	
	Low Energy	High Energy	Low Energy	High Energy	Low Energy	High Energy
Avg. Labour/Unit (No.)	14.60	20.67	14.18	13.75	4.00	3.30
Avg. Skilled Labour/Unit (No.)	10.20	15.33	10.45	9.83	2.45	2.22
Avg. Unskilled Labour/Unit (No.)	4.40	5.33	3.73	3.92	2.13	1.86
Total Labour (No.)	6.90	8.56	7.27	7.45	2.71	2.38
Skilled Labour (No.)	4.80	6.39	5.40	5.32	1.66	1.55
Unskilled Labour (No.)	2.10	2.17	1.88	2.14	1.45	1.40
Value of Output (Rs.)	1,451,010	1,476,065	1,479,353	1,501,175	806,941	808,936
Labour Cost (Rs.)	100,781	127,238	102,316	104,660	43,221	41,437
Fuel Costs (Rs.)	36,223	41,296	37,557	45,794	24,749	32,748
Raw Material Cost (Rs.)	1,164,468	1,284,306	1,235,644	1,290,595	670,693	702,905
Other Costs (Rs.)	7,461	10,651	8,914	10,488	1,453	1,509
Total Cost (Rs.)	1,308,932	1,463,491	1,384,432	1,451,538	740,115	778,598
Firewood (Tonnes)	28.16	33.76	23.19	29.76		
Coal (Tonnes)			2.38	2.67		
Saw Dust (Tonnes)					10.74	13.68
CO (kg)	422.41	506.38	349.29	447.99	161.10	205.21
CH_4 (Kg)	12.67	15.19	10.55	13.52	4.83	6.16
N_20 (kg)	1.69	2.03	1.56	1.98	0.64	0.82
SO_2 (kg)	22.53	27.01	33.78	41.21	8.59	10.94
NOx (kg)	42.24	50.64	45.92	57.35	16.11	20.52
TSP (kg)	219.65	263.32	183.68	235.29	83.77	106.71
CO_2 (kg)			3179.30	3566.31		
Total Fuel (GJ)	422.41	506.38	386.77	490.81	161.10	205.21
Ash (Tonnes)	1.35	1.58	2.41	2.37	1.71	1.39
Pupae &Cocoon Waste (Tonnes)	6.37	6.55	6.33	6.45	5.40	5.17
Multivoltine Cocoons (Tonnes)	8.55	7.17	9.14	9.14		
Bivoltine Cocoons (Tonnes)	6.98	6.65	7.15	7.53		
Dupion Cocoons (Tonnes)					6.40	6.17
Water (KL)	80.43	79.07	156.24	184.06	54.36	95.48

Even though the influence is marginal, we carried out ANOVA to study the significance of this influence on the level of energy consumption.

5.7 Factors for ANOVA Analysis in Silk Reeling Cluster

As in the case of brick and tile cluster we made an attempt to model the variations in energy consumption and thereby pollution level through its relationship with human resource, technology and external & structural factors using ANOVA. All the sample units irrespective of technology/scale (i.e., multiend, cottage and Charakha) are included in the analysis. We have observed that the Charakha units, which are low in technology level, however, consume less energy per tonne of silk output. But the quality of silk produced is inferior to that of other two categories and this reflected by the sale price of the raw silk (i.e., value of output). To incorporate this, we have performed ANOVA with energy consumption norm as dependent variable in two forms – energy consumption per kilogram of silk (MJ/kg) and energy consumption per rupee value of silk output (KJ/Rs).

5.7.1 Human Resource Factors

As described in the methodology, three variables, Owner/Manager/ Supervisor qualification levels, labour set skill levels and value of labour are taken into account in this factor.

I. *Owner/Manager/Supervisor Qualification Level:* In silk reeling industry cluster at Ramnagaram, it has been observed that it is a common practice that the owner himself manages the whole unit. Majority of the owners of sample units have qualifications of 10^{th} standard and below. Only two, one with B.Com and the other with pre-university qualification are above high school standard. Therefore, we have grouped the units into two levels. The units with owner having education up to primary level as low and high school and above as high qualification groups.

II. *Labour Skill Level:* Three levels – low, medium and high – are used in the ANOVA analysis. The combination of ratio of number of skilled labourers to the unskilled labourers and value of labour (labour cost per labour) has been used as a basis for arriving at these skill levels. First, we grouped the units having a ratio of below 1.5 into low and above 1.5 in the high skill level class interval. Secondly, the units are grouped into low where the value of labour is up to Rs. 65/labour/day and above this in the high class interval. Combining the two we arrived at the three labour skill levels.

Further, to ascertain the importance of these variables in explaining the variations in the dependent variable (energy consumption norm), we performed simple One-way ANOVA. This resulted in both the variables labour skill level and owner/manager qualification level to be significant, independent of each other.

5.7.2 Technology Factors

Under technology factor, we have considered three factors based on Production Technology (Technology Level) being used, Age of Plant and Machinery and other Innovations and Modifications carried out in the unit.

I. *Technology Level*: Technology levels are identified based on the kind of reeling technology in use. The Charakha units have been grouped as low, cottage units as medium and multiend as high technology level group.

II. *Age of Plant and Machinery*: The units are classified into three groups, the first one with plant & machinery of above 15 years old, second with plant & machinery of 10 to 15 years old and third group with plant & machinery of up to 10 years old.

III. *Other Innovations/Modifications*: Since the units are not doing any kind of innovations we did not include this variable in the analysis of silk reeling cluster.

The simple one-way ANOVA analysis between each of these variables and the energy consumption norm variable resulted in only technology level variable to be significant in explaining the variations. The other variable, age of plant and machinery found to be not significant and therefore excluded from further analysis.

5.7.3 Structural and External Factors

I. *Age of the unit*: Here the units are classified into three groups based on the year of inception. Units with an age of 16 years and above, between 10 and 16 years and up to 10 years have been classified into groups 1, 2 and 3 respectively.

II. *General Environmental conditions*: The project team members' observation on each of the items in the general environment related questionnaire enabled us to generate unit-wise total scores indicating the level of environmental conditions. Based on the total scores obtained, each unit has been categorized into good, average and bad in terms of general environmental conditions.

III. *Interaction Levels*: The interactions among the units as well as with any external agencies are found to be non-existent in the cluster. Therefore this variable was excluded from the analysis.

As in the case of brick and tile cluster, we combined these variables into one external and structural factor for including in the model. The original groupings of the units based on the individual variables have been aggregated to form the combine groupings. In other words, the units have been grouped into high, medium, and low levels based on the total scores under a single external and structural factor.

5.8 Results and Discussion

To study the influence of the above factors on the energy consumption levels forms the basic purpose of ANOVA. The dependent variable considered here is energy consumption per unit of silk output in two forms – energy in MJ/kg of silk and energy in KJ/Rs. of silk. In addition, we have carried out ANOVA to find out the relationship between considered factors and other dependent variables - the cost of production and value of output.

5.8.1 Relationship between Factors and Energy Consumption

As in the case of brick and tile cluster, we have used *sequential sums of squares method* for the analysis of variance to explain the relationship between the considered factors and dependent variables. The factors are included in the order of labour skill level, technology level, structural and external factor and owner's qualification. In the same order, the factors have been used for ANOVA with different dependent variables.

The details of the final factors/variables considered for the analysis and the type of classifications made and the number of units in each of the groups are presented in Table 5.15. From the table one could observe that the analysis design is an unbalanced one because the cell frequencies (number of units in each group) are unequal. Using the SPSS (Statistical Package for Social Sciences) software, the ANOVA has been carried out.

Table 5.15: Factors Considered for Univariate ANOVA

Factors	**Levels**	**Classes**	**No. of Units in each Class Intervals**
Labour Skill Level	Low	1.00	18
	Medium	2.00	20
	High	3.00	17
Technology Level	Low	1.00	21
	Medium	2.00	23
	High	3.00	11
Structural and External Factor	Low	1.00	14
	Medium	2.00	24
	High	3.00	17
Owner Qualification Level	Low	1.00	35
	High	3.00	20

In the first part of the analysis, only two factors labour skill level and technology level are found to be significant. The other two factors, namely, structural and external factor and the owner qualification level are found to be not significant and explaining very little variations in the dependent variable. Also, no interaction effects have been found to be significant to include in the model. Therefore we carried out the ANOVA again by removing these variables. The results of this analysis are presented in Table 5.16. From the table, it appears that both the factors significantly explain the variations in the energy/silk variable. However, the variable technology level explains maximum amount of variation, followed by labour skill level. It is important to remember here that though there are variations in the energy consumption levels with the change in technology level, the energy level goes up as the unit moves up on the technology ladder. The interaction effect between labour skill and technology levels is found to be insignificant and therefore not included in the model. The high value of R^2 indicates that the model is able to explain significant amount of variation in the dependent variable.

Table 5.16: Univariate ANOVA Results for the Relationship Between Energy (MJ)/kg of Raw Silk and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	364643.748	2	182321.874	59.246	.000
Technology Level	579699.140	2	289849.570	94.187	.000
Sum of Squares due to Factors	944342.887	4	236085.722	76.716	.000
Sum of Squares due to Error	153869.352	50	3077.387		
Total Sum of Squares	1098212.239	54			
R Squared	0.860				
Adjusted R Squared	0.849				

Similar analysis is performed using the energy in KJ per Rs. of silk output as dependent variable. The results of the ANOVA on the final reduced model are presented in Table 5.17. Both the technology and labour skill level factors in that order significantly explain the variations in the dependent variable. It is interesting to note that the R^2 value has reduced significantly to 0.553 compared to 0.860 for the previous model. We are aware of the fact that the technology level factor is derived on the basis of the differences in reeling types – multiend, cottage and Charakha. Also, we know that the energy consumption levels are similar for multiend and cottage units. It is the Charakha units, which have low energy consumption norm and at the same time produce inferior quality raw silk. To capture this discrepancy we have used KJ/Rs. of silk output as dependent variable. In other words, this is done to reflect the low quality of silk produced by Charakha units in terms of price it fetches to the owner. But the result indicates that the pricing of raw silk does not reflect the quality of raw silk. If this analysis has resulted in low R^2 and technology level factor as not significant, then we could have concluded that the raw silk price reflects the quality. Therefore, at least, from the perspective of energy consumption levels, it is advantageous to remain at the Charakha stage rather than moving up the ladder. This is also observed in the Ramanagaram cluster, where the multiend technology has not gained any popularity and some of the units are on the verge of closing down.

Table 5.17: Univariate ANOVA Results for the Relationship Between Energy (kJ)/Rs of Raw Silk and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	52737.014	2	26368.507	13.482	.000
Technology Level	68255.131	2	34127.566	17.450	.000
Sum of Squares due to Factors	120992.145	4	30248.036	15.466	.000
Sum of Squares due to Error	97789.111	50	1955.782		
Total Sum of Squares	218781.256	54			
R Squared	0.553				
Adjusted R Squared	0.517				

5.8.2 Relationship between Factors and Value of Output

The results of the analysis of the relationship between the considered factors and value of output are presented in Table 5.18. As in the previous case, only technology and labour skill levels in that order significantly explain the variations in value of output per kg of raw silk output. No interaction effects are found to be significant to include in the model. The high R-square indicates the suitability of the considered model in explaining the variations in the value of output.

5.8.3 Relationship between Factors and Cost of Production

The ANOVA attempted with respect to the considered factors and total cost per kg of raw silk basically attempts to test the hypothesis whether higher levels of labour skill, technology, owner's qualification and structural & external factor tend to reduce the overall cost of production. However, the results presented in Table 5.19 show that only the technology and labour skill levels significantly explain the variations in the total cost per kg of silk. Other factors are found to be insignificant and excluded from the model.

Table 5.18: Univariate ANOVA Results for the Relationship Between Value of Output per kg of Raw Silk and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	2099323.482	2	1049661.741	2296.573	.000
Technology Level	3811869.005	2	1905934.502	4170.027	.000
Sum of Squares due to Factors	5911932.222	8	738991.528	1616.852	.000
Sum of Squares due to Error	21024.563	46	457.056		
Total Sum of Squares	5932956.786	54			
R Squared	0.996				
Adjusted R Squared	0.996				

From the ANOVA performed with different dependent variables, we may arrive at the following conclusions with respect to silk reeling cluster.

I. Technology level is the most important factor explaining variations in the level of energy consumption, value of output and cost of production.

II. Human resource factor, constituting only labour skill level is the second most important factor determining the level of energy consumption, value of output and cost of production.

III. External and structural factor and owner's qualification level are not found to be significant in explaining variations in the dependent variables. Even no significant interaction effects are found to be contributing to the variations in dependent variables.

Table 5.19: Univariate ANOVA Results for the Relationship Between Total Cost per kg of Raw Silk and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	1520952.553	2	760476.276	54.505	.000
Technology Level	4045206.912	2	2022603.456	144.964	.000
Sum of Squares due to Factors	5587334.870	8	698416.859	50.057	.000
Sum of Squares due to Error	641813.627	46	13952.470		
Total Sum of Squares	6229148.498	54			
R Squared	0.897				
Adjusted R Squared	0.879				

The results of the above analysis do not indicate the direction of changes in the dependent variables with the changes in the level of independent variables. Even the comparative analysis performed based on the energy consumption level (Table 5.14) did not show any pattern. In other words, it is not clear whether the improvement in skill levels or technology levels results in reduced energy consumption levels. To ascertain this fact we have compared the various estimated parameters across the group of units formed using labour skill and technology level factors.

5.9 Comparison of Various Estimated Parameters Across Groups Based on the Factors

5.9.1 Labour Skill Level Based Groups

The analysis presented earlier indicated that changes in the levels of labour skill, result in significant variations in dependent variables like energy consumption, value of output and costs. It would be interesting to know how some of the important parameters vary across groups formed on the basis of these factors. Table 5.20 contains the average estimates of various parameters for the silk reeling units falling under the groups of low, medium and high labour skill levels. It may be observed from the table that the ratio of skilled to unskilled labourer per tonne of raw silk produced is the lowest for low and highest for high skilled group units. However, both the number of skilled and unskilled labour requirement to produce one tonne silk reduces with the increase in skill level. This is difficult to justify and this may be due to partial information obtained from Charakha units regarding the number of labourers. The dominance of Charakha units going up as the skill level increases can be seen from the gradual reduction in the scale of production. The average fuel consumption per tonne of silk ranges from a high of 450.7 GJ/tonne in the low to 340.3 GJ/tonne in the medium and 246.98 GJ/brick in the high skilled groups. This shows that the energy consumption comes down with the increase in labour skill levels. The same trend is observed in the case of ash, pupae & cocoon waste and wastewater.

In terms of cost, the total cost per tonne of silk reduces as labour skill levels go up. This is also observed in the cases of labour and fuel costs. The estimated average consumption of various fuel types per tonne of silk for the units in different groups are also presented in Table 5.20. Only the low and medium skill group units consume coal. The table also contains average estimates of various types of pollutants for different groups of units, which are found to be reducing with the increase in labour skill levels. From this analysis, we can conclude that the labour skill level improvement will result in the reduction in the level of energy and material use and thereby pollution levels. However, unlike in the case of brick and tile cluster, we could not observe any pattern of composition of skilled and unskilled labourers to make any specific recommendation.

Table 5.20: Comparison of Various Parameters for Different Group of Units based on Labour Skill Levels

	Low	Medium	High
Skilled Labour (No. per Unit)	11	8	4
Unskilled Labour (No. per Unit)	4	4	2
Skilled Labour (No./tonne of silk)	5	4	3
Unskilled Labour (No./tonne of silk)	3	2	1
Raw Silk Production/year/unit (kg)	2093.33	1848.00	1616.47
Fuel/Silk Output (GJ/tonne)	450.74	340.34	246.98
Total Cost (Rs./ tonne of Silk)	1,352,639	1,181,055	937,145
Labour Cost (Rs./ tonne of Silk)	98,837	86,749	60,264
Fuel Cost (Rs./ tonne of Silk)	39,430	37,732	30,994
Firewood (tonnes/tonne of Silk)	29.46	25.64	30.35
Coal (tonnes/tonne of Silk)	2.63	2.46	----
Sawdust (tonnes/tonne of Silk)	12.00	12.06	12.19
Ash (tonnes/tonne of Silk)	2.23	2.04	1.35
Pupae & Cocoon Waste (tonnes/tonne of Silk)	6.36	6.19	5.35
Water (KL/tonne of Silk)	144.08	110.17	91.76
Multivoltine Cocoons (tonnes/tonne of Silk)	8.29	9.13	----
Bivoltine Cocoons (tonnes/tonne of Silk)	6.97	7.36	7.34
Dupion Cocoons (tonnes/tonne of Silk)	6.00	6.60	6.14
CO (kg/tonne of Silk)	428.21	314.31	246.98
CH_4 (kg/tonne of Silk)	12.89	9.48	7.41
N_20 (kg/tonne of Silk)	1.81	1.37	0.99
SO_2 (kg/tonne of Silk)	31.95	27.29	13.17
NOx (kg/tonne of Silk)	49.43	39.06	24.70
TSP (kg/tonne of Silk)	223.90	164.86	128.43
CO_2 (kg/tonne of Silk)	3518.12	3284.72	----

5.9.2 Technology Level Based Groups

The average parameters estimated for units coming under different groups formed based on technology levels are presented in Table 5.21. From the table it may be observed that the average energy consumption per tonne of silk is the lowest in the case of units in the low technology group and it is the highest for high technology group. In other words energy consumption levels increase with the upward movement in the technology level. The Charakha units falling under the low technology group mainly use traditional Chula for boiling low quality cocoons and producing low quality raw silk.

Table 5.21: Comparison of Various Parameters for Different Group of Units based on Technology Levels

	Low	Medium	High
Fuel/Silk Output (GJ/tonne)	182.11	441.05	468.21
Total Cost (Rs./ tonne of Silk)	758,440	1,419,444	1,393,237
Labour Cost (Rs./ tonne of Silk)	42,371	103,539	115,212
Fuel Cost (Rs./ tonne of Silk)	28,558	41,855	38,990
Raw Silk Production/year/unit (kg)	1468.57	1982.61	2334.55
Firewood (tonnes/tonne of Silk)	----	26.62	31.21
Coal (tonnes/tonne of Silk)	----	2.53	----
Sawdust (tonnes/tonne of Silk)	12.14	----	----
Ash (tonnes/tonne of Silk)	1.56	2.39	1.48
Pupae & Cocoon Waste (tonnes/tonne of Silk)	5.29	6.39	6.47
Water (KL/tonne of Silk)	73.94	170.76	79.69
Multivoltine Cocoons (tonnes/tonne of Silk)	----	9.14	7.86
Bivoltine Cocoons (tonnes/tonne of Silk)	----	7.35	6.78
Dupion Cocoons (tonnes/tonne of Silk)	6.29	----	----
CO (kg/tonne of Silk)	182.11	400.79	468.21
CH_4 (kg/tonne of Silk)	5.46	12.10	14.05
N_20 (kg/tonne of Silk)	0.73	1.78	1.87
SO_2 (kg/tonne of Silk)	9.71	37.66	24.97
NOx (kg/tonne of Silk)	18.21	51.88	46.82
TSP (kg/tonne of Silk)	94.70	210.61	243.47
CO_2 (kg/tonne of Silk)	----	3382.99	----

The low quality of production process with traditional technology may be the reason for less amount of energy requirements. The difference in energy consumption level between medium and high technology groups is not significant. The medium and high technology units require higher levels of total cost, labour cost and fuel cost to produce one tonne of silk compared to low technology units. However, they produce better quality silk, which fetches better price. Ash produced per tonne of silk is the highest for medium technology units because of the coal usage compared to other two groups. Pupae and cocoon waste increases with the increase in technology level. The average emission levels exhibit mixed patterns across technology levels.

5.10 Abatement Measures to Reduce Pollution Levels in the Silk Reeling Cluster

From the results of the previous analysis we could not come to a definite conclusion that upgrading labour skill set would result in efficient energy utilization and thereby reduction in pollution levels. Similarly, adoption of newer technologies along with the scaling up of production resulted in increased energy consumption levels. Under these circumstances adopting energy efficient technology would be an appropriate abatement measure that is likely to enable reduction in pollution levels. The suggested technology shift as an abatement measure is the replacement of conventional wood based system for process heating with a gasifier-based system. The Tata Energy Research Institute (TERI) has implemented this technology in a few of the cottage units in Ramanagaram. During our survey, we came across a couple of units, which have installed gasifier systems for meeting their process heating demand and they reported significant savings in firewood usage.

5.10.1 Technology Shift – Conventional Wood based system to Gasifier based system

Here we have made an attempt to analyse the shift from conventional wood based system for process heating to gasifier-based system in cottage units. In the Ramanagaram cluster there are about 700 cottage based silk reeling units. Predominantly, these units use firewood and coal as a fuel for producing the required process heat. In the present analysis, for comparison, we have used two types of conventional wood based system alternatives – one with the fuel consumption norm obtained from the sample cottage units and the other with standard firewood consumption norm to produce one kg of raw silk – to be replaced by gasifier system with firewood as fuel. For the conventional system, the information on capital and fuel costs is obtained from the sample units. The information for gasifier system is obtained from TERI through personal communication. For the purpose of analysis a discount rate of 10% is assumed. The lifespan has been taken to be equal for both the systems at 15 years. In the case of conventional system, the life span of devices ranges from two to three years. To equate this to the life of gasifier system, we have included the present value of the replacement costs in capital cost of conventional system. The results of the analysis of cost and benefits of shifting from conventional wood based to gasifier systems are presented in Table 5.22.

The comparative analysis is made for typical cottage based silk reeling units with a capacity of 1800 kg raw silk per year. The initial investment required for a conventional system is Rs. 15,000. However, after the inclusion of replacement costs it becomes Rs. 71,728, which is less than the Rs. 100,000 required for a gasifier system. From the table we may observe that the annual operations and maintenance cost of Rs. 3000 for a gasifier system is four times higher than the conventional system. The annual energy consumption levels (in MJ/kg) are highest for the conventional system of the sample cluster, lowest for the gasifier system and in between for the conventional standard system. The typical system in the cluster uses coal along with firewood whereas the standard conventional system uses only firewood. Even the total fuel cost per year follows the same trend. It is clear from the table that a shift to a gasifier system results in enormous savings. In terms of pollution level, one could observe a substantial reduction from the conventional (cluster average) system to gasifier system.

Table 5.22: Cost and Benefits of Technology Change for a Typical Cottage Silk Unit

	Conventional Wood System (Cluster average)	**Conventional Wood System (Standard)**	**Gasifier System**
Capital + Replacement Cost (Rs.)	71728	71728	100000
Silk Production/Year (kg)	1800	1800	1800
O&M Cost (Rs./year)	750	750	3000
Annualised Capital + O&M Cost (Rs./Year)*****	10180.34	10180.34	16147.38
Wood Price (Rs./kg)	1.2	1	1.2
Coal Prices (Rs./kg)	5.7	0	0
Wood Consumption (kg/kg)	26.92	22.5	12
Coal Consumption (kg/kg)	2.31	0	0
Energy Consumption (MJ/kg)	449.94	337.50	180.00
Energy Consumption (GJ/Year)	809.89	607.50	324.00
Total Fuel Cost (Rs./Year)	81835	40500	25920
CO (kg)	729.82	607.50	324.00
CH_4 (kg)	22.05	18.23	9.72
N_20 (kg)	3.27	2.43	1.30
SO_2 (kg)	71.30	32.40	17.28
NOx (kg)	96.46	60.75	32.40
TSP (kg)	383.87	315.90	168.48
CO_2 (Tonnes)	5.56	0.00	0.00

Changing of Technology →	**Conventional (Cluster Avg.) to Gasifier System**	**Conventional (Standard) to Gasifier System**
Additional Investment (Rs.)	28272	28272
Additional Annualised Capital+O&M (Rs.)	5967.04	5967.04
Savings in Fuel Cost (Rs./Year)	55914.7	14580
Savings in Fuel Consumption (GJ/Year)	485.89	283.50
Cost of Saved Energy (Rs./GJ)	12.28	21.05
Value of Saved Energy (Rs./GJ)	115.08	51.43
Reduction in Pollution Levels		
CO (kg)	405.82	283.50
CH_4 (kg)	12.33	8.51
N_20 (kg)	1.98	1.13
SO_2 (kg)	54.02	15.12
NOx (kg)	64.06	28.35
TSP (kg)	215.39	147.42
CO_2 (Tonnes)	5.56	0.00

Note: *****At 10% discount rate and for a life of 15years.

From Table 5.22, we may observe that the additional investments required for the shift are not very high. The savings in fuel consumption are quite significant in both kinds of shifts. However, the savings for the typical sample unit is significantly high compared to the standard conventional unit. This clearly shows how inefficiently the cottage units in Ramanagaram use the energy. This gets clearer when we compare the cost of saved energy and value of saved energy for the two shifts. The cost of saved energy for Conventional (Cluster Average) → Gasifier System shift is significantly lower at Rs. 21.05 per GJ compared to Rs. 12.28 per GJ for Conventional (Standard) → Gasifier System. Even the value of saved energy is more than two times higher in the case of the former shift compared to Conventional (Standard) → Gasifier System. In other words, it is economical not only to the conventional efficient system but it is further more attractive to the cottage units operating in the cluster. The table also contains the information on potential reductions in pollution levels that could be achieved due to the shifts, which are quite significant. Therefore, it is both economically as well as environmentally attractive to shift from conventional wood based to gasifier systems.

Further, we have extended this analysis of shifting to a more efficient technology to the whole of sampled cottage units of the cluster (Table 5.23). From the table one could observe that the savings in terms of quantum of energy and energy costs are substantial. The value of saved energy is almost ten times the cost of saved energy, which indicates that the level of benefits one could accrue on account of shift from conventional wood to gasifier based system. Even the reductions in pollution levels are substantial.

Table 5.23: Cost and Benefits of Technology Change for Sample Cottage based Silk Units

	Conventional Wood System (Cluster average)	**Gasifier System**
Capital + Replacement Cost (Rs.)	1,649,742	2,300,000
Silk Production/Year (kg)	45,600	45,600
O&M Cost (Rs./Year)	17,250	69,000
Annualised Capital + O&M Cost (Rs./Year)*****	234,148	371,390
Energy Consumption (GJ/Year)	20517.30	8208.00
Total Fuel Cost (Rs./Year)	2,073,145	656,640
CO (kg)	18488.81	8208.00
CH_4 (kg)	558.63	246.24
N_20 (kg)	82.92	32.83
SO_2 (kg)	1806.32	437.76
NOx (kg)	2443.53	820.80
TSP (kg)	9724.80	4268.16
CO_2 (Tonnes)	140.78	0.00
Changing of Technology →	**Conventional Wood System (Cluster Avg) to Gasifier System**	
Additional Investment (Rs.)	650,258	
Additional Annualised Capital + O&M (Rs.)	137,242	
Savings in Fuel Cost (Rs./Year)	1,416,505	
Savings in Fuel Consumption (GJ/Year)	12309.30	
Cost of Saved Energy (Rs./GJ)	11.15	
Value of Saved Energy (Rs./GJ)	115.08	
Reduction in Pollution Levels		
CO (kg)	10280.81	
CH_4 (kg)	312.39	
N_20 (kg)	50.09	
SO_2 (kg)	1368.56	
NOx (kg)	1622.73	
TSP (kg)	5456.64	
CO_2 (Tonnes)	140.78	

CHAPTER 6: PUFFED RICE MAKING CLUSTER – DAVANAGERE

6.1 Introduction

Puffed rice is used as a source of supplementary meal or snack item by middle and upper income households in Indian cities and towns. It is an easily digested and wholesome product. Puffed rice making is a traditional activity. This activity is not commonly found across regions but confined to only certain locations.

In Karnataka, Davanagere has a major concentration of puffed rice makers on the outskirts of the city so much so that the place is called ‘Mandakki Layout’ (which means ‘puffed rice’ layout). The layout comprises about 600 puffed rice making units in the state. According to official estimates, these units meet about 90% of the puffed rice demand of the state.

6.2 Puffed Rice Making: Process and Needs

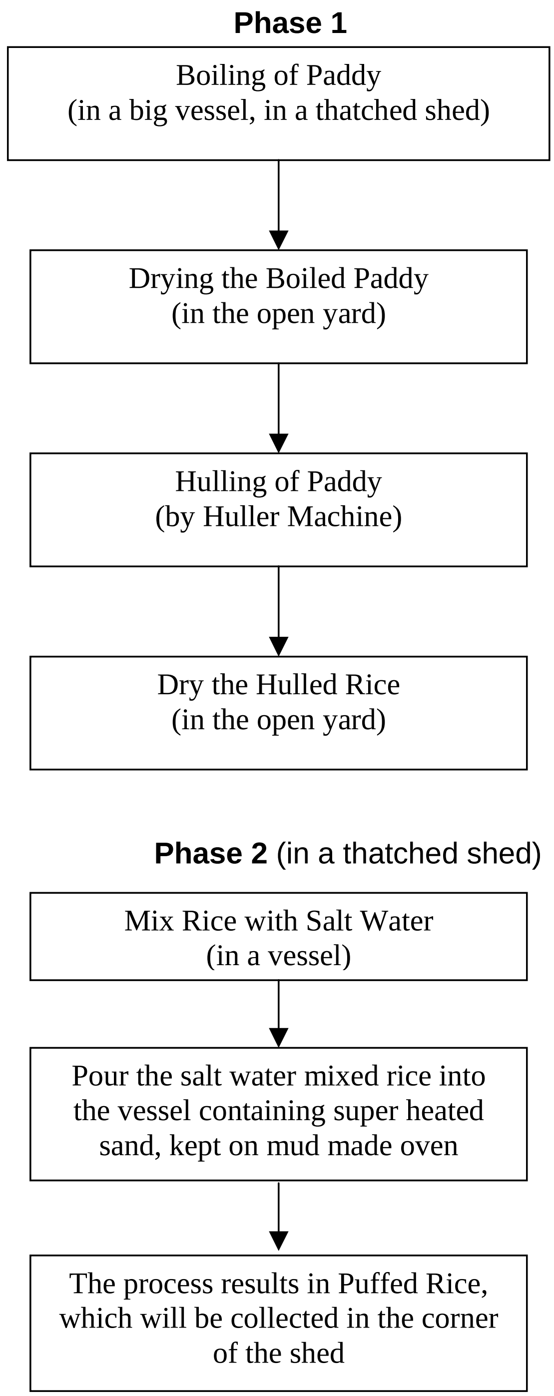
Puffed rice making involves largely skill based processes and therefore, requires hardly any equipment. A puffed rice maker requires paddy, salt and water as inputs, a drum, three vessels of various sizes, one spatula and one sieve – all to transform the inputs into output (puffed rice), with the help of energy inputs – rice husk, ground nut husk and scrap automobile tyres.

The puffed rice making process involves two phases (Figure 6.1)

The first phase involves conversion of paddy into rice. The procured paddy is boiled in a drum and then dried up in an open yard. Then the paddy is hulled in a huller machine to separate husk from rice. The hulled rice is then dried in an open yard. The first phase generates rice as the main product and rice husk as the bye-product. The bye-product rice husk is used as a source of fuel by all the puffed rice making units in Davanagere.

The second phase of puffed rice making consists of converting rice into puffed rice. The whole process takes place inside a thatched shed. The process begins with the mixing of rice with salt water in a vessel. Then, the salt water mixed rice is put into the vessel containing heated sand, kept on an oven made of mud. The rice is mixed with the hot sand with a spatula and as puffed rice emerges, it is separated from the sand with a sieve.

Figure 6.1 Puffed Rice Making Process



To boil paddy and heat the sand three kinds of energy inputs are used: rice husk, ground nut husk and used scrap tyres. It is the high heating intensity of scrap tyres, which has made many a puffed rice maker to use them along with rice and groundnut husks. While rice husk is the bye-product of the first stage of the process of puffed rice making, groundnut husk is available in plenty as Davanagere district is one of the major centres of groundnut cultivation.

The concentration of 600 units in one locality and their usage of scrap tyres, among others, for puffed rice making has resulted in 'visibly intensive' air pollution in the Mandakki Layout. The entire atmosphere in the layout is thickened with black smoke all around. Thus, air pollution is the major environmental problem caused by puffed rice making units in Mandakki Layout in Davanagere. Further, the whole process of puffed rice making generates waste in the form of ash, which causes land pollution. This adds to the 'untidy environment' of puffed rice units (which do not have properly constructed building and floor space).

6.3 Puffed Rice Making Units in Davanagere: Features

Puffed Rice making is a traditional industry. Though officials of the District Industries Centre, Davanagere are aware of the existence of about 600 units in Mandakki Layout, they do not have any systematic database of puffed rice making units. Therefore, there was no scope for developing a scientific random sampling.

We have covered a total of 46 puffed rice making units in the Mandakki Layout of Davanagere. As we could see, the units are, more or less, of uniform size and the technique/process of puffed rice making across the cluster is said to be the same. The entrepreneurs who started the 46 units are illiterates, with the exception of one who has studied upto pre-university education.

As the process of puffed rice making is skill based rather than machinery based, it is this process of conversion of rice (after mixing with salt water) into puffed rice, which calls for a skilled worker. The other activities like boiling paddy, drying the boiled paddy, drying the hulled rice are all performed by unskilled workers. All the 46 units surveyed, uniformly employed four workers, of which one is skilled and the other three are unskilled (Table 6.1).

Table 6.1 Employment in Puffed Rice Units

No of Units	Skilled Workers	Unskilled Workers	Total Workers
46	46	138	184

As stated earlier, the materials used are paddy, salt and sand, the energy inputs are rice husk, groundnut husk and tyres, the bye-product is rice husk and the final product is puffed rice (Table 6.2)

Table 6.2 Materials, Energy Inputs, Bye-Product and Final Product in Puffed Rice Units

No of Units	Materials	Sources of Energy	Bye Product	Final Product
46	Paddy, Salt, Sand	Rice Husk, Groundnut Husk, Tyres	Rice Husk	Puffed Rice

Thus, puffed rice units in Davanagere are of uniform size, follow common process for puffed rice making with similar materials and labour inputs and sources of fuel. These units are ancestral and therefore, inherited by the present owners of all the 46 units surveyed.

6.4 Puffed Rice Units: Inputs, Cost, Production and Pollution

The summary data for one year on inputs, sources of fuel and output for the 46 units are presented in Table 6.3. On an average, a puffed rice unit consumes about 70 tonnes of paddy, nearly a tonne of salt, about a tonne of sand along with about 15 tonnes of rice husk and three tonnes of scrap tyres to produce 45 tonnes of puffed rice in an year. The comparable average costs per unit are Rs. 0.42 million for paddy, about Rs. 2500 for salt, about Rs. 700 for sand, about Rs. 11,000 for rice husk and nearly Rs 7700 for scrap tyres, apart from labour cost of nearly Rs. 81,000 and other cost of Rs. 5000 per year (Table 6.4). Thus, energy costs form hardly four percent of the total cost and therefore, puffed rice making is not energy intensive.

Table 6.3: Summary Data (per Year) for the Sample Units of the Cluster (For 46 Units)

	No. of Units	Total	Average/Unit	Standard Deviation
Paddy (Tonnes)	46	3225	70.11	3.37
Salt (Tonnes)	46	40.08	0.87	0.24
Sand (Tonnes)	46	48.48	1.05	0.13
Rice Husk (Tonnes)	46	709.5	15.42	0.74
Scrap Tyre (Tonnes)	46	141.46	3.08	0.34
Total Fuel (GJ)	46	14036.22	305.14	19.73
Puffed Rice (Tonnes)	46	2083.46	45.29	2.74

Table 6.4: Production Cost Details per Year (Rs.)

	Total	Average/Unit	Standard Deviation
Paddy	19,350,000	420,652	20,208
Salt	114,900	2497.83	965.53
Sand	33,067	718.85	92.05
Rice Husk	510,560	11099.13	2994.59
Scrap Tyre	353,650	7688.04	848.02
Labour	3,715,900	80780	10503
Others	230000	5000	1725.62
Total Cost	24,308,077	528,436	24,889
Value of Output	27,117,900	589,520	25,473

However, given the emission factors of rice husk and scrap tyres (Table 6.5), puffed rice making units do generate significant amount of pollution, particularly air pollution (Table 6.6). The composition of gases released reveal that carbon dioxide (CO_2) accounts for the largest proportion followed by CO, TSP, NOx, SO_2, CH_4 and N_2O. It also generates ash causing land pollution.

Table 6.5: Emission Factors (kg/Tonne)

	Rice Husk	Scrap Tyre
CO	15	2.84
CH_4	0.45	0.0258
N_20	0.06	0
SO_2	0.8	11.9
NOx	1.5	13.6
TSP	7.8	11.22
CO_2		2080
Ash	210	47.8

Note: NAEI (1996), NAWT (2001), IPCC (1996)

Table 6.6: Summary of Environmental Pollution Details

	Total	Average/Unit	Standard Deviation
Ash (Tonnes)	155.76	3.39	0.17
CO (kg)	11044.25	240.09	12.06
CH_4 (kg)	322.92	7.02	0.34
N_20 (kg)	42.57	0.93	0.04
SO_2 (kg)	2250.97	48.93	4.62
NOx (kg)	2988.11	64.96	5.71
TSP (kg)	7121.28	154.81	9.54
CO_2 (Tonnes)	294.24	6.40	0.71

The energy used and pollution generated per tonne of puffed rice is given in Table 6.7. The raw materials and sources of fuel used per tonne of puffed rice is presented in Table 6.8.

Table 6.7: Pollution Generated and Energy use per tonne of Puffed Rice

	Average	Standard Deviation	Minimum	Maximum
Ash (kg)	74.91	4.23	69.79	83.13
CO (kg)	5.31	0.30	4.95	5.89
CH_4 (kg)	0.155	0.009	0.144	0.172
N_20 (kg)	0.020	0.001	0.019	0.023
SO_2 (kg)	1.08	0.09	0.94	1.28
NOx (kg)	1.44	0.11	1.27	1.68
TSP (kg)	3.42	0.21	3.17	3.86
CO_2 (kg)	141.22	13.58	119.17	170.97
Energy (GJ)	6.75	0.42	6.21	7.65

Table 6.8: Raw Material and Fuel use per tonne of Puffed Rice

	Average	Standard Deviation	Minimum	Maximum
Paddy (kg)	1551.18	86.36	1442.31	1714.29
Salt (kg)	19.28	5.40	9.96	28.57
Sand (kg)	23.33	3.07	17.14	29.76
Rice Husk (kg)	341.26	19.00	317.31	377.14
Scrap Tyre (kg)	67.90	6.53	57.29	82.20

Given the fact that puffed rice units clustered in Mandakki Layout of Davanagere are of uniform size, involve similar proportions of skilled and unskilled labour, use similar material and energy inputs and follow common process of puffed rice making, it becomes easy to extend the results of 46 units to the 600 units of the cluster to estimate the quantum of inputs, output, cost, value of output and quantum of pollution generated. The estimates are presented in Table 6.9. From the table we may observe that even though the pollution levels are not significant in terms of contributions to the climate change, they are significant in terms of local impacts, which they could create. Since a large number of units located in a concentrated way in a cluster will pollute the local environment by emitting suspended particulate matter in a large quantity in addition to other pollutants, it would definitely affect the health conditions of the local people.

Table 6.9: Estimates for the Puffed Rice Cluster (600 Units)

Input and Output (Quantities)	
Paddy (Tonnes)	42065.22
Salt (Tonnes)	522.78
Sand (Tonnes)	632.35
Rice Husk (Tonnes)	9254.35
Scrap Tyre (Tonnes)	1845.13
Total Fuel (GJ)	183081.13
Puffed Rice (Tonnes)	27175.57
Production Cost and Value of Output (Rs. Million)	
Paddy	252.39
Salt	1.50
Sand	0.43
Rice Husk	6.66
Scrap Tyre	4.61
Labour	48.47
Others	3.00
Total Cost	254.32
Value of Output	353.71
Environmental Pollution Details	
Ash (Tonnes)	2031.61
CO (Tonnes)	144.06
CH_4 (Tonnes)	4.21
N_20 (Tonnes)	0.56
SO_2 (Tonnes)	29.36
NOx (Tonnes)	38.98
TSP (Tonnes)	92.89
CO_2 (Tonnes)	3837.87

6.5 Puffed Rice Units: How to Mitigate Pollution?

It is appropriate to probe the ways and means of mitigating pollution in the Mandakki Layout, given the quantum of estimated pollution for the cluster. In general, pollution generated by an industrial unit could be attributed to either technology or level of skills of workers or entrepreneurial education level or sources of energy inputs used. The size of puffed rice units are very small, be it in terms of labour or investment but the number of units located in the cluster is fairly large. One alternative to overcome the problem of pollution is to replace the existing units by one single mechanized puffed rice making plant (like in Italy). But that will lead to large scale displacement of labour and therefore, not feasible, leave alone the prohibitive cost of required investment.

The level of pollution is not related to the level of skills of labour either. Therefore, it is not possible to mitigate pollution through training/education of the existing labour force. The other issue is related to energy inputs. Currently, puffed rice making units use both rice husk and scrap tyre as the source of energy. It is clear from Table 6.5 that rice husk generates more CO, CH_4 and N_2O compared to scrap tyre but the latter generates more SO_2, NOx, TSP, apart from a large quantum of CO_2. Therefore, within the existing constraints, it may be possible to mitigate pollution by encouraging puffed rice units to use rice husk as a substitute to scrap tyres (which generates more carcinogenic gases).

CHAPTER 7:FOUNDRY INDUSTRY CLUSTER, BELGAUM

7.1 Backdrop

Belgaum region is one of the important centres of foundry industry in India. It has a history of more than 50 years. The first foundry, Damodar Iron works, was set up in 1947. The growth of foundry industry in terms of number of units was slow in the 60s and 70s. But there was a rapid expansion in terms of foundry units in the 80s. This was attributed to overall increase in the industrial activity in Belgaum with many large scale industries such as BEMCO and Ashok Iron and Steel works coming up in the region as well as the growth of automobile industry in Pune and Mumbai (Raghavendra, 2002).

According to the estimates of District Industries Centre, Belgaum there are about 110 small scale foundries, which are located within a radius of 3 kilometers in the Udyambag, Channamma nagar and Machhe industrial estates. The casting capacity ranges from a few tonnes per month upto 2000 tonnes per month, producing both ferrous and non-ferrous castings. According to the estimates of DIC, Belgaum, the Belgaum foundries produce about 6,000 tonnes of castings per month and employ about 10,000 workers directly (Raghavendra, 2002).

The castings produced are of a very wide range of applications and weighing from a few grams to a few tonnes per piece. The speciality of these foundries is their ability to promise castings as per the customer requirements at a very competitive price. The castings are marketed all over the country, particularly in cities like Bangalore, Chennai, Mumbai, Pune and Delhi.

Foundry industry is one of the mainstays of the regional economy. The work force available in and around is highly skilled and this is the other reason for the growth of this industry in the region. The foundry industry in Belgaum also has its problems, which hinders its further growth. The problem of infrastructure is very much evident. There is a shortage of electricity, water, good roads and so on. Most of the units, being in the tiny sector, have limited resources. They are on the lower level of technological development. Very few foundries have the technical expertise to achieve the technical specification being now demanded by the customers.

7.2 Foundry Operations and Pollution

A foundry is a casting manufacturing system. Casting is the process of forming objects by pouring liquid metal into a prepared mould and allowing the melt to solidify. It is one of the basic methods available for shaping metals for useful needs (Raghavendra, 2002).

The fine fundamental steps in making sand castings are pattern making and post pouring operations like fettling and heat treatment (Raghavendra, 2002). Patterns are required to make moulds. A pattern may be simply visualized as an approximate replica of the exterior of casting. Cores are forms, usually made of sand, which are placed in a mould cavity to form the interior surface of castings. Thus, the void space between the core and mould cavity surface is what eventually becomes the casting. Cores are produced using core boxes in the core room in parallel with moulding. Moulding consists of operations such as ramming of sand around a pattern, withdrawing a pattern to leave its imprint as a mould activity, placing of core in the mould activity, and the finishing and closing of the mould. Before closing, the moulds are coated and heated properly. The mould is then ready for pouring.

Melting and pouring consists of the preparation of molten metal for casting. Melting of metal is done in furnaces and ladles transfer the molten metal to the moulding area where the moulds are poured. Melting is done in parallel with mould making. The post pouring operations include cleaning or fettling (removal of sand, scale and excess metal in the form of gates from the casting), heat treatment, surface treatment, machining and inspection.

These foundry operations generate different kinds of air pollution, depending upon the kinds of furnace in use and the kinds of energy inputs that they use. In general, a typical foundry has several emission points: fugitive particulate, fumes and fugitive dust. (Figure 1) (Fugitive particulate emissions are generated from the receiving, unloading and conveying of raw materials. Scrap preparation with heat will emit smoke, organic compounds, and carbon monoxide; scrap preparation with solvent degreasers will emit organics).

The emission released from melting furnaces include particulate matter, carbon monoxide, organic compounds, sulphur dioxide, nitrogen oxides and small quantities of chlorides, and fluorides are generated from incomplete combustion of Carbon additives, flux additions, and dirt and scale on the scrap charge. Organic material on scrap and furnace temperature affects the amount of carbon monoxide generated. Fine particulate fumes emitted from melting furnace results from the condensation of volatized metal and metal oxides.

Crucible/Open Hearth Furnace

A furnace is used for making steel from a mixture of scrap-iron and pig-iron, for glass-making, and in several other industrial processes. The iron or other material is placed in a shallow hearth, and heated by a mixture of fuel-gas and air burnt above it. Waste gases leaving the furnace give up much of their heat to the incoming fuel-gas and air in a heat regenerator. As a result, the temperature of the flame in the hearth reaches about 1,650°C.

Cupolas

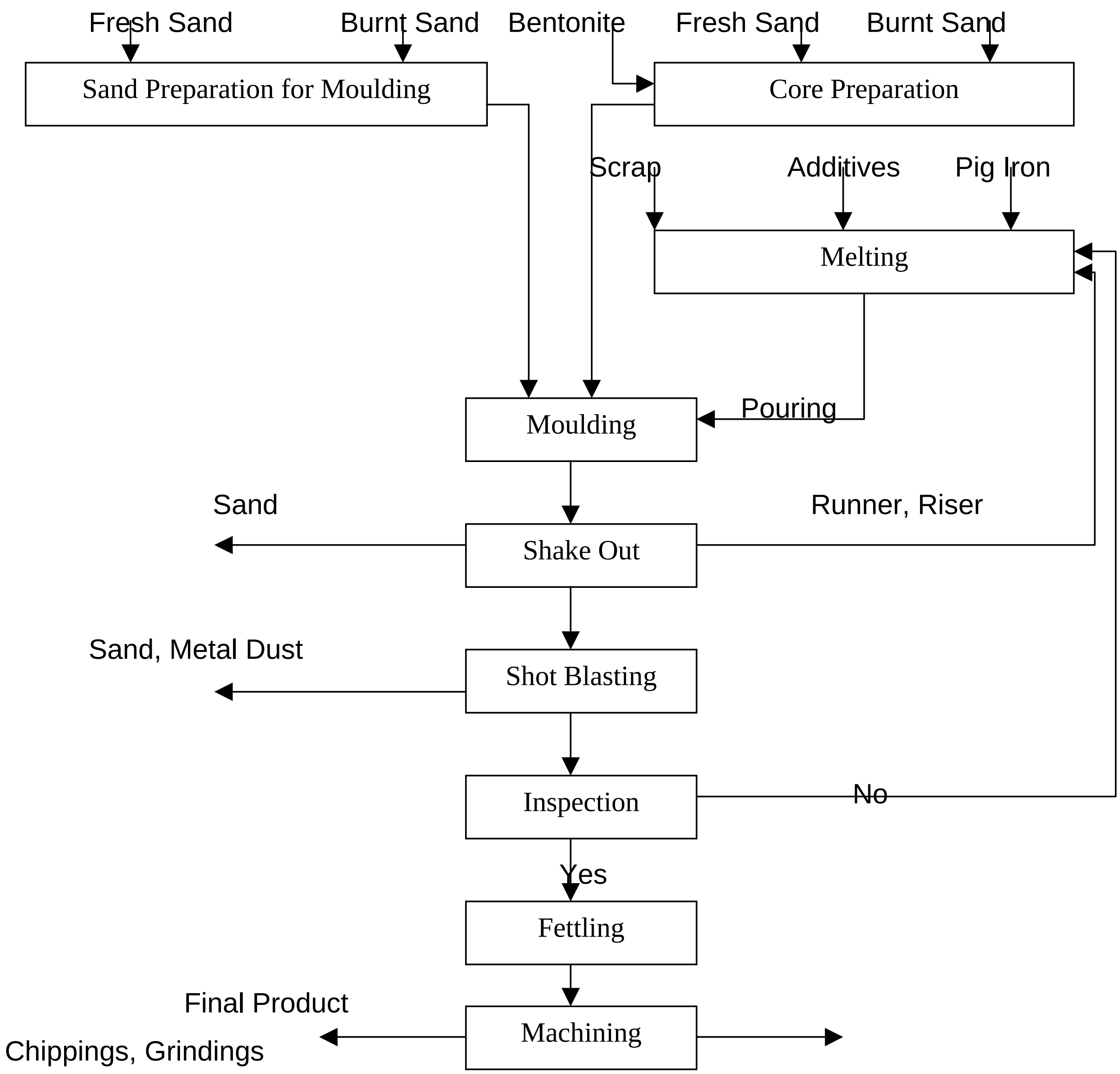
Cupola furnaces are tall, cylindrical furnaces used to melt iron and ferro alloys in foundry operations. Alternating layers of metal and ferro alloys, coke, and limestone are fed into the furnace from the top.

Coke burned in cupola furnace produces several emissions. Incomplete combustion of coke causes carbon monoxide emissions and sulphur in the coke give rise to sulphur dioxide emissions. Toxic emissions from cupolas include both organic and inorganic materials. Cupolas produce the most toxic emissions compared to other melting equipment.

Blast Furnaces

The blast furnace is a huge, steel stack lined with refractory brick, where iron ore, coke and limestone are dumped into the top, and preheated air is blown into the bottom. The raw materials require 6 to 8 hours to descend to the bottom of the furnace where they become the final product of liquid slag and liquid iron. These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions. Once a blast furnace is started it will continuously run for four to ten years with only short stops to perform planned maintenance.

Figure 1: Flow Chart of a Typical Foundry



Source: NPC (March, 2001)

Electric Arc Furnaces

Electric arc furnaces are often used in large steel foundries and steel mills. The metal is charged into the furnace, with additives to make recovery of slag easier, and heat to melt the metal is produced with an electric arc from three carbon or granite electrodes. Frequently mills producing steel with EAF technology are called mini-mills.

During melting in an electric arc furnace, particulate emissions of metallic and mineral oxides are generated by the vaporization of iron and transformation of mineral additives. Carbon monoxide emissions result from combustion of graphite from electrodes and carbon added to the charge. Hydrocarbon results from vaporization and incomplete combustion of any oil remaining on the scrap iron charge.

Electric Induction Furnaces

Induction furnaces are the most widely used type of furnace for melting iron and are increasingly popular for melting non-ferrous metals. They are popular because they provide excellent metallurgical control and are relatively pollution free.

Using clean steel scrap produce particulate emissions comprising largely iron oxides. Dust emissions from electric induction furnaces also depend on the charge material composition, the melting method (cold charge or continuous) and the melting rate of the materials used. The highest emissions occur during the cold charge.

Particulate emissions are generated during the refining of molten iron before pouring. Emissions from pouring consist of metal fumes from the melt, and carbon monoxide, organic compounds, and particulate evolved from the mold and core materials. Emissions continue as molds cool. The major pollutant emitted in mold and core production operations is particulate from sand reclaiming, sand preparation, sand mixing with binders and additives and mold and core forming. Organics, carbon monoxide, and particulate are emitted from core baking and organic emissions from mold drying. Finishing operations emit particulates during the removal of burrs, ricers, and gates and during the shot blast cleaning.

7.3 Characteristics of Foundry Units, Belgaum

As there is no systematic data available on the existing foundry units of Belgaum, either with the District Industries Centre, Belgaum or with any association of small scale industries, we have chosen foundry units quite randomly located in Udyambag, Chennamma and Machhe Industrial Estates. We have gathered data from a total of

43 foundry units. It is appropriate to describe the basic characteristics of these units in terms of the entrepreneurial background, employment, investment, energy inputs used, technology, products, etc.

The educational background of entrepreneurs reveal that majority of the foundry entrepreneurs are atleast, graduates (Table 7.1). Only two of the 43 entrepreneurs did not have even school education – whereas an equal number are business postgraduates. What is significant to note is that more than one half of the entrepreneurs are either technical graduates (37%) or technical diploma holders (18%). More than one fourth of the entrepreneurs had graduation in non-technical disciplines. However it is clear that the level of education of entrepreneurs in the foundry industry in general, is higher both absolutely and relative to other three clusters covered by us. This could be partly due to the technology requirements of the industry, which is higher relative to the other three clusters.

Age of Units

The type of technology and its current replacement value in foundry units are presented in Table 7.2. Nearly 60% of the units have cupola furnaces whereas the rest are having more or less, in equal proportions either electric arc/induction and blast furnaces or cold/divided blast furnaces or crucible/OHF furnaces. In terms of current replacement value, electric arc/induction and blast furnace units involved the highest investment followed by cold/divided blast furnace units, crucible/OHF furnace units and cupola based units. The lowest average investment value of cupola based units could be due to the fact that these units have come up much earlier than the remaining units.

Since foundry units are much more machinery based than bricks, puffed rice or silk reeling units, the proportion of technical and skilled labour in total labour force is relatively high, irrespective of the kind of technology in use (Table 7.3). While technical labour accounted for nearly 10% of the labour force, skilled labour accounted for more than one-third of the labour force, semi-skilled (about 21%) and unskilled labour (about 35%) accounted for the remained labour force.

Table 7.1: Educational Background of Entrepreneurs

Educational Level	No. of Entrepreneurs
Nil	2
Pre-University	3
Diploma	8
Degree	12
Bachelor of Engineering	16
MBA	2
Total	43

Table 7.2: Technology and Current Replacement Value of Foundry Units

	Technology	No. of Units	Average Current Replacement Value (Rs. Millions)
1.	Electric Arc/Induction and Blast Furnace	6	5.60
2.	Cold/Divided Blast Furnace	6	1.40
3.	Crucible/OHF	6	1.38
4.	Cupola	25	0.89
	Total	43	9.27

Table 7.3: Skill Composition of Employment in Foundry Units

Skill Level	No. of Employees	% to Total
Unskilled	454	35.86
Semi-Skilled	259	20.46
Skilled	429	33.89
Technical	124	9.79
Total	1266	100.00

The raw materials used by the foundries are common to all the units, irrespective of the technologies (except cold/divided blast furnace units), which comprise pig iron ingots, scrap, non-ferrous metal, limestone and moulding sand (Table 7.4). The cold/divided blast furnace units use all raw materials except non-ferrous metals. The source of energy differs depending upon the technology of the furnace. While three units, which have only electric arc furnaces, use only electricity, the units with both induction and blast furnaces use both coke and firewood as the sources of energy. The same is true with respect to units with cold/divided blast furnaces. The units with crucible/OHF furnaces, in addition, use furnace oil and diesel. The cupola based units use coal, coke and firewood. The major product of these foundries is gray cast iron, SG Iron, and non-ferrous metal products. While cupola and crucible/OHF based units produce all the three, electric/induction and blast furnace based units produce only gray cast/SG Iron whereas cold/divided blast furnace based units produce only gray cast iron (Table 7.5).

Table 7.4: Major Raw Materials of Foundries

Technology	No. Units	Raw Materials Used				
		Pig Iron Ingots	Scrap	Lime Ston e	Mouldin g Sand	Non-ferrous metal
Electric Arc/Induction Furnace	5	Yes	Yes	Yes	Yes	Yes
Crucible/OHF	6	Yes	Yes	Yes	Yes	Yes
Cold/Divided Blast Furnace	6	Yes	Yes	Yes	Yes	No
Cupola	25	Yes	Yes	Yes	Yes	Yes

Table 7.5. Major Products of Foundry Units

Technology	No. of Units	Major Products
Crucible/OHF	6	Gray cast iron, SG Iron, non-ferrous metals
Cupola	25	Gray cast iron, SG Iron, non-ferrous metals
Electric Arc/Induction/Blast Furnace	6	Gray cast iron, SG Iron, Steel
Cold/Divided Blast Furnace	6	Gray Cast Iron

The summary data for the foundry units on their consumption of raw materials, energy inputs, and products and by-products are presented in Table 7. 6 and the production cost details in Table 7.7.

Table 7.6: Summary Data (Per Year) for the sample units of the cluster (For 43 units)

	No. of Units	Total	Average/ Unit	Standard Deviation
Pig Iron (Tonnes)	39	12479.0	319.97	370.0
Scarp Steel (Tonnes)	38	8883.0	233.76	273.48
Non-Ferrous Scrap (Tonnes)	4	191.0	47.75	39.25
Other Material (Tonnes)	2	22.0	11.0	12.73
Lime Stone (Tonnes)	34	1543.0	45.38	40.21
Moulding Sand (Tonnes)	43	15557.0	361.79	794.67
Ceramic Core Sand (Tonnes)	3	120.5	40.17	52.73
Firewood (Tonnes)	29	1586.0	54.69	65.71
Coal (Tonnes)	6	300.0	50.0	21.26
Coke (Tonnes)	32	3466.0	108.31	132.18
Furnace Oil (KL)	3	48.60	16.20	17.46
Electricity (MWh)	6	4633.75	772.29	1308.83
Total Fuel (GJ)	43	145192.8	3376.58	4109.18
Diesel for power generation (KL)	31	71.48	2.31	4.95
Gray Cast Iron (Tonnes)	38	17925.0	471.71	449.92
Steel Products (Tonnes)	1	4.0	4.0	----
SG Iron (Tonnes)	4	1729.0	432.25	612.24
Non-Ferrous Products (Tonnes)	4	168	42.0	36.59
Slag (Tonnes)	34	---	---	---

It is clear that moulding sand and pig iron ingots followed by scrap steel form the dominant raw material components. Coke and firewood are the major energy inputs used. Whereas among the products, gray cast iron accounts for the dominant share of total output (Table 7.6). In terms of cost, raw materials accounted for the largest share of 64%, followed by energy inputs (22%) and labour (14%) (Table 7.7). Among the costs of raw materials, pig iron ingots accounted for more than 52% of the total raw material cost and more than one-third of the total production cost. Among the energy inputs, the cost of coke found more than half of the total energy cost and about 8% of the total production cost. Electricity is the other major component of the cost, accounting for 37% of the total energy cost and 6% of the total production cost.

Table 7.7: Production Cost Details per Year (Rs.)

	Total	Average/Unit	Standard Deviation
Pig Iron	106,289,327	2,725,367	3,035,298
Scrap Steel	72,489,665	1,907,623	2,206,233
Non-Ferrous Scrap	14,340,600	3,585,150	4,854,436
Other Material	2,060,000	1,030,000	1,371,787
Lime Stone	1,131,180	33,270	49,031
Moulding Sand	7,653,730	177,994	267,306
Ceramic Core Sand	74,300	24,767	21,400
Firewood	1,965,990	67,793	93,210
Coal	2,257,500	376,250	170,646
Coke	24,980,154	780,641	886,273
Furnace Oil	534,600	178,200	192,082
Electricity for Production	18,535,000	3,089,167	5,235,313
Diesel for Power Gen.	1,429,560	46,115	98,995
Labour	44,692,000	1,039,349	1,668,565
Electricity-Others	6,284,000	146,140	159,451
Other Cost	13,141,235	355,169	722,704
Total	31,859,201	7,392,074	8,113,719

The composition of the value of output in terms of end products is given in Table 7.8. Gray cast iron being the major end product, its value formed almost 78% of the total output value followed by SG Iron (17.4%), non-ferrous products (4.6%) and steel products (0.21%). Given the technology, raw material and energy inputs and the variety of end products, it is appropriate to ascertain the kind and quantum of environmental pollution caused by the foundry units. Both energy and material inputs that cause pollution and their standard emission factors are taken into consideration (Table 7.9). The summaries of environmental pollution details are given in the Table 7.10.

Table 7.8: Value of Output Details per Year (Rs)

	Total	Average/Unit	Standard Deviation
Grey Cast Iron	337,118,850	8,871,549	9,069,136
Steel Products	920,000	920,000	0
SG Iron	75,428,000	18,857,000	24,414,590
Non-Ferrous Products	19,940,000	4,985,000	6,688,724
Total	433,406,850	10,079,229	11,682,873

Table 7.9: Emission Factors (kg/Tonne)

	Firewood	Coal*	Coke	Lime Stone	Furnace Oil
CO	15	1.40	4.1		6.19
CH_4	0.45	0.059	0.011		0.161
N_2O	0.06	0.088	0.221		0.121
SO_2	0.8	24.61	19.0		39.31
NOx	1.5	10.35	4.8		13.83
TSP	7.8	2.80	0.288		1.73
CO_2		2350	3100	440	3109.37
Ash	20	130	100		
Slag				666.67	

Note: Climate Change-India (2001), EM-1.4(1999), IIASA(2001), IPCC(1996), NAEI(1999).
*Imported Coal.

Table 7.10: Summary of Environmental Pollution Details

	Total	Average/ Unit	Standard Deviation
Slag (Tonnes)	1028.67	30.26	26.81
Ash (Tonnes)	417.32	10.98	12.96
CO (kg)	38739.63	968.49	1236.03
CH_4 (kg)	776.96	19.42	28.08
N_2O (kg)	893.13	22.33	29.25
SO_2 (kg)	76320.74	1908.02	2317.06
NOx (kg)	22759.33	568.98	629.54
TSP (kg)	14288.88	357.22	497.04
CO_2 (Tonnes)	12272.08	306.80	384.05

Slag and ash are the two kinds of wastes that are generated by the foundry units' manufacturing process. Among the gaseous pollutants, Carbon dioxide (CO_2) generation is the maximum followed by SO_2, Carbon Monoxide (CO), NOx, TSP, N_2O and CH_4. The average pollution generation and energy use per tonne of castings is presented in Table 7.11. It follows the same pattern as that of the total pollution. Wastes in terms of slag which (accounts for more than 76 kgs per tonne of castings) is higher than that of the ash (about 25 kgs per tonne of castings). The generation of CO_2 is highest (About 774 kgs per tonne of castings) followed by SO_2, CO, NOx, TSP, N_2O and CH_4.

The average raw material and fuel consumption per tonne of casting reveals that among the raw materials, the non-ferrous scrap accounts for the minimum share followed by pig iron, scrap steel, other materials, ceramic core sand and lime stone respectively (Table 7.12). Among the energy inputs, apart from electricity and furnace oil, coke, coal and fire wood are used – the use of coke being twice as much as that of coal and fire wood.

Table 7.11: Pollution Generated and Energy use per tonne of Castings

	Average	Standard Deviation	Minimum	Maximum
Slag (kg)	76.48	55.29	2.16	333.34
Ash (kg)	25.39	13.17	10.91	85.00
CO (kg)	2.19	2.03	0.52	10.58
CH_4 (kg)	0.043	0.055	0.001	0.236
N_2O (kg)	0.053	0.032	0.013	0.196
SO_2 (kg)	5.18	3.77	1.94	22.41
NOx (kg)	1.58	1.29	0.55	7.88
TSP (kg)	0.77	0.96	0.04	4.12
CO_2 (kg)	773.77	442.77	326.00	2545.0
Energy (GJ)	7.86	4.94	3.43	28.9

Table 7.12: Raw Material and Fuel use per tonne of Castings

	Average	Standard Deviation	Minimum	Maximum
Pig Iron (kg)	637.56	262.07	83.14	1175.70
Scrap Steel (kg)	469.13	239.37	62.50	1002.38
Non-ferrous Scrap (kg)	970.66	125.26	833.33	1078.65
Other Material (kg)	294.44	369.27	33.33	555.56
Lime Stone (kg)	114.73	82.93	3.24	500.00
Moulding Sand (kg)	646.79	654.46	40.00	2702.70
Ceramic Core Sand (kg)	125.28	181.15	2.50	333.33
Firewood (kg)	108.10	129.93	5.00	520.00
Coal (kg)	127.64	41.90	50.00	166.67
Coke (kg)	243.26	129.76	100.00	750.00
Furnace Oil (L)	433.33	235.70	266.67	600.00
Electricity (kWh)	941.39	825.25	135.14	2173.22

Given the consumption of raw materials and energy inputs, it is appropriate to know how the input requirement, output and quantum of pollution generation vary between foundry units, which use different technologies. The details on labour inputs, raw material and energy inputs and the respective costs, value of output, pollution generation can be broadly classified for three kinds of foundries: (1) Those which use crucible /open hearth furnace, (2) Those, which use cupola, and (3) Those, which use cold / divided blast furnace (Table 7.13). The cold/divided blast furnace based units used lowest amount of labour per tonne of castings, compared to cupola based units which, inturn, required less labour compared to crucible/ open hearth furnace units. Therefore, the labour cost is the lowest for Cold/ Divided blast furnace units followed by Cupola and Crucible/Open hearth furnace units. Even the energy inputs used and therefore, the total fuel cost per tonne of castings followed similar pattern. Therefore, Cold/Divided blast furnace units generated lowest amount of pollution per tonne castings where as crucible/open hearth furnace units generated the highest amount of pollution, interms of gases (CO_2, SO_2, CO, NOx, TSP, N_2O, CH_4) as well as wastes (ash and slag).

The scenario does not change significantly, even if the three kinds of foundries are compared for a single product. The comparative details on labour, labour cost, fuel cost, raw material cost, total cost, and pollution per tonne of (Cast Iron) castings reveals that the cold/divided blast furnace units are the least expensive and least polluting followed by cupola and crucible/open hearth furnace units (Table 7.14). This indicates that if environmental pollution has to be abated in foundries, the best strategy could be to promote cold/divided blast furnace based foundries and avoid the rest.

Table 7.13: Technology/Scale Specific Groups - A Comparison (Per Tonne of Castings)

	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Groups →	Crucible/Open Hearth Furnace		Cupola (hot & cold)		Cold/Divided Blast Furnace	
Avg. Labour/Unit (No.)	17.33	13.25	29.38	27.03	33.67	15.00
Avg. Technical/Unit (No.)	2.50	1.00	2.67	1.30	6.20	5.07
Avg. Skilled Labour/Unit	8.33	8.33	12.70	12.56	12.00	6.93
Avg. Semi Skilled	8.00	0.00	12.46	11.53	4.00	0.00
Avg. Unskilled Labour/Unit	7.20	3.90	12.85	14.53	26.20	14.24
Total Labour (No.)	0.184	0.145	0.074	0.043	0.071	0.034
Technical Personnel (No.)	0.040	0.049	0.007	0.004	0.012	0.005
Skilled Labour (No.)	0.080	0.051	0.031	0.025	0.020	0.014
Semi Skilled Labour (No.)	0.133	0.000	0.032	0.033	0.018	0.000
Unskilled Labour (No.)	0.066	0.052	0.032	0.027	0.058	0.044
Value of Output (Rs.)	78916.	98988.1	18209.	3315.8	16833.	2483.3
Labour Cost (Rs.)	4242.1	2915.52	1675.0	1058.45	2449.9	1896.58
Fuel Costs (Rs.)	3198.7	1779.19	1606.9	455.73	1306.7	671.49
Raw Material Cost (Rs.)	56936.	75171.2	9629.7	1395.9	9155.7	1330.2
Other Costs (Rs.)	2783.5	3688.05	922.75	838.17	666.47	752.82
Total Cost (Rs.)	67160.	82654.8	13834.	2300.0	13578.	1124.0
Firewood (Tonnes)	0.20	0.28	0.09	0.08	0.06	0.04
Coal (Tonnes)			0.13	0.04		
Coke (Tonnes)	0.31	0.13	0.22	0.06	0.16	0.07
Furnace Oil (KL)	0.43	0.24				
CO (kg)	3.29	2.77	1.70	1.07	1.42	0.54
CH_4 (Kg)	0.069	0.087	0.032	0.034	0.025	0.018
N_20 (kg)	0.069	0.026	0.045	0.019	0.038	0.015
SO_2 (kg)	9.43	6.80	4.13	1.14	3.08	1.37
NOx (kg)	3.05	2.51	1.25	0.35	0.85	0.32
TSP (kg)	1.07	1.52	0.62	0.62	0.45	0.32
CO_2 (kg)	1103.6	481.98	657.35	227.26	533.02	207.97
Ash (kg)	34.23	11.03	22.72	5.92	17.04	6.92
Slag (Tonnes)	94.44	34.69	68.08	27.67	66.36	29.10
Total Fuel (GJ)	12.72	5.63	6.53	1.90	5.16	1.77
Pig Iron (Tonnes)	0.98	0.16	0.60	0.22	0.60	0.39
Scrap Steel (Tonnes)	0.23	0.16	0.46	0.18	0.46	0.35
Non-ferrous Scrap (Tonnes)	0.92	0.12	1.08			
Other Material (Tonnes)	0.29	0.37				
Lime Stone (Tonnes)	0.14	0.05	0.10	0.04	0.10	0.04
Moulding Sand (Tonnes)	1.08	0.95	0.52	0.50	0.60	0.49
Ceramic Core Sand			0.09	0.16		

Table 7.14: Technology/Scale Specific Groups - A Comparison for Cast Iron (Per Tonne of Castings)

	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Groups →	Crucible/Open Hearth Furnace		Cupola (hot & cold)		Cold/Divided Blast Furnace	
Avg. Labour/Unit (No.)	17.00	15.79	30.22	27.31	33.67	15.00
Avg. Technical/Unit (No.)	2.00	0.00	2.67	1.30	6.20	5.07
Avg. Skilled Labour/Unit	10.00	10.10	13.05	12.80	12.00	6.93
Avg. Semi Skilled			13.42	11.49	4.00	0
Avg. Unskilled Labour/Unit	8.00	4.36	13.37	14.73	26.20	14.24
Total Labour (No.)	0.099	0.044	0.072	0.043	0.071	0.034
Technical Personnel (No.)	0.009	0.005	0.007	0.004	0.012	0.005
Skilled Labour (No.)	0.071	0.062	0.029	0.024	0.020	0.014
Semi Skilled Labour (No.)			0.034	0.033	0.018	
Unskilled Labour (No.)	0.032	0.006	0.032	0.028	0.058	0.044
Value of Output (Rs.)	18375.0	1797.0	18097.	3338.4	16833.	2483.3
Labour Cost (Rs.)	2543.75	1519.10	1639.5	1065.87	2449.9	1896.58
Fuel Costs (Rs.)	2414.75	759.39	1582.5	448.63	1306.7	671.49
Raw Material Cost (Rs.)	10620.6	624.9	9524.3	1320.5	9155.7	1330.2
Other Costs (Rs.)	429.50	175.91	907.82	852.80	666.47	752.82
Total Cost (Rs.)	16008.6	1333.2	13654.	2161.8	13578.	1124.0
Firewood (Tonnes)	0.20	0.28	0.09	0.08	0.06	0.04
Coal (Tonnes)			0.13	0.04		
Coke (Tonnes)	0.31	0.13	0.22	0.06	0.16	0.07
CO (kg)	3.51	3.44	1.70	1.10	1.42	0.54
CH_4 (Kg)	0.070	0.111	0.033	0.035	0.025	0.018
N_20 (kg)	0.078	0.024	0.044	0.019	0.038	0.015
SO_2 (kg)	6.06	2.39	4.08	1.14	3.08	1.37
NOx (kg)	1.72	0.51	1.24	0.36	0.85	0.32
TSP (kg)	1.25	1.92	0.64	0.63	0.45	0.32
CO_2 (kg)	1015.50	441.01	647.22	226.31	533.02	207.97
Ash (kg)	34.23	11.03	22.48	5.92	17.04	6.92
Slag (Tonnes)	94.44	34.69	69.09	27.84	66.36	29.10
Total Fuel (GJ)	10.81	3.36	6.46	1.91	5.16	1.77
Pig Iron (Tonnes)	0.98	0.16	0.62	0.21	0.60	0.39
Scrap Steel (Tonnes)	0.23	0.16	0.46	0.18	0.46	0.35
Lime Stone (Tonnes)	0.14	0.05	0.10	0.04	0.10	0.04
Moulding Sand (Tonnes)	1.09	0.95	0.53	0.50	0.60	0.49
Ceramic Core Sand			0.13	0.18		

7.4 Comparison of Various Estimated Parameters Across Groups Based on Energy Consumption Level

The foundry cluster in Belgaum produces variety of castings, grey cast iron, special grade iron castings, non-ferrous castings and steel alloy casting. The comparison of units becomes difficult because of the diversified mix of the products and different input requirements. Therefore, for all kinds of future analysis, we have used only 37 foundry units (out of 43 surveyed), which produce only grey cast iron. To study how the different parameters vary on an average with the change in energy consumption levels, we grouped the 37 foundry units into low, medium and high energy consumption per tonne of casting groups. The Table 7.15 contains the details of various estimated parameters for a production level of one tonne of grey cast iron. The average fuel required for the three groups respectively is 4.19 GJ, 6.34 GJ and 9.62 GJ. This clearly shows that the foundry cluster in Belgaum shows significant variations in energy consumption level.

From Table 7.15, we may observe that there is a clear indication of increased labour inefficiency (including technical personnel) in terms of labour requirement per tonne of castings with the increase in energy consumption levels. Only exceptions are the requirement of technical persons and semi-skilled labourers per tonne of castings in the case of medium energy level units are the lowest. Even in terms of cost of production, the medium energy level units perform better than lower energy units but both groups have significant lower requirements compared to high energy group. Both the raw material use and pollution levels go up with the increase in energy consumption levels. This may be an indication that the unit, which is energy inefficient, is also inefficient in terms of the whole production process.

This comparative analysis suggests that there may be other factors including technology, causing variations in the energy consumption level. Therefore, to study whether there is any influence of other factors on the level of energy consumption, we have carried out analysis using ANOVA technique.

7.5 Factors for ANOVA Analysis in Foundry Cluster

As discussed in previous chapters, we are relating the variations in energy consumption and thereby pollution level with human resource, technology and external & structural factors. This relationship is being tested using ANOVA method.

7.5.1 Human Resource Factors

As usual, we considered three variables, Owner/Manager/ Supervisor qualification levels, labour set skill levels and value of labour.

I. *Owner/Manager/Supervisor Qualification Level:* In foundry cluster at Belgaum, unlike the other clusters, it has been observed that the owners are supported by both qualified managers and supervisors in managing the unit. The units have been grouped into three levels based on the qualifications of owners, managers and supervisors. Initially, the units have been assigned scores of one to three based on the qualification levels of owners, managers and supervisors separately. The scores for owners have been assigned as up to pre-university level as one, diploma and non-technical graduates as two and technical graduates and above as three. In the case of managers and supervisors, if both are below pre-university level then one, if one of them is a graduate or diploma holder and the other one below pre-university level then two, if both are graduates or diploma holders then three. Finally, the scores are combined and depending on the total scores, the units have been grouped respectively as low, medium and high qualification groups.

II. *Labour Skill Level:* In this cluster there are four kinds of work force. Majority of the units have technical, skilled, semi-skilled and unskilled personnel to perform various activities. As usual, we tried to group the units into three labour skill levels – low, medium and high – for ANOVA analysis. To arrive at the groupings, first, the technical and skilled personnel are combined as one type, and semi-skilled and unskilled labourers are combined as the other type. Then the ratio of the first type to the second type personnel has been used as a basis for arriving at the labour skill levels. We grouped the units having a ratio of below 0.5 in the low, between 0.5 and 1 in the medium and above 1 in the high skill level class interval.

III. *Value of Labour*: The value of labour has been estimated using the annual cost per labour. Again three levels are identified with the units where the value of labour is up to Rs. 18,000/year are grouped into low, between Rs. 18,000 to Rs. 35,000/year into medium and above Rs. 35,000/year into high level of value of labour.

Table 7.15: Comparison of Various Parameters for Different Group of Units based on Energy Consumption Levels (Per tonne of Castings)

	Low Energy	Medium Energy	High Energy
Energy (GJ)	4.19	6.34	9.62
Technical Persons (No.)	0.0080	0.0055	0.0117
Skilled Labour (No.)	0.0223	0.0301	0.0569
Semi-Skilled Labour (No.)	0.0190	0.0182	0.0701
Unskilled Labour (No.)	0.0359	0.0379	0.0386
Labour Cost (Rs)	1683.19	1567.41	2590.54
Total Cost (Rs)	13548.04	13470.26	15062.49
Fuel Cost (Rs)	1571.01	1559.64	2289.07
Firewood (Tonnes)	0.052	0.091	0.136
Coal (Tonnes)	0.143	0.108	0.120
Coke (Tonnes)	0.133	0.194	0.307
Electricity (MWh)	1086.81	----	135.14
Pig Iron (Tonnes)	0.65	0.59	0.71
Scrap Steel (Tonnes)	0.48	0.52	0.37
Lime Stone (Tonnes)	0.10	0.10	0.11
Moulding Sand (Tonnes)	0.59	0.36	1.02
Ceramic Core Sand (Tonnes)	----	0.02	0.33
Ash (kg)	15.53	21.52	31.64
Slag (kg)	68.83	67.78	70.36
CO (kg)	1.02	1.75	2.74
CH_4 (kg)	0.020	0.033	0.051
N_20 (kg)	0.027	0.045	0.070
SO_2 (kg)	2.83	3.89	5.70
NOx (kg)	0.93	1.15	1.61
TSP (kg)	0.43	0.62	0.92
CO_2 (kg)	437.83	637.61	936.28

Further, the significance of each of the variables in explaining the variations in dependent variable (energy consumption per brick) is tested using simple One-way ANOVA. This resulted in labour skill level to be the most important variable in explaining the variations in the dependent variable. The value of labour found to be the second most significant variable. The owner/manager qualification also found to be a significant variable. All the three significant variables are included in the overall model for explaining the variations in the dependent variable.

7.5.2 Technology Factors

Under technology factor, we have considered three factors based on Production Technology (Technology Level) being used, Age of Plant & Machinery and other Innovations and Modifications carried out in the unit.

I. *Technology Level*: Technology levels are identified based on the type of melting furnace (crucible, open-hearth, cupola, blast furnace and electric arc/induction furnace in the ascending order of technology level), other supporting devices (moulding machines, sand mullers, material handling systems, testing equipments, etc.) and technology upgradation (addition of modern furnaces and other devices). Each of these variables is assigned with scores ranging from 1 to 3. These individual scores have been summed up to obtain the total score for the technology factor for each unit. Then the individual units are grouped into three technology factor levels. The units having a total score in the range of 1-3 as low, 4-5 as medium and above 6 as high technology level group.

II. *Age of Plant and Machinery*: The units are classified into three groups, the first one with plant & machinery of above 10 years old, second with plant & machinery of 5 to 10 years old and third group with plant & machinery of up to 5 years old.

III. *Other Innovations/Modifications*: Since we could not get proper information on different kinds of innovations we did not include this variable in the analysis of this cluster.

The one-way ANOVA analysis between the two variables and the energy consumption per tonne of castings resulted in only technology level variable to be significant in explaining the variations. The other variable, age of plant and machinery found to be not significant and therefore excluded from further analysis.

7.5.3 Structural and External Factors

a. *Age of the unit*: Here the units are classified into three groups based on the year of inception. Units with an age of 13 years and above, between 5 and 13 years and up to 5 years have been classified in to groups 1, 2 and 3 respectively.

b. *General Environmental conditions*: The responses filled by the project team members in the general environment related questionnaire enabled us to generate unit-wise total scores indicating the level of environmental conditions. Based on the total scores obtained, each unit has been categorized into good, average and bad in terms of general environmental conditions.

c. *Interaction Levels*: Based on the responses given by the units to the different types of interaction related questions, the total score for each unit is obtained. Using these total scores, the units have been grouped into high, medium and low interaction level categories.

The above variables in combination reflect the unit's overall ability to accept challenges, gather information, willingness to innovate and implement, present a modern outlook and express concern for the environment. Therefore, as done in the case of brick and tile cluster, we decided to combine these variables into one external and structural factor for including in the model. The original groupings of the units based on the individual variables have been aggregated to form the combine groupings.

7.6 Results and Discussion

To study the influence of the above factors on the energy consumption levels forms the basic purpose of ANOVA. The dependent variable considered here is energy consumption per tonne of grey iron casting. In addition, an attempt will be made to study the relationship between considered factors and value of output and total cost of production.

7.6.1 Relationship between Factors and Energy Consumption

As proposed in the methodology, we have used *sequential sums of squares method* for the analysis of variance to explain the relationship between the considered factors and dependent variables. The ANOVA is performed by considering the factors - labour skill level, technology level, owner qualification (includes manager and supervisor qualifications), value of labour and structural and external factor as independent and energy consumption per tonne of casting as dependent variable.

The details of the final factors/variables considered for the analysis and the type of classifications made and the number of units in each of the groups are presented in Table 7.16. From the table one could observe that the analysis design is an unbalanced one because the cell frequencies (number of units in each group) are unequal. Using the SPSS (Statistical Package for Social Sciences) software, the ANOVA has been carried out.

Table 7.16: Factors Considered for Univariate ANOVA

Factors	Levels	Classes	No. of Units in each Class Intervals
Labour Skill Level	Low	1.00	13
	Medium	2.00	12
	High	3.00	12
Technology Level	Low	1.00	11
	Medium	2.00	16
	High	3.00	10
Value of Labour	Low	1.00	13
	Medium	2.00	10
	High	3.00	14
Structural and External Factor	Low	1.00	12
	Medium	2.00	12
	High	3.00	13
Owner Qualification Level	Low	1.00	10
	Medium	2.00	16
	High	3.00	11

The results of this analysis are presented in Table 7.17. The table mainly contains the information on the total sum of squares, how much of sum of squares is accounted by the main effects of the considered factors, the sum of squares accounted by the interaction among the variables, unaccounted variance (error term) and R-square.

From the Table 7.17, it can be seen that all the five factors significantly explain the variations in the energy/tonne of casting variable. However, the variable labour skill level explains maximum amount of variation, followed by technology level. The other three factors, namely, value of labour, owner's qualification and structural & external factor in that order, explain relatively less amount of variations but they are significant to include in the model. It appears from this analysis that the labour skill levels and technology levels are the most important factors, which determine the level of energy consumption.

There are many interaction effects, which are found to be significant to be included in the model. The strong relationship of technology level factor with human resource factors like labour skill level, owner qualification level and value of labour are indicated by the significant interaction effects between them (Table 7.17). In this case, we may interpret them as higher the human resource factor levels better the technology level or vice versa and thereby improved energy consumption norm. The other interaction effects are found to be insignificant. The high value of R-square indicates that the model is able to explain the significant amount of variation in the dependent variable. Finally, one may arrive at a conclusion that along with changes in technology levels, the significant contribution of other factors might have caused variations in energy consumption levels. It appears from this analysis that adopting the efficient technology alone may not result in reduced energy consumption levels. However, along with this, if the unit concentrates on having an appropriate mix of technical, skilled, semi-skilled and unskilled labour forces, better wages, better interaction with the outside world and good house keeping, the energy consumption levels and thereby pollution levels could be significantly reduced. The analysis of essential differences among the various groups of units formed based on the above factors will be discussed in latter sections.

Table 7.17: Univariate ANOVA Results for the Relationship Between Fuel/tonne of Castings and Considered Factors

Source of Variation	Sum of Squares	DF	Mean Sum of Squares	F	Significance of F
Labour Skill Level	72.303	2	36.152	57.589	.000
Technology Level	61.402	2	30.701	48.906	.001
Owner Qualification Level	19.629	2	9.815	15.635	.007
Value of Labour	27.428	2	13.714	21.846	.003
Structural and External Factor	7.445	2	3.722	5.930	.048
Labour Skill by Technology Level	18.662	4	4.665	7.432	.025
Labour Skill by Owner Qualification	5.921	4	1.480	2.358	.186
Technology Level by Owner Qualification	16.666	4	4.167	6.637	.031
Labour Skill by Technology Level by Owner Qualification	10.270	2	5.135	8.180	.027
Labour Skill by Value of Labour	13.460	3	4.487	7.147	.029
Labour Skill by Structural and External Factor	4.146	2	2.073	3.302	.122
Technology Level by Structural and External Factor	1.310	2	.655	1.043	.418
Sum of Squares due to Factors	258.642	31	8.343	13.291	.004
Sum of Squares due to Error	3.139	5	.628		
Total Sum of Squares	261.781	36			
R Squared	0.988				
Adjusted R Squared	0.914				

The attempts made to find out the explanation power of the above independent factors in explaining the variations in the value of output and total cost of production proved to be futile. The analyses did not result in any significant variables that could be included in the model.

From the ANOVA performed with energy/tonne of castings as dependent variable, we may arrive at the following conclusions with respect to brick and tiles cluster.

I. Human resource factors, constituting labour skill level, owner's qualification level and value of labour, are the most important factors determining the level of energy consumption.

II. Technology level is the second most important factor explaining variations in the level of energy consumption.

III. General appearance of the units, environmental conditions and interaction levels also to a certain extent indicate the overall performance of the units in terms of efficiency of material and energy use.

The above analysis indicate that the abatement measures need to be adopted to reduce the level of pollution through efficient use of energy and material has to focus more importantly on the human resource factors along with the technology factor.

7.7 Comparison of Various Estimated Parameters Across Groups Based on the Factors

I. Labour Skill Level Based Groups

The analysis presented earlier indicated that changes in the levels of labour skill, owner's qualification, value of labour, technology, etc., result in significant variations in energy consumption levels. Logically, the next step would be to know how some of the important parameters vary across groups formed on the basis of these factors. Table 7.18 contains the average estimates of various parameters for the foundry units falling under the groups of low, medium and high labour skill levels. It is clear from the table that the combination of average technical plus skilled personnel and semi-skilled plus unskilled labourers per foundry unit decreases with the increase in labour skill levels. Only exception is that the combination of technical plus skilled personnel per unit slightly increases from low to medium labour skill level. However, the ratio of these combinations (technical plus skilled and semi-skilled plus unskilled) increases with the increase in skill levels indicating the dominance of technical/skilled personnel in units of high skilled groups. Even in terms of labour requirement per tonne of castings, the requirement of all kinds of personnel decreases with the increase in skill level but opposite is the case with ratio of combination of labourers. It may also be observed from the table that the value of labour (labour cost per labour per year) increases substantially with the increase in labour skill level. It is clear from this analysis that the effectiveness of labour skill level is determined more by the relative share of different kind of personnel and the level of compensation package they receive rather than the absolute number of labourers in each category.

Table 7.18: Comparison of Various Parameters for Different Group of Units based on Labour Skill Levels

	Low	Medium	High
Technical Persons (No. per Unit)	6.33	4.00	3.43
Skilled Labour (No. per Unit)	12.00	15.20	10.33
Semi-skilled Labour (No. per Unit)	11.50	18.25	9.50
Unskilled Labour (No. per Unit)	30.09	11.13	9.89
Technical Persons (No./tonne)	0.0097	0.0084	0.0074
Skilled Labour (No./tonne)	0.0476	0.0418	0.0217
Semi-Skilled Labour (No./tonne)	0.0394	0.0408	0.0167
Unskilled Labour (No./tonne)	0.0561	0.0324	0.0191
Castings Production/year/unit (Tonnes)	461.62	434.25	537.08
Energy/tonne of Casting (GJ)	8.52	6.37	5.17
Total Cost (Rs./tonne)	14235.12	14551.88	13369.22
Labour Cost (Rs./tonne)	2226.86	1875.60	1778.63
Labour Cost per Labour per year (Rs.)	22319.14	24796.71	38769.76
Fuel Cost (Rs./tonne)	1959.48	1871.75	1616.91
Firewood (tonnes/tonne)	0.137	0.091	0.051
Coal (tonnes/tonne)	----	0.144	0.111
Coke (tonnes/tonne)	0.252	0.230	0.175
Electricity (MWh/tonne)	135.14	1062.50	1111.11
Pig Iron (tonnes/tonne)	0.68	0.71	0.56
Scrap Steel (tonnes/tonne)	0.43	0.39	0.54
Lime Stone (tonnes/tonne)	0.11	0.10	0.10
Moulding Sand (tonnes/tonne)	0.84	0.74	0.42
Ceramic Core Sand (tonnes/tonne)	0.168	----	0.040
Ash (kg/tonne)	27.26	23.20	19.03
Slag (kg/tonne)	72.24	67.13	67.30
CO (kg/tonne)	2.61	1.73	1.19
CH_4 (kg/tonne)	0.050	0.034	0.020
N_20 (kg/tonne)	0.062	0.044	0.037
SO_2 (kg/tonne)	4.86	4.21	3.50
NOx (kg/tonne)	1.37	1.31	1.06
TSP (kg/tonne)	0.89	0.67	0.42
CO_2 (kg/tonne)	820.08	652.44	560.32

The average fuel consumption per tonne of castings ranges from a high of 8.52 GJ/tonne in the low to 6.37 GJ/tonne in the medium and 5.17 GJ/tonne in the high skilled groups. This shows that the energy consumption comes down with the increase in labour skill levels. In terms of fuel types, the use of firewood dominates the units in low skill groups and coal is used only by units of medium and high labour skilled groups. The efficiency of coke usage improves with the increase in skill levels. In terms of cost, both the labour and fuel cost per tonne of castings reduce as labour skill levels go up. However, there is a mixed trend in the case of total cost. From the table we may also note that there is clear trend of pollution levels per tonne of castings reducing with the increase in skill levels.

II. Value of Labour Based Groups

The average parameters estimated for the units grouped under the low, medium and high value of labour classes present contrasting findings (Table 7.19). The average labour requirements of all kinds per unit are significantly high in the case of all units under high value of labour group compared to low value of labour group, and in comparison with the medium group they are high in all labour types except semi-skilled labour. Comparison between low and medium groups presents a mixed picture. The technical and unskilled personnel are lower, and skilled and semi-skilled labourers are higher in the case of medium group compared to low value of labour group. The labour requirement per tonne of castings also exhibits similar mixed picture. In terms of overall labour productivity, the high value of labour group fares the best, then the low group and the last being the medium group. One may interpret this finding as the level of increase in pay package needed for increasing the labour productivity. This becomes clearer, when we observe the labour cost per labour per year, which is substantially high in the high value of labour group compared to other two groups. In other words, the wage level increase may result in increased labour productivity but the increase needs to be substantial and it should reflect the actual skill levels of the workforce.

The medium group units are worse even in terms of energy use per tonne of castings, the best being the units of low value of labour groups (Table 7.19). The same trend continues with the labour and total costs but the fuel cost shows an upward trend with the increase in value of labour. In the case of fuel consumption level and cost, this trend may be due to the composition of fuel types. In terms of pollution levels, the low value of labour group fares the best, then the high group and the medium group being the worst. Overall, we may conclude that the value of labour factor based grouping shows that the parameter levels are different across groups but we cannot conclusively tell that the increase in value of labour brings in overall efficiency in the foundry units.

III. Owner's Qualification Based Groups

Table 7.20 contains the various estimated parameters for the groups of units formed on the basis of owner's qualification level. Comparison between average number of technical, skilled, semi-skilled and unskilled labourers per unit does not show any logical pattern. However, when we compare the different kinds of human resource requirement per tonne of castings, it appears that the lower qualified owners attempt to compensate their lower qualifications by having higher share of technical/skilled workers. This becomes clear when we compare the share of technical plus skilled to semi-skilled plus unskilled workers of the units grouped under different level of owner's qualification. The relative shares are 71% for low, 68% for medium and 49% for high owner's qualification level. However, these efforts of the owner's are not reflected in terms of energy consumption per tonne of castings, which reduces significantly with the increase in qualification levels. The technical knowledge gained by the owners and the managerial staff may be the main reason for low energy consumption norm, which may not be easily compensated by having higher skilled people.

Table 7.19: Comparison of Various Parameters for Different Group of Units based on Value of Labour

	Low	Medium	High
Technical Persons (No. per Unit)	4.00	2.00	6.00
Skilled Labour (No. per Unit)	10.22	12.63	14.09
Semi-skilled Labour (No. per Unit)	6.60	25.00	12.00
Unskilled Labour (No. per Unit)	16.92	13.57	23.44
Technical Persons (No./tonne)	0.0085	0.0077	0.0087
Skilled Labour (No./tonne)	0.0223	0.0621	0.0242
Semi-Skilled Labour (No./tonne)	0.0272	0.0678	0.0212
Unskilled Labour (No./tonne)	0.0415	0.0420	0.0284
Castings Production/year/unit (Tonnes)	442.00	267.60	659.64
Energy/tonne of Casting (GJ)	5.83	8.53	6.30
Total Cost (Rs./tonne)	12821.45	15072.63	14478.90
Labour Cost (Rs./tonne)	1038.30	2533.68	2426.10
Labour Cost per Labour per year (Rs.)	13537.93	24910.88	47303.34
Fuel Cost (Rs./tonne)	1485.21	1856.19	2104.82
Firewood (tonnes/tonne)	0.070	0.160	0.065
Coal (tonnes/tonne)	0.147	0.120	0.103
Coke (tonnes/tonne)	0.200	0.255	0.218
Electricity (MWh/tonne)	----	----	769.58
Pig Iron (tonnes/tonne)	0.67	0.70	0.61
Scrap Steel (tonnes/tonne)	0.41	0.47	0.48
Lime Stone (tonnes/tonne)	0.10	0.12	0.09
Moulding Sand (tonnes/tonne)	0.54	0.69	0.78
Ceramic Core Sand (tonnes/tonne)	0.003	0.333	0.040
Ash (kg/tonne)	20.78	27.05	23.18
Slag (kg/tonne)	69.67	78.38	59.53
CO (kg/tonne)	1.41	2.88	1.58
CH_4 (kg/tonne)	0.026	0.061	0.025
N_20 (kg/tonne)	0.040	0.059	0.049
SO_2 (kg/tonne)	3.80	4.75	4.26
NOx (kg/tonne)	1.16	1.42	1.21
TSP (kg/tonne)	0.52	1.10	0.49
CO_2 (kg/tonne)	603.28	785.34	692.12

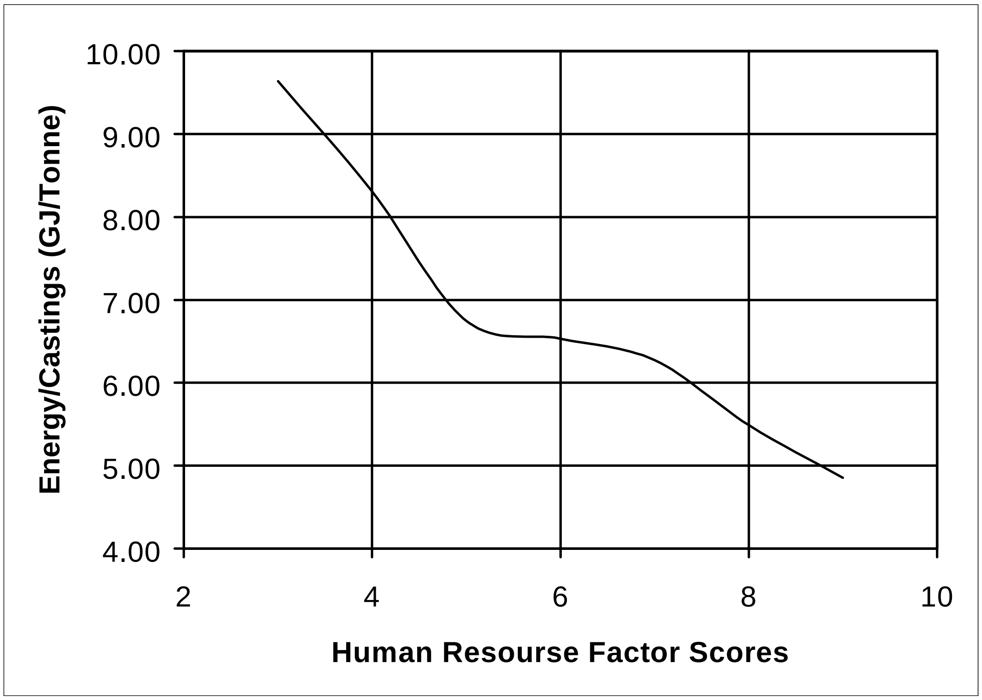
Table 7.20: Comparison of Various Parameters for Different Group of Units based on Owner's Qualification Levels

	Low	Medium	High
Technical Persons (No. per Unit)	2.00	6.75	3.27
Skilled Labour (No. per Unit)	17.71	9.58	12.11
Semi-skilled Labour (No. per Unit)	22.50	5.50	11.33
Unskilled Labour (No. per Unit)	16.86	21.08	14.63
Technical Persons (No./tonne)	0.0088	0.0085	0.0084
Skilled Labour (No./tonne)	0.0604	0.0284	0.0222
Semi-Skilled Labour (No./tonne)	0.0546	0.0160	0.0307
Unskilled Labour (No./tonne)	0.0434	0.0379	0.0314
Castings Production/year/unit (Tonnes)	338.10	501.94	567.73
Energy/tonne of Casting (GJ)	9.09	6.31	5.22
Total Cost (Rs./tonne)	15218.57	13441.52	13896.34
Labour Cost (Rs./tonne)	2780.98	1457.29	1970.33
Labour Cost per Labour per year (Rs.)	26003.25	24160.81	29775.96
Fuel Cost (Rs./tonne)	1981.35	1820.70	1672.03
Firewood (tonnes/tonne)	0.168	0.077	0.044
Coal (tonnes/tonne)	0.120	0.130	0.127
Coke (tonnes/tonne)	0.274	0.214	0.185
Electricity (MWh/tonne)	----	623.12	1062.50
Pig Iron (tonnes/tonne)	0.67	0.73	0.55
Scrap Steel (tonnes/tonne)	0.45	0.44	0.48
Lime Stone (tonnes/tonne)	0.13	0.09	0.10
Moulding Sand (tonnes/tonne)	0.87	0.47	0.79
Ceramic Core Sand (tonnes/tonne)	0.333	0.021	----
Ash (kg/tonne)	28.88	22.73	18.92
Slag (kg/tonne)	83.34	61.96	67.21
CO (kg/tonne)	3.05	1.60	1.16
CH_4 (kg/tonne)	0.064	0.029	0.016
N_20 (kg/tonne)	0.064	0.044	0.040
SO_2 (kg/tonne)	5.08	4.14	3.50
NOx (kg/tonne)	1.51	1.26	0.98
TSP (kg/tonne)	1.16	0.59	0.32
CO_2 (kg/tonne)	835.51	649.37	590.57

The total cost of production and labour cost per tonne of castings does not show any pattern with the increase in owner's qualification level. The fuel costs show the same trend of energy consumption levels. The table also contains group-wise average estimates of various pollutant types, the levels of which reduce with the increase in qualification levels.

To study the relationship between the human resource factors and energy consumption per tonne of castings, we combined the labour skill level, value of labour and owner's qualification level variables to form a common human resource factor with nine classification levels. The lowest level has a group of units with low labour skill, value of labour and owner's qualification level and moving in the order to highest level of skill, value of labour and qualification level. Figure 7.2 shows a plot of human resource factor groups versus the average fuel consumption per tonne of castings for the units belonging to these groups. From the figure, we may observe that the energy use decreases with the increase in the human resource quality. The rate of decrease is steep and almost linear except that at about the medium level of human resource quality there is a significant reduction in the rate of decrease in energy consumption level. This may be an indication of the need for the strategic change in the human resource quality improvement after a certain stage to achieve further reduction in energy consumption levels.

Figure 7.2: Relationship Between Human Resource Factor and Energy Consumption



IV. Technology Level Based Groups

The average parameters estimated for units coming under different groups formed based on technology levels are presented in Table 7.21. In terms of workforce requirement per tonne of castings, it appears that as the technology level increases the skill level requirement comes down. This is obvious because as the technology level increases the need for number of technical persons, skilled labour, semi-skilled labour per tonne of casting comes down and on the other hand the trend is opposite in the case of unskilled labourers. From the table it may be observed that the average energy consumption per tonne of castings is the highest in the case of units in the low technology group and there is not much difference between medium and high technology groups. In terms of pollution levels, the medium technology group units perform better in the case of some pollutant types and high technology in some other types.

Table 7.21: Comparison of Various Parameters for Different Group of Units based on Technology Levels

	Low	Medium	High
Technical Persons (No. per Unit)	1.75	2.82	9.33
Skilled Labour (No. per Unit)	9.00	10.00	21.00
Semi-skilled Labour (No. per Unit)	26.67	6.43	13.75
Unskilled Labour (No. per Unit)	4.63	14.83	36.75
Technical Persons (No./tonne)	0.0103	0.0083	0.0076
Skilled Labour (No./tonne)	0.0451	0.0315	0.0256
Semi-Skilled Labour (No./tonne)	0.0884	0.0184	0.0181
Unskilled Labour (No./tonne)	0.0255	0.0408	0.0443
Castings Production/year/unit (Tonnes)	265.91	328.44	947.70
Energy/tonne of Casting (GJ)	8.66	5.93	5.91
Total Cost (Rs./tonne)	14334.26	13720.54	14290.42
Labour Cost (Rs./tonne)	2016.05	1814.67	2158.87
Labour Cost per Labour per year (Rs.)	31296.41	25706.85	33512.09
Fuel Cost (Rs./tonne)	2014.40	1539.26	2055.06
Firewood (tonnes/tonne)	0.128	0.069	0.091
Coal (tonnes/tonne)	0.109	0.147	----
Coke (tonnes/tonne)	0.282	0.208	0.182
Electricity (MWh/tonne)	----	----	769.58
Pig Iron (tonnes/tonne)	0.71	0.63	0.64
Scrap Steel (tonnes/tonne)	0.42	0.45	0.49
Lime Stone (tonnes/tonne)	0.11	0.12	0.07
Moulding Sand (tonnes/tonne)	0.60	0.62	0.83

	Low	Medium	High
Ceramic Core Sand (tonnes/tonne)	0.187	0.003	----
Ash (kg/tonne)	29.00	21.25	19.98
Slag (kg/tonne)	72.18	78.29	44.32
CO (kg/tonne)	2.56	1.32	2.11
CH_4 (kg/tonne)	0.051	0.021	0.043
N_20 (kg/tonne)	0.060	0.042	0.046
SO_2 (kg/tonne)	5.19	3.92	3.52
NOx (kg/tonne)	1.57	1.15	1.01
TSP (kg/tonne)	0.97	0.43	0.76
CO_2 (kg/tonne)	827.65	636.80	588.56

V. Structural and External Factor Based Groups

The average estimates of various parameters for production level of one tonne of castings for units falling under the three different groups formed on the basis of structural and external factor are presented in Table 7.22. The personnel requirement per tonne of castings shows a decreasing trend with the increase in the level of structural and external factor. The fuel consumption norm shows a decreasing trend with the increase in the factor levels. The patterns are mixed with respect to total, labour and fuel costs. The pollution levels decrease with the increase in the factors. Overall, we can conclude that with relatively high level of interaction and better environmental performance, the comparison shows that the units perform well in terms of most of the parameters.

Overall the analysis presented earlier has clearly indicated that the higher grouped units in terms of labour skill level, owner’s qualification, value of labour, technology level and structural & external factor tend to excel in comparison with units in the lower groups with few exceptions.

Table 7.22: Comparison of Various Parameters for Different Group of Units based on Structural and External Factor Levels

	Low	Medium	High
Technical Persons (No. per Unit)	2.80	5.25	4.75
Skilled Labour (No. per Unit)	8.00	12.50	15.18
Semi-skilled Labour (No. per Unit)	7.00	14.75	14.29
Unskilled Labour (No. per Unit)	9.88	22.75	20.67
Technical Persons (No./tonne)	0.0111	0.0085	0.0067
Skilled Labour (No./tonne)	0.0554	0.0317	0.0235
Semi-Skilled Labour (No./tonne)	0.0416	0.0317	0.0307
Unskilled Labour (No./tonne)	0.0385	0.0318	0.0304
Castings Production/year/unit (Tonnes)	260.42	518.33	639.38
Energy/tonne of Casting (GJ)	7.80	6.76	5.73
Total Cost (Rs./tonne)	14247.86	13497.56	14397.29
Labour Cost (Rs./tonne)	1862.58	1819.08	2201.55
Labour Cost per Labour per year (Rs.)	25527.73	26091.16	28252.88
Fuel Cost (Rs./tonne)	2196.02	1633.85	1644.51
Firewood (tonnes/tonne)	0.122	0.091	0.080
Coal (tonnes/tonne)	0.050	0.143	0.143
Coke (tonnes/tonne)	0.250	0.212	0.202
Electricity (MWh/tonne)	1111.11	135.14	1062.50
Pig Iron (tonnes/tonne)	0.75	0.58	0.65
Scrap Steel (tonnes/tonne)	0.46	0.46	0.44
Lime Stone (tonnes/tonne)	0.12	0.09	0.11
Moulding Sand (tonnes/tonne)	0.63	0.75	0.64
Ceramic Core Sand (tonnes/tonne)	0.021	----	0.333
Ash (kg/tonne)	27.16	22.44	20.90
Slag (kg/tonne)	77.24	61.12	70.70
CO (kg/tonne)	2.20	2.02	1.48
CH_4 (kg/tonne)	0.038	0.041	0.028
N_20 (kg/tonne)	0.060	0.046	0.040
SO_2 (kg/tonne)	4.93	4.01	3.81
NOx (kg/tonne)	1.36	1.22	1.18
TSP (kg/tonne)	0.69	0.77	0.56
CO_2 (kg/tonne)	827.93	643.78	597.40

7.8 Abatement Measures to Reduce Pollution Levels in the Foundry Cluster

From the results of the previous analysis we may be able to come up with the following abatement measures that are likely to influence in reducing the pollution levels –

i. Improvements in the overall human resource quality. In other words, having an appropriate mix of technical, skilled, semi-skilled and unskilled personnel.

ii. Appropriate level of compensation package which properly reflects the skill level of the workforce.

iii. Appropriate compensation of lower owner's qualification levels with a better skill set of work force.

iv. Adoption of efficient technology for the production of bricks and tiles. One of the technologies could be VSBK for this purpose.

v. Encouragement of incremental innovations at different stages of production process. These could be in terms better methods of moulding, material handling, casting and testing.

vi. Higher interaction with the external world.

To implement some of the above measures, the foundry units need to incur additional cost. If the unit decides either to hire technically competent people or skilled labourers or provide necessary training to the existing labourers to upgrade their skills, this requires additional cost. Similarly, technology up-gradation involves substantial new investment. Implementation of any of these measures needs to be justified in terms of corresponding economic benefits to the units. Pollution reduction alone as the resulting benefit will not influence the unit owners to incur additional cost to implement the abatement measures. It is the financial benefit what they may look for this purpose. However, some of the other measures like incremental innovations and higher external interaction may not result in any significant additional cost and the units can implement them easily.

7.8.1 Human Resource Quality Up-gradation

As discussed above, we have considered Human Resource Quality (HRQ) up-gradation package as one of the abatement measures to reduce pollution levels. The package considers the mix of technical, skilled, semi-skilled and unskilled workforce and the compensation package to judge the level of human resource quality. To estimate the cost and benefits of this option we have considered two cases. In the first instance, we have attempted to analyse the shifts from low to medium, low to high and medium to high levels of HRQ package in the case of a foundry unit. The foundry unit has a capacity of producing 450 tonne of castings per annum and exhibits similar characteristics of foundry units in the Belgaum cluster. The human resource cost/person/year ranges from Rs. 22,319 in low, Rs. 27,073 in medium to Rs. 34,689 in high HRQ level. The total workforce required is 54 for low, 45 for medium and 38 for high HRQ level. The composition of technical, skilled, semi-skilled and unskilled personnel for the three levels of HRQ sets are presented in Table 7.23. It is more than the absolute numbers the relative composition, which is more important from the overall effectiveness of unit performance. These numbers are based on the averages from the sample units.

Table 7.23: Cost and Benefits of Human Resource Quality Up-gradation for Typical Foundry Units

	Low Human Resource Quality	**Medium Human Resource Quality**	**High Human Resource Quality**
Human Resource Cost (Rs./person/year)	22319	27073	34689
Production (tonnes/year)	450	450	450
Personnel Required (No.)	54	45	38
Technical (No.)	4	7	3
Skilled Labour (No.)	15	8	12
Semi-skilled Labour (No.)	16	7	12
Unskilled Labour (No.)	19	23	11
Total Labour Cost (Rs./Year)	1,205,233	1,218,284	1,318,172
Total Fuel Cost (Rs./Year)	881,765	842,285	727,611
Fuel Consumption (GJ/Year)	3833.96	2867.75	2327.44
Shifting of Quality Set →	**Low to Medium**	**Low to High**	**Medium to High**
Additional Labour Cost (Rs.)	13051	112938	99887
Savings in Fuel Cost (Rs.)	39479	154154	114675
Savings in Fuel Consumption (GJ/Year)	966.21	1506.52	540.31
Cost of Saved Energy (Rs./GJ)	13.51	74.97	184.87
Value of Saved Energy (Rs./GJ)	40.86	102.32	212.24
Savings in Firewood (Tonnes)	20.74	38.41	17.67
Savings in Coal (Tonnes)	-64.95	-49.92	15.03

	Low Human Resource Quality	Medium Human Resource Quality	High Human Resource Quality
Savings in Coke (Tonnes)	9.47	34.27	24.81
Savings in Limestone (Tonnes)	3.45	3.33	-0.11
Reduction in Ash (Tonnes)	1.83	3.70	1.88
Reduction in Slag (Tonnes)	2.30	2.22	-0.08
Reduction in Pollution Levels			
CO (kg)	394.95	638.00	243.06
CH_4 (kg)	7.32	13.46	6.14
N_20 (kg)	7.84	11.38	3.53
SO_2 (kg)	295.50	613.11	317.61
NOx (kg)	24.37	138.22	113.85
TSP (kg)	99.05	213.89	114.84
CO_2 (Tonnes)	75.43	116.89	41.46

The analysis results are presented in Table 7.23. The total labour cost, fuel cost and fuel consumption are estimated using the norms obtained for each of the HRQ groups. From the table it may be observed that the proposed shifting from lower HRQ set to upper HRQ set provides very good returns in terms of cost saved due to reduced energy consumption. The cost of energy saved is estimated by dividing the additional human resource cost by the quantum of energy saved due to the shift. The value of energy saved is estimated using the ratio of total cost of energy saved to quantum of energy saved. Shifting from low to medium HRQ set, results in lowest cost of saved energy of Rs. 13.51/GJ and the corresponding value of saved energy is Rs. 40.86/GJ. The cost and value of energy saved for low to high and medium to high HRQ sets are Rs. 74.97/GJ and Rs. 102.32/GJ, Rs. 184.87/GJ and Rs. 212.24/GJ respectively. Since the value of saved energy is higher than the cost of saved energy all the shifts are economically feasible. The table also contains the information on the possible reduction in estimated pollution levels due to the three kinds of shifts described above. These shifts also result in reduced burden of ash disposal. In the case of reduction in the quantity of slag, the positive reductions are achievable in the cases of shift from low to medium and low to high HRQ sets. In the case of medium to high HRQ shift, the reduction is negative. Overall the shifts are economically and environmentally attractive propositions.

The analysis has been extended to study the impacts of the above kind of HRQ set shifts on the 37 sample grey iron foundry units of the Belgaum cluster. This is done by simply multiplying the single typical unit parameters by 37. The estimates of additional labour cost, fuel cost saved, cost of energy saved and value of energy saved for different kinds of shifts are presented in Table 7.24. The results are similar to that discussed with respect to the typical unit earlier. Only difference is that these estimates give a total picture for the considered sample units of Belgaum cluster. Similarly, the table contains information on reductions that one could achieve by shifting from lower to upper HRQ levels in terms of quantity of fuels, ash and pollution levels. Overall from the table we may observe that these reductions are quite significant. Therefore, to reduce energy consumption levels and thereby pollution levels, the first and foremost activity at the foundry cluster is to upgrade the HRQ set by providing appropriate training to the existing workers or hire required skill set people and arrive at a proper compensation package. The analysis has clearly showed that the benefits to the entrepreneurs are significant and will be able to more than compensate for the cost involved for training and higher wages to more competent personnel.

7.9 Technology Shift Comparisons

One of the abatement measures considered to reduce pollution by reducing the energy consumption level is through technology shifts. Initially, we have made an attempt to compare the different melting technologies that are common in foundries. The results of this comparison are presented in Table 7.25.

From the table we may observe that in terms of investment levels the crucible pit technology is the cheapest and divided blast furnace being the most expensive technology. In terms of energy consumption per tonne of castings, the crucible pit is the most inefficient and divided blast furnace being the most efficient technology. The table also contains the cost and pollution estimates of all the technologies.

To analyse the technology shifts two alternatives are considered – conventional hot blast cupola to lined hot blast cupola and cold blast furnace to divided blast furnace. Table 7.26 contains the comparative results of the shifts. From the table we may observe that the shifts analysed in terms of per tonne of castings are economically feasible as well as environmentally less polluting. In the case of both shifts the value of saved energy is significantly higher than the cost of saved energy indicating the economic feasibility of the shifts. The pollution reductions due to the shift from conventional hot blast cupola to lined hot blast cupola are positive in most cases except CO, CH_4, and TSP. The shift from cold blast furnace to divided blast furnace fares better in terms of pollution reductions where only reduction in slag is negative.

Table 7.24: Cost and Benefits of Human Resource Quality Up-gradation for Sample Iron Foundry Units

	Low Human Resource Quality	Medium Human Resource Quality	High Human Resource Quality
Human Resource Cost (Rs./person/year)	22319	27073	34689
Number of Units	37	37	37
Production (tonnes/year)	17657	17657	17657
Personnel Required (No.)	1998	1665	1406
Technical (No.)	148	259	111
Skilled Labour (No.)	555	296	444
Semi-skilled Labour (No.)	592	259	444
Unskilled Labour (No.)	703	851	407
Total Labour Cost (Rs. Million/Year)	44.59	45.08	48.77
Total Fuel Cost (Rs. Million/Year)	34.60	33.05	28.55
Fuel Consumption (GJ/Year)	150436	112524	91324
Shifting of Quality Set →	**Low to Medium**	**Low to High**	**Medium to High**
Additional Labour Cost (Rs.)	483,183	4,179,372	3,696,189
Savings in Fuel Cost (Rs.)	1,549,073	6,048,659	4,499,586
Savings in Fuel Consumption (GJ/Year)	37911.90	59112.58	21200.68
Cost of Saved Energy (Rs./GJ)	12.74	70.70	174.34
Value of Saved Energy (Rs./GJ)	40.86	102.32	212.24
Savings in Firewood (Tonnes)	813.68	1507.01	693.33
Savings in Coal (Tonnes)	-2548.54	-1958.94	589.60
Savings in Coke (Tonnes)	371.39	1344.75	973.36
Savings in Limestone (Tonnes)	135.27	130.77	-4.50
Reduction in Ash (Tonnes)	71.64	145.27	73.63
Reduction in Slag (Tonnes)	90.18	87.18	-3.00
Reduction in Pollution Levels			
CO (kg)	15496.79	25033.75	9536.97
CH_4 (kg)	287.18	528.26	241.09

	Low Human Resource Quality	**Medium Human Resource Quality**	**High Human Resource Quality**
N_20 (kg)	307.80	446.44	138.64
SO_2 (kg)	11594.62	24056.93	12462.31
NOx (kg)	956.24	5423.61	4467.37
TSP (kg)	3886.58	8392.70	4506.12
CO_2 (Tonnes)	2959.90	4586.52	1626.62

Table 7.25: Comparisons of Technologies of Iron Foundries
(Information is per tonne of castings unless mentioned specifically)

	Crucible Pit	Conventional Hot Blast Cupola	Lined Hot Blast Cupola	Cold Blast Furnace	Divided Blast Furnace	Electric Induction Furnace
Furnace Investment (Rs)	30,000	100,000	175,000	800,000	1,400,000	1,200,000
Production/Year (Tonnes)	196.3	310	505	578.4	510	380
Discount Rate (%)	10	10	10	10	10	10
Estimated Life (Years)	10	20	20	25	25	25
Annualised Capital Cost (Rs./Year)	4882.36	11745.96	20555.43	88134.46	154235.3	127295.1
Annualised Capital Cost (Rs.)	24.88	37.89	40.70	152.38	302.42	334.99
Energy Consumption (GJ)	10.81	6.56	6.25	5.83	3.67	3.91
Fuel Cost (Rs.)	2414.75	1757.15	1431.16	1495.33	932.02	4347.22
Labour Cost (Rs.)	2543.75	1609.62	1532.40	1867.16	2931.82	2666.67
Raw material Cost (Rs.)	10620.63	9592.89	9611.98	9177.22	8598.64	8070.83
Total Cost (Rs.)	16008.63	13794.19	13446.55	13278.44	12755.32	16154.17
Firewood (Tonnes)	0.198	0.041	0.115	0.086	0.025	----
Coal (Tonnes)	----	0.13	0.12	----	----	----
Coke (Tonnes)	0.31	0.25	0.19	0.18	0.12	----
Electricity (MWh)	----	----	----	----	----	1086.81
Ash (kg)	34.23	25.05	20.38	19.45	12.50	----
Slag (kg)	94.44	74.63	66.72	58.51	73.86	----
CO (kg)	3.51	1.19	2.01	1.53	0.87	----
CH_4 (kg)	0.070	0.018	0.043	0.025	0.013	----
N_20 (kg)	0.078	0.044	0.043	0.044	0.028	----
SO_2 (kg)	6.06	4.67	3.60	3.54	2.30	----
NOx (kg)	1.72	1.45	1.10	0.96	0.61	----
TSP (kg)	1.25	0.42	0.79	0.45	0.23	----
CO_2 (kg/tonne)	1015.50	711.82	589.06	601.93	420.75	----

Table 7.26: Technology Shift Analysis
(Information is per tonne of castings unless mentioned specifically)

	Conventional Hot Blast Cupola to Lined Hot Blast Cupola	Cold Blast Furnace to Divided Blast Furnace
Additional Annualised Capital Cost (Rs.)	2.81	150.05
Savings in Energy Consumption (GJ)	0.32	2.15
Savings in Fuel Cost (Rs.)	325.99	563.30
Cost of Saved Energy (Rs./GJ)	8.83	69.64
Value of Saved Energy (Rs./GJ)	1022.96	261.45
Savings in Pollution Levels		
Ash (kg)	4.67	6.94
Slag (kg)	7.91	-15.35
CO (kg)	-0.82	0.66
CH_4 (kg)	-0.025	0.012
N_20 (kg)	0.002	0.016
SO_2 (kg)	1.07	1.24
NOx (kg)	0.35	0.35
TSP (kg)	-0.36	0.22
CO_2 (kg/tonne)	122.76	181.18

CHAPTER 8: SUMMARY AND CONCLUSIONS

8.1 Backdrop

Small Scale Industry (SSI) occupies a prominent place in Indian economy due to its sustained contribution to industrial production, exports and employment, among others, since independence (Planning Commission, 2001; CPCB, 2001a; CPCB 2001b). As of now, there are about 3.4 million SSI units which generated employment for approximately 19 million people, contributed over 45% of the gross turnover in the manufacturing sector, more than 37% of the manufacturing exports and about 30% of the total exports (Government of India, 2002; CPCB, 2001b). However, majority of these units are also known for managing with meagre financial, technical and infrastructure resources (CPCB, 2001a).

Till recently, there was hardly any reference made either in government reports and documents or in research literature, to the environmental implications and impact of small scale industries with reference to India. It could be due to the implicit assumption that small enterprises are too small to cause any environmental damage. The environmental impact of an individual SSI unit may be too miniscule to attract attention but the combined effect of operation of a large number of SSI units on the environment can be of a high magnitude, especially when they are clustered in certain locations closer to residential or commercial centres.

In fact, SSI units in India are located either in organised industrial estates or in unauthorized clusters or scattered or located in non-confirming areas (CPCB, 2001a). In general, it is observed that the level of pollution caused by SSI sector in India per unit of output is higher than that of their counterparts in developed countries due to the usage of outdated and inefficient technologies, lack of enforcement and implementation of pollution control programmes, lack of public/market pressure for improving environmental performance, etc. among others (CPCB, 2001a).

India has developed its own environmental policy regime over the period of last three decades, with an exclusive Ministry of Environment and Forests in the Government of India. The policy regime largely comprises legislations and therefore, belongs to the Command and Control (CAC) category. Economic instruments comprising tax incentives and subsidies are the other dimension of the policy regime. Though the environmental policy regime is applicable to all economic activities in the country, the SSIs have to obtain No Objection Certificate (NOC) and consent from the Central Pollution Control Board, Ministry of Environment and Forests, Government of India only in 17 product categories. However, in Karnataka, every SSI unit has to obtain consent from Karnataka State Pollution Control Board and renew it every year and tiny SSI units once in every ten years.

This would give an impression that SSIs in Karnataka are comprehensively covered by the environmental legislation and State Pollution Control Board would have full particulars of SSI units operating in the state. But, in reality, it was found that the Board lacks resources and staff to ensure that small enterprises comply with the environmental regulations of the state. This was reflected in the fact that the State Pollution Control Board had a list of only 6000 units as against the SSI population of 0.25 million in Karnataka at the end of March 2001.

This indicates that a substantial chunk of the SSIs in Karnataka function outside the purview of environmental legislation and control of the state. Therefore, the state machinery does not have the full knowledge of the environmental status of SSIs, comprising kinds and levels of pollution generation, causal factors, etc. in different sectors and clusters of the state. It is with this backdrop that the current study is undertaken with reference to four small industry clusters in the state.

8.2 Environmental Impact of Small Firms: Empirical Evidence

In fact, there are not many empirical studies conducted with reference to SSIs in developing countries, leave alone India. This could be because there are some (Schumaker, 1989) who consider small plants ‘environment friendly’ and therefore, the best choice for sustainable development. But, in contrast, there are others (Beckerman, 1995) who argue that small factories are pollution intensive, costly to regulate and far more environmentally harmful than large factories.

Ghose (2001) has identified 14 product categories of small firms, which have the high pollution potential. Many of these such as tanneries, chemical processing, textile dyeing & printing, metal finishing, foundries with cupolas, brick kilns, lime kilns, stone crushers and metal processing could be identified in the form of clusters in developing countries like India.

In fact, spontaneous emergence of SSI clusters is an important feature of small industry growth in India. According to UNIDO (2000), there are about 2000 rural clusters of small enterprises apart from 350 SME clusters in India. While the latter comprises largely modern industries, the rural clusters are predominantly skill-based clusters and consist of unorganized sector tiny units with very little access to market, information and technology. Thus, clusters, particularly traditional clusters account for a considerable share of SSI population in India.

Therefore, we have chosen four natural and traditional clusters of small firms in Karnataka. These traditional clusters are chosen, in addition, for the following reasons: (1) Firms in traditional clusters generally use obsolete technology, which necessarily generates pollution from the processes by consuming more inputs; (2) Entrepreneurs are likely to be less educated or illiterate and likely to have less environmental awareness; (3) Entrepreneurs' level of income will be low and therefore, cannot think of substituting 'better technology', even if its availability is known; (4) Lack of understanding on the technical specification and implications of pollution standards; (5) Low level of managerial and technical ability and skills among owners, managers and labour force.

But clusters, in general, offer scope for collective action for its own improvement through either technology development and joint R&D or joint marketing strategies, training programmes, etc. However, in the Indian context, limited empirical evidence based on a few clusters reveal that small firms in clusters have not initiated any joint action on their own, to reduce environmental pollution. It is only in response to external threat in the form of legal action towards closure or external assistance for improvements or a combination of both that small firms in clusters have joined together to incur costs for pollution abatement. However, the problem of environmental pollution in SSI clusters need not be and in fact, not uniform in terms of its profile, magnitude and causal factors and therefore, the remedial measures as well.

To that extent, a study of pollution profile, magnitude, causal factors and remedial measures will not only enrich the literature on the environmental impact of small industry clusters but also will bring out policy implications for promoting pollution abatement without adversely affecting small industry growth in the region.

8.3 Present Study and its Methodology

The major objective of this study is to probe and ascertain the nature and magnitude of environmental pollution in small industry clusters of Karnataka. This is to be done by identifying the pollutants and developing a pollution profile for each cluster; probe the factors that influence the current level of pollution; identify the appropriate pollution abatement measures; determine its costs and benefits and develop a policy framework to promote environment friendly small industry growth in the state.

To study these objectives, four of the environmentally polluting small industry clusters in the state are chosen. They are Brick & Tiles cluster in Malur of Kolar district, Silk Reeling cluster in Ramanagaram of Bangalore rural district, Puffed Rice units cluster in Davanagere of Davanagere district and Foundry cluster in Belgaum of Belgaum district. As the nature of each of these four clusters in terms of technology, material and energy inputs, skill composition of labour force is different, separate questionnaires are developed for data collection. However, the questionnaires, in general, had four sections to cover: (1) Basic information on the industry, (2) Materials consumed/produced, (3) Technology and (4) Human resources. As there was no scope for scientific random sampling, we aimed at gathering data from at least, 40 units from each of the four clusters, quite randomly. We, in fact, gathered data from 45 units in the bricks cluster, 55 units in the silk reeling cluster, 46 units in the puffed rice cluster and 43 units in the foundry cluster.

The pollutants are identified and pollution profile is developed for each cluster by studying the basic characteristics of the units in each cluster in terms of technology in use, nature of manufacturing, kinds and quantum of material as well as energy inputs, kinds and quantum of wastes, bye-products and final products. The pollution levels are determined based on the level of consumption of raw material and energy. Also, the influences of factors like nature of technology in use, the skill levels of employees, managerial style and interaction levels on the variations in the pollution levels are established. Thus, pollution levels of different kinds of pollutants are estimated based on the data gathered from the sample units on these variables (different types of raw material and energy) and by making use of standard pollution coefficients (emission factors) for various types of energy (and in few cases raw material) inputs. In addition, the various kinds of wastes generated during the production process are estimated.

Pollution is estimated not only for the overall sample units but also per unit of enterprise, as well as per unit of output. The factors, human resource, technological, process, external and structural, influencing the level of environmental pollution are logically identified in consultation with literature and experts. By using multifactor analysis of variance (ANOVA), we determined the significance levels of these factors in explaining the variations in the energy use and thereby pollution levels. It also facilitated to identify and develop appropriate pollution abatement measures within the constraints of clustered units and their respective costs and benefits. These analyses along with literature survey and discussion with experts enabled us to propose an alternative policy framework to reduce the environmental impacts of small industry operations.

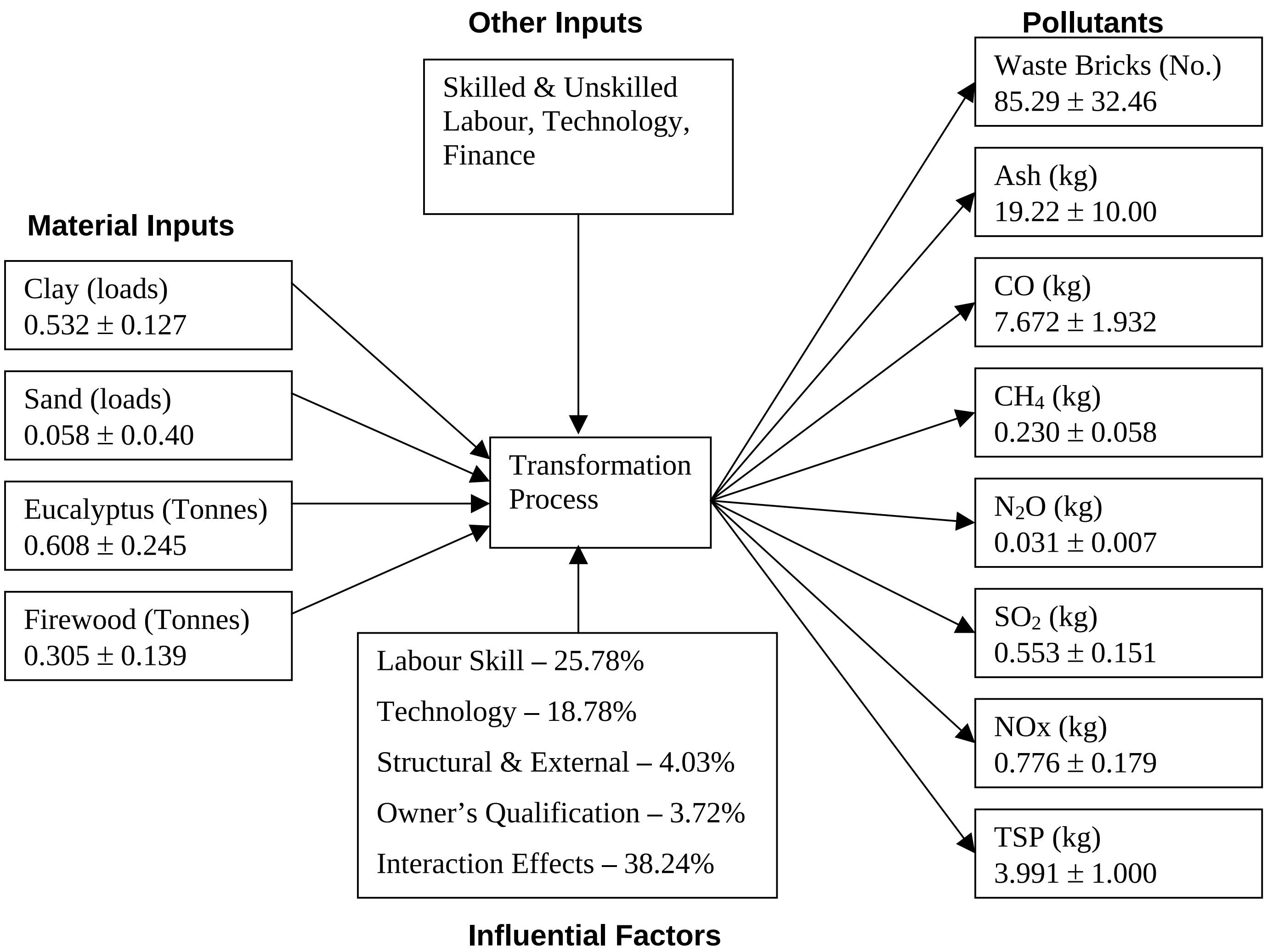
8.4 Environmental Pollution in Small Industry Clusters of Karnataka: Profile, Magnitude, Abatement Measures and Costs & Benefits

8.4.1 Bricks & Tiles

Traditionally, bricks are manufactured using different types of kilns, however the common types are (1) rural clamps or brick clamps, which is the oldest method of firing bricks, (2) Intermittent Downdraught Kiln (IDK), (3) Bull's Trench Kiln (BTK) and (4) Vertical Shaft Brick Kiln (VSBK), which represents the latest technology and the most energy efficient. In Malur, majority of the sample units used IDK technology and only a minority used conventional rural clamps technology. The emergence of a large number of brick making units, irrespective of the kind of kilns used, is attributed to the abundant availability of Chinese clay in the region, which has got powerful plasticity and can withstand any form of weather conditions. This plasticity is the main requirement for manufacturing tiles and bricks.

The entrepreneurial background of the 45 sample units reflected diverse educational levels – ranging from illiterates upto post-graduation, majority being educated upto either secondary school or diploma and degree holders. Of these 45 entrepreneurs, majority (60%) had an interaction on a perennial basis either horizontally (with other brick manufacturers) or vertically (with material suppliers/agents who market bricks) or both. All the sample units used firewood as the source of energy – while some used exclusively firewood, others used branches and leaves of eucalyptus, in addition and one unit makes use of coal, apart from firewood. Brick making units engaged both skilled and unskilled labour, the former is used mainly for brick moulding and brick firing whereas the latter for transporting materials, moulded and burnt bricks. Most of these units had poor ventilation design and building condition, house keeping and storage environment of bricks. Ash and waste bricks/tiles are dumped in the unit premises. While the former is taken away by agarbathi manufacturers, the latter by nearby villagers – once in six months. On the whole, air pollution due to the consumption of eucalyptus leaves, firewood and coal, is the major environmental concern, identified in the brick units' cluster in Malur. On an average, one thousand bricks consumed 7,702 MJ energy and generated CO (8 kgs), TSP (4 kgs), NOx (0.78 kgs), SO_2 (0.55 kgs), CH_4 (0.23 kgs) and N_2O (0.03 kgs), apart from waste bricks (85 nos) and ash (19 kgs). The CO_2 emission is not considered because all firewood and eucalyptus leaves and twigs have been obtained in a sustainable manner. The analysis also revealed that the energy consumption levels and thereby pollution levels vary significantly across units in the cluster. The influence of various identified factors on these variations are ascertained through ANOVA. The results indicate that the variations in the levels of labour skill, technology, structural and external factor, owner's qualification in that order influence the variations in pollution levels (Figure 8.1). In addition, these factors in interaction among each other cause significant variations in pollution levels. From this, the logical conclusion could be that not only the energy use but how it is used also determines the pollution levels.

Fig 8.1: Flow Balance for Brick Manufacturing at Malur, Kolar (Per 1000 Bricks)



The summary (average values and standard deviation) of the material/energy inputs, the pollution profile and relative significance of factors causing variations in pollution levels is presented in Figure 8.1.

As far as pollution abatement is concerned, it is found that the size of a unit, in terms of value of output, has certain implications. A larger sized unit consumed less than proportionate quantum of factor inputs, including that of energy, and therefore, generated less pollution. However, what is more important is the identification of factors that influence the consumption of energy inputs and therefore, pollution. Our analysis (through ANOVA) revealed that labour skill levels, owner's qualification and technology levels are the most important factors, which determined the level of energy consumption. Therefore, the pollution abatement measures through efficient use of energy and materials have to focus on the human resource factor, particularly labour skill levels, along with the technology factor. This is also because the total cost per 1000 bricks reduces as labour skill levels go up. If a brick unit changes the ratio of skilled to unskilled labour from 1:1.6 to 1:0.47, it will realise cost savings to the extent of more than Rs. 70/- per 1000 bricks. Of course, such a shift leads to a higher labour cost but the savings due to the reduced energy costs are nearly five times the additional labour cost that a unit has to incur. In total, we found that there is an inverse relationship between the human resource factor (comprising labour skill and owner's qualification level) and the average fuel consumption per brick. The summarized results presented in Table 8.1 show that the value of energy saved (cost savings) is significantly higher than the additional cost incurred (for skill up-gradation) per unit of energy saved. This also results in reduction in pollution levels of various pollutants ranging from 10 to 26% for different movement of skill levels.

Another abatement measure that could be considered to reduce pollution through the reduction of energy consumption is through technology shifts. As seen, it is the IDK technology, which is widely prevalent in brick units in Malur. Therefore, the alternative could be a shift from IDK to VSBK technology. But VSBK technology uses only coal as fuel for firing bricks, unlike IDK technology, which uses eucalyptus leaves and firewood as fuel. Therefore to compare VSBK technology, two types of IDK alternatives are used – one with biomass and the other with coal as a fuel, the latter to be replaced by VSBK with coal as fuel.

The technology shifts are primarily analysed for two kinds of shifts – IDK (biomass) to VSBK (coal) and IDK (coal) to VSBK (coal). We found that the additional investments required for the shift are not very high but the savings in fuel consumption are quite significant in both kinds of shifts.

In the case of shift of IDK (biomass) to VSBK (coal) there will be substantial reduction in pollution levels due to the emissions of CO, CH_4 and TSP but at the same time there will be significant increase in the emission levels of SO_2, NOx and CO_2 (Table 8.1). The combination of pollutants that could be reduced and those that could increase due to the shift includes both local and global pollutants. Of course, the shift would cause a substantial increase in CO_2 emission. Further, in the context of Malur based brick units, such a shift may not be advisable because their fuel requirements are met locally in a sustainable manner. Therefore, economically as well as environmentally, it may not be justifiable to replace the biomass based IDK technology by VSBK technology.

Given this, we would suggest that Malur based brick units should be encouraged to focus on skill upgradation of labour as that will lead to substantial reduction of energy consumption and therefore, pollution. The question is why skill component of labour force should make such a large difference? We found that improvements in the skill levels of labour will lead to improvements in the efficiency of material and energy use due to the following factors: -

1. Quality of bricks is largely dependant on the clay preparation, brick moulding and drying of green bricks. Skilled labour can ensure better performance in all these aspects.

2. Firing practises determine the level of fuel consumption and the quality of final burnt bricks. Proper arrangement of bricks in the kiln, firing and circulation of fumes around the stacked bricks require skilled labour.

Table 8.1: Cost & Benefits of Abatement Measures for Brick Industry Cluster

Performance Measures	Labour Skill Set Up-gradation			Technology Change	
	Low - Medium	Low - High	Medium - High	IDK (Biomass) to VSBK (Coal)	IDK (Coal) to VSBK (Coal)
Cost of Saved Energy (Rs./GJ)	6.97	12.36	19.35	1.04	1.65
Value of Saved Energy (Rs./GJ)	35.57	30.34	23.56	3.77	72.57
Savings in Energy (%)	14.69	26.03	13.28	51.27	40.00
Possible Reduction in Pollution Levels					
CO (%)	10.80	26.81	17.95	98.26	40.00
CH_4 (%)	10.80	26.76	17.89	95.19	40.00
N_20 (%)	10.81	25.96	16.99	46.37	40.00
SO_2 (%)	11.61	23.77	13.75	-177.63	40.00
NOx (%)	10.80	24.53	15.39	-38.46	40.00
TSP (%)	10.80	26.73	17.86	93.32	40.00
CO_2 (%)	---	---	---	$- \infty$	40.00
Waste Bricks (%)	22.23	-51.08	-94.27	---	---
Reduction in Ash (%)	4.65	5.85	1.26	---	---

The pertinent question is who will bring out skill upgradation of labour and who has to bear the cost? how? Because skill improvements of labour will lead to more benefits than the costs involved, through improvements of material and energy use, the owners of the units themselves should bear the cost as it is they who realise the benefits subsequently. To achieve this, policy makers through Karnataka State Pollution Control Board can play an instrumental role first by means of communicative instruments through seminars and distribution of pamphlets in the cluster informing the entrepreneurs about the benefits that would accrue to them and to the society by going for skill upgradation of labour. If that fails, they should adopt economic instruments: 'local pollution tax' should be imposed based on the relative composition of unskilled and skilled labour. It should be progressive and should increase as the proportion of unskilled labour increases. Of course, imposition of 'pollution tax' is easier said than done because it would be virtually impossible for the authorities to get reliable figures on the composition of skilled and unskilled labour from the entrepreneurs. The other alternative could be conducting training (say once in a year) for upgrading the skills of labour in the cluster itself by the Taluk Industries Centre at a very nominal fee. The local brick makers association should be involved in conducting such training programmes. This would facilitate pollution abatement to a great extent in the cluster.

8.4.2 Silk Reeling

Silk reeling is the intermediate stage in the process of silk production (that links cocoons with silk weaving). Silk reeling can be done through three alternative techniques:

1. Traditional – manual – charakha method,
2. Semi – mechanized technique of using cottage basins, and
3. Multiend reeling machine.

Ramanagaram in Bangalore rural district is one of the well-known silk reeling clusters of Karnataka, which comprises units belonging to all the three technologies. We have covered 22 each charakha and cottage units and 11 multiend units.

As it is a traditional industry, majority of the entrepreneurs of the 55 sample units did not have more than school education, nearly a quarter of them being illiterates. Since, charakha units are the most traditional and manually operated, their average level of investment (current value) is the lowest whereas the mechanized multiend units represented the highest average investment (current value). This is also reflected in charakha units having the lowest average number of basins (3) followed by cottage units (8 basins) and multiend units (10 basins). While charakha units use firewood and sawdust, cottage units use firewood and coal whereas multiend units use only firewood as energy inputs. The cottage and multiend units, generated raw silk waste and cocoon & pupae waste as bye-products whereas charakha units generated only cocoon & pupae waste as bye-products, in the process of raw silk production. The very quality of raw silk of charakha units being poor, the production process hardly generates any raw silk waste.

Silk reeling units, particularly charakha and cottage units generated three kinds of pollution: water, land and air pollution. Cocoon cooking results in water pollution, dumping of cocoon & pupae waste and raw silk waste in the unit premises cause land pollution and the process of cooking cocoons with paddy husk, coal, saw dust and firewood not only causes gas emissions but generates ash and stinking smell all around. On an average, the 55 silk reeling units in the process of producing one tonne of raw silk output, generated nearly six tonnes of pupae & cocoon waste, 116 KL of waste water, about two tonnes of ash, 3382 kgs of CO_2, 331 kgs of CO, 173 kgs of TSP, 38 kgs of N_2O while consuming about 348 GJ energy.

The patterns of energy and inputs consumption, products, bye-products and pollution generation between charakha, cottage and multiend units brought out that the multiend units consumed the highest amount of fuel, generated the highest quantum of ash, pupae & cocoon wastes as well as gases like CO, TSP and N_2O. On the whole, it appeared that among all, it is the traditional charakha units, which caused least environmental pollution. Even the cost of production and value of output per tonne of raw silk were higher for multiend and cottage units compared to charakha units. This is because charakha units mainly depended on the cheaper variety of raw materials and produced low quality raw silk using primitive technologies for boiling cocoons and reeling raw silk. This results in low cost, low energy use and low value of output.

However, our analysis based on ANOVA did not help us to determine the factors that influence energy consumption and pollution generation. Though we found technology level and human resource factor comprising only labour skill level as the important factors explaining variations in the levels of energy consumption, value of output and cost of production, it did not enable us to come to a definite conclusion. Neither, upgrading labour skills nor adoption of improved technology indicated efficient energy utilisation and pollution reduction. The summary of material/energy inputs, pollution profile and relative significance of factors causing variation in pollution is presented in Figure 8.2. Both the average values and standard deviations are depicted in the flow chart for the inputs as well as the pollutants.

Therefore, we compared the existing system to an energy efficient technology, that is, the conventional wood based system with a gasifier-based system, the latter as an alternative to the former. We found that such a shift would result in enormous energy cost savings and substantial reduction in pollution (Table 8.2). However, such as shift can only be realised if it is wholly financed by the government. Neither communicative and economic instruments nor CAC instruments could be successful for the simple reason that the silk reelers belong to the economically weaker sections. The only alternative is to encourage them to form a silk reelers' cooperative and adopt a gasifier-based system.

Fig 8.2: Flow Balance for Silk Reeling at Ramanagaram, Bangalore Rural (Per tonne of Raw Silk)

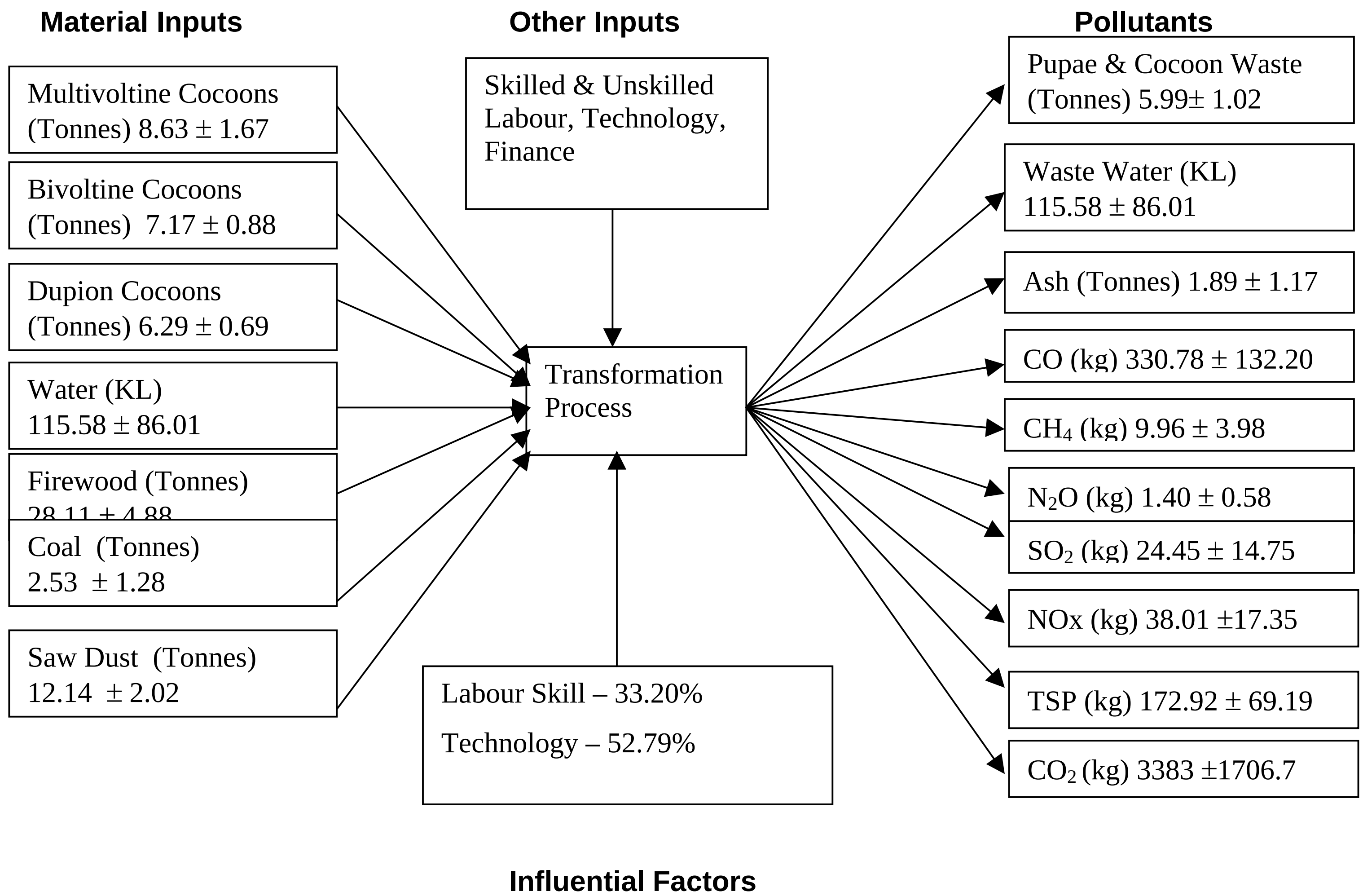


Table 8.2: Cost & Benefits of Abatement Measures for Silk Reeling Cluster

Performance Measures	Technology Change	
	Conventional (Cluster Average) to Gasifier System	**Conventional (Standard) to Gasifier System**
Cost of Saved Energy (Rs./GJ)	12.28	21.05
Value of Saved Energy (Rs./GJ)	115.08	51.53
Savings in Energy (%)	59.99	46.67
Possible Reduction in Pollutants		
CO (%)	55.61	46.67
CH_4 (%)	55.92	46.68
N_20 (%)	60.55	46.50
SO_2 (%)	75.76	46.67
NOx (%)	66.41	46.67
TSP (%)	56.11	46.67
CO_2 (%)	100.00	0

8.4.3 Puffed Rice Making

Puffed rice making is a labour skill based activity in Davangere and therefore, does not involve any machinery. The process of puffed rice making involves two phases: the first phase consists of conversion of paddy into rice and the second phase comprises conversion of rice, after mixing with salt water, into puffed rice. The boiling of paddy to convert paddy into rice and the boiling of sand to convert the salt water mixed rice into puffed rice require energy inputs. Puffed rice makers in the Mandakki Layout of Davangere used rice husk (which is the by-product of the conversion of paddy into rice) and scrap tyres as the energy inputs – both lead to air pollution, apart from the generation of ash, which adds to the unhygienic environment of the locality.

Our sample of 46 puffed rice making units exhibited uniform size, in terms of labour and its skill composition, and uniform production process. The entrepreneurs are illiterates and the energy inputs used are similar – rice husk and scrap tyres. The by-product is rice husk and the final product is puffed rice. Of course, puffed rice making is not an energy intensive activity because energy costs formed hardly four percent of the total cost of production. But the use of energy inputs, particularly scrap tyres lead to significant air pollution, through the emission of gases like CO_2, NOx, SO_2 and TSP (apart from CO, CH_4 and N_2O, which are more significantly contributed by rice husk).

This is substantiated by the fact that the entire atmosphere of Mandakki Layout in Davangere is thickened with black smoke emanating from the heavily concentrated puffed rice units. We estimated that the 600 units in the area would release about 3838 tonnes of CO_2 and about 144 tonnes of CO in an year, apart from TSP (93 tonnes), NOx (39 tonnes), SO_2 (29 tonnes), CH_4 (4 tonnes) and N_2O (0.56 tonnes).

How to mitigate pollution in the Mandakki Layout is a major challenge, for which we could not come out with any easy solution. The units are tiny sized and mechanized technology is neither readily available nor a feasible alternative, given the impact it would have on employment and the investment requirements. Within the constraints, therefore, we felt, the only way of pollution abatement is to encourage puffed rice makers to use only rice husk and not scrap tyres, which generates huge amounts of CO_2, NOx, SO_2 and TSP, apart from many carcinogenic material. The summary (average and standard deviation) of material input and pollution profile is given in Figure 8.3.

In this case, to mitigate pollution, particularly by avoiding the use of scrap tyres, banning the use of scrap tyre for puffed rice making through a legislation may be the appropriate solution.

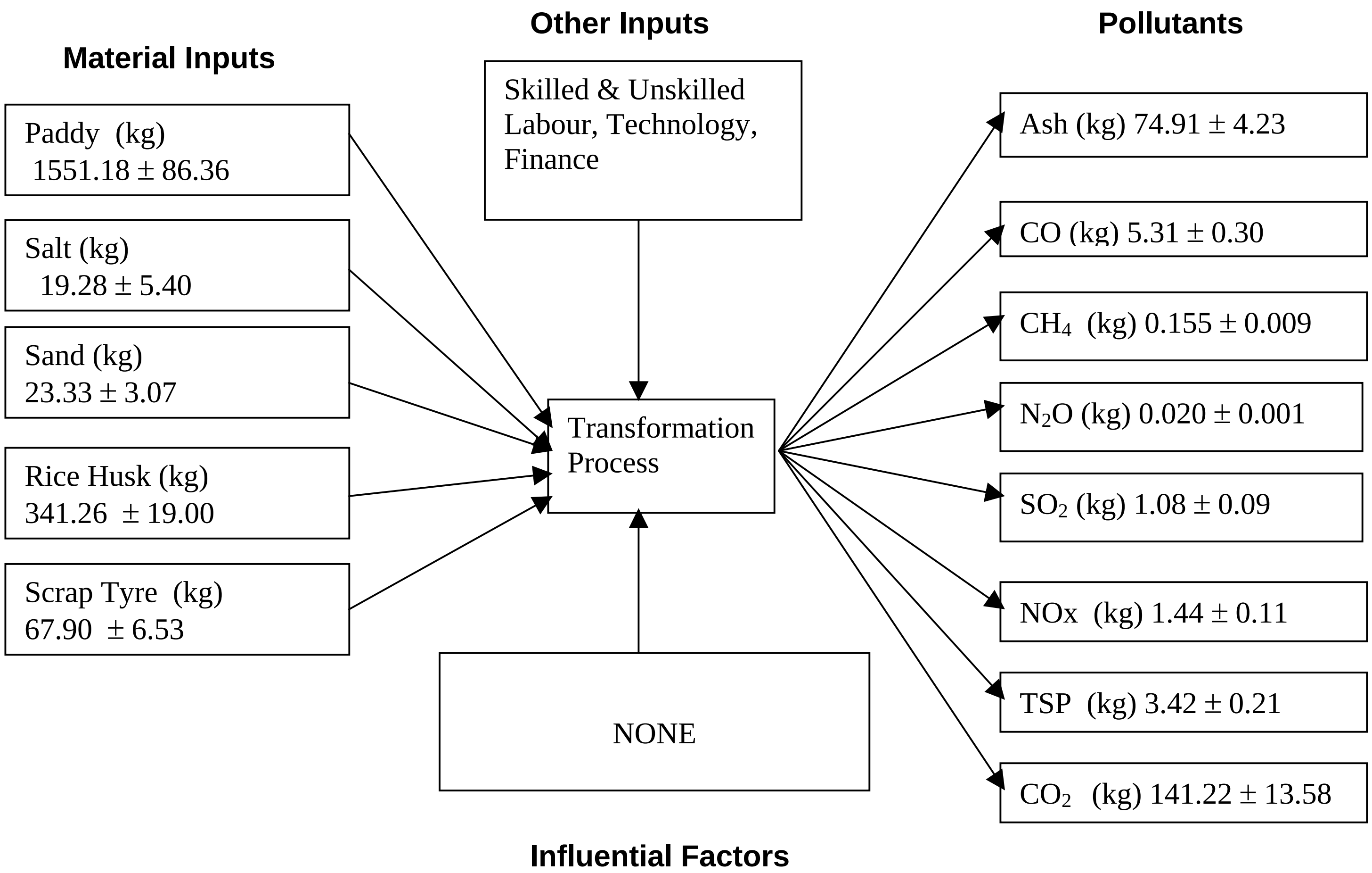
8.4.4 Foundry Cluster

Foundry in Belgaum is the only relatively modern industry among the four clusters covered by us. A foundry is a casting manufacturing system. Casting is the process of forming objects by pouring liquid metal into prepared mould and allowing the melt to solidify. The foundry operations generate different kinds of air pollution, depending upon the kinds of furnace in use and the kinds of energy inputs that they use. In general, a foundry emits fugitive particulates, fumes and fugitive dust. The emissions released from melting furnaces include particulate matter, CO, organic compounds, SO_2, NO, among others. The three kinds of furnaces that a foundry unit could use are cupola, blast furnace, electric arc furnace or electric induction furnace.

We have covered a total of 43 foundry units in Belgaum. As it is a relatively modern industry, the level of education of entrepreneurs is relatively high and majority of the entrepreneurs are degree holders, particularly engineers. Majority of the foundries used cupola furnaces whereas the rest used electric arc/induction furnace, cold/divided blast furnace and crucible/OHF. The foundries are machinery oriented units much more than that of bricks, silk reeling and puffed rice, and the proportion of unskilled labour accounted for just about one-third of the total labour force. The rest comprised technical, skilled and semi-skilled labourers.

While the raw materials used by all the 43 foundries are similar, the energy inputs and final products differed. Electric arc and induction furnaces used only electricity, cold/divided blast furnaces used only coke and firewood, cupola furnaces used in addition, coal whereas crucible/OHF furnaces used, furnace oil and diesel, apart from coke and firewood. But for six units, which produced only non-ferrous castings, all produce grey iron castings.

Figure 8.3: Flow Balance for Puffed Rice Making, Davanagere (Per tonne of Puffed Rice)



The pollution profile of foundry units comprised slag, ash and gases. The 46 units, on an average, generated about 76 kgs of slag, 25 kgs of ash, CO_2 (774 kgs), SO_2 (5 kgs), CO (2 kgs), NOx (1.6 kgs), among others, while consuming about 8 GJ of energy per tonne of castings. A comparative analysis for three kinds of foundries: crucible/open hearth furnace, cupola and cold/divided blast furnace, revealed that the cold/divided blat furnace units are the least expensive, least energy intensive and least polluting among all. Both the average value and the standard deviation of material/inputs and pollution levels per tonne of castings are summarized and presented in Figure 8.4. The figure also shows the relative significance of factors causing variations in pollution levels.

A classification of 37 foundry units (out of 43 units surveyed), which produced only grey cast iron into low, medium and high based on energy consumption levels per tonne of castings, revealed that the variation between groups is significant. We found that the units, which are energy inefficient, are inefficient in terms of the whole production process. We also found out through ANOVA, that human resource factors comprising labour skill, owner's qualification and value of labour are the most important factors determining the variations in the energy consumption level of a foundry unit. Technology level is the second most important factor. Therefore, we felt that for pollution abatement, the focus should be on human resource factors along with the technology factor. A shift of units from low to high human resource quality will result in fuel savings, which will be more than the additional labour cost that has to be incurred for improving labour quality and a drastic reduction in pollution. Therefore, to reduce energy consumption levels and thereby pollution levels, the first and foremost activity at the foundry cluster could be to upgrade the Human Resource Quality (HRQ) set by providing appropriate training to the existing workers or hire required skill set people and arrive at a proper compensation package.

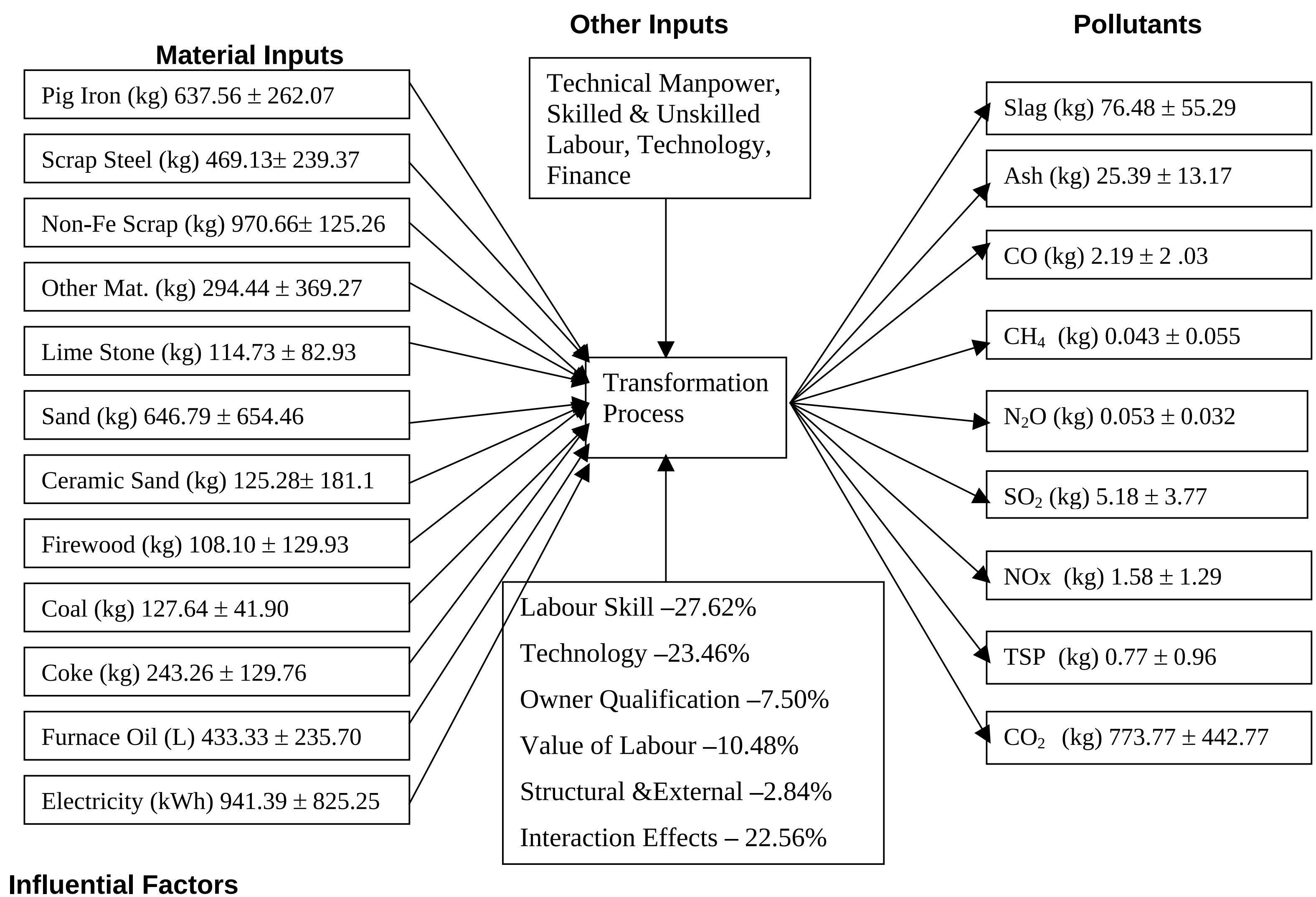
To analyse the technology shifts, two alternatives are considered – from conventional hot blast cupola to lined hot blast cupola and from cold blast furnace to divided blast furnace. In the case of both the shifts, the value of saved energy is significantly higher than the cost of saved energy indicating the economic feasibility of the shifts. Even the overall pollution reductions in both the shifts are positive and significant. The summarized results of the cost and benefits of both human resource quality up-gradation and technology shifts are presented in Table 8.3.

To encourage the technology shifts to reduce pollution, economic instruments should be used. As the level of education of the entrepreneurs is fairly high, mere communicative instruments will not be effective. Those foundries, which use conventional technologies and cause higher degree of pollution should be imposed ‘local pollution tax’ and those who are willing to adopt ‘more efficient technologies’ should be encouraged to do so by means of subsidised credit by the District Industries Centre.

Table 8.3: Cost & Benefits of Abatement Measures for Foundry Cluster

Performance Measures	Human Resource Quality Up-gradation			Technology Change	
	Low - Medium	**Low - High**	**Medium - High**	**Conventional Hot Blast Cupola to Lined Hot Blast Cupola**	**Cold Blast Furnace to Divided Blast Furnace**
Cost of Saved Energy (Rs./GJ)	13.51	74.97	184.87	8.83	69.64
Value of Saved Energy (Rs./GJ)	40.86	102.32	212.24	1022.96	261.45
Savings in Energy (%)	25.20	39.29	18.84	4.85	36.98
Possible Reduction in Pollutants					
CO (%)	33.64	54.34	31.19	-69.25	42.95
CH_4 (%)	32.46	59.71	40.34	-141.81	49.60
N_20 (%)	28.16	40.85	17.66	3.71	35.98
SO_2 (%)	13.50	28.02	16.78	22.84	35.04
NOx (%)	3.97	22.50	19.30	24.10	36.14
TSP (%)	24.65	53.22	37.92	-85.68	49.01
CO_2 (%)	20.44	31.67	14.12	17.25	30.10
Ash (%)	14.89	30.18	17.97	18.65	35.70
Slag (%)	7.07	6.83	-0.25	10.60	-26.24

Figure 8.4: Flow Balance for Foundry Industry, Belgaum (Per tonne of Castings)



8.5 Recommendations

Small Scale Industries are the second largest segment of Indian economy in terms of employment as well as exports. Their sustained economic performance is imperative for India's economic development. A considerable proportion of SSIs in India are considered to be polluting in nature, thereby causing adverse impact on the environment. Many of these are naturally located in the form of clusters across the country and are in the traditional sector.

Limited empirical evidence indicates that environmental awareness among entrepreneurs of small industry clusters in developing countries like India is rather poor and therefore, they have not initiated any joint action voluntarily for pollution abatement. It is either due to the pressure of legal action or offer of external assistance or both that small firms in clusters jointly invested to counter environmental pollution. Further, the problem of pollution abatement is not just confined to technology change but has a larger socio-economic dimension. Therefore, the issue of pollution abatement has to be studied and tackled sector wise in the broader economic perspective.

Our study of the four small industry clusters of Karnataka only substantiated the above inferences made by us from literature review. Our objective is not pollution abatement *per se* but we analysed the scope and its feasibility for pollution reduction through economizing the consumption of energy inputs, which has a direct bearing on the cost of production and therefore, competitiveness of a small firm. As brought out in the context of bricks and foundry clusters, a reduction in the consumption of energy inputs and therefore, a reduction in cost of production as well as pollution can be achieved through not only technology shifts but more importantly an improvement in the quality of human resources comprising labour skills and entrepreneurial qualifications.

In fact, in the case of both brick units and foundry units, we found an inverse relationship between energy consumption and quality of human resource factors. Of course, it is difficult to improve the qualifications of entrepreneurs but it could be compensated by raising the composition of skilled labour in the total labour force. This would result in benefits in the form of saved energy, which would more than offset the additional cost to be incurred for hiring more skilled labour. The overall outcome will be reduced pollution. As the economic benefits are more than the costs to be incurred, we feel, policy makers should play only an instrumental role in enabling entrepreneurs to go for the required improvements by incurring the necessary costs.

Of course, Government of India has already introduced schemes for promoting pollution prevention technologies in some of the SSIs (CPCB, 2001a). But they are more confined to pollution prevention than energy efficiency improvement. These schemes suggest: (1) fixing of air pollution control device in the form of gravity settling chambers in existing fixed chimney's of IDK to improve combustion process and air pollution control, and (2) fitting air pollution control equipment based on scrubbing technology in cupola blast furnace. However, Government of India has not yet launched any programme for pollution abatement in silk reeling and puffed rice units' clusters. In the former, we found that the most inferior technology is not only less expensive but also more environment friendly (This may be specific to silk reeling industry). A shift towards better technology is not desirable, from the points of view of both pollution abatement and efficiency improvement. The only alternative that we would suggest is a shift from conventional wood system to gasifier-based system (if possible by forming a reelers' cooperative society in the cluster) – to save energy and reduce pollution. As far as puffed rice making is concerned, the units are fairly similar and tiny and the process is simple. We could not come out with any recommendation of feasible alternative technology or improvement in human resource factors. However, we do suggest that within constraints, it is advisable to discontinue the use of scrap tyres (preferably through a legislation) and reduce pollution to that extent, particularly because that would put an end to the emission of carcinogenic gases.

All these lead us to one question: How significant is environmental pollution generated by the four small industry clusters of Karnataka relatively? We compared the pollution of the four SSI clusters with a typical Coal Thermal Power Plant (of the capacity of 210 MW) (Table 8.4). The comparative figures for the four full clusters (not just the sample units surveyed) and the coal thermal plant reveal that but for CO and CH_4, the total pollution of the four SSI clusters are not that significant relative to that of the coal thermal plant of 210 MW. This implies that the contribution of SSIs to global pollution may not be considerable though their operations do have significant implications for the local environment. Given this, it would be appropriate to focus on economizing the use of energy inputs through variations in labour skill composition and shifts to feasible alternative technologies, wherever possible. This would enable small firms to achieve a significant reduction in the quantum of energy consumption as well as pollution levels and a consequent increase in their efficiency and competitiveness.

What is equally important is to propose an alternative policy framework to promote environment friendly small-scale industrialisation. Based on our study, we would like to propose the following strategy. First and foremost, it is imperative to strengthen the infrastructure of State Pollution Control Board in terms of adequate technical personnel. This will enable them to conduct periodic surveys of pollution intensive industries, large as well as small, and to ensure that they adhere to the environmental laws and regulations of the state. If possible, State Pollution Control Board should make use of the services of District Industries Centres and Taluk Industries Centres to ensure that SSI units comply with environmental laws of the country.

New SSI units must be allowed to come up, irrespective of the size of investment, only after obtaining consent from the State Pollution Control Board through their regional offices or even through the respective District Industries Centres/Taluk Industries Centres. In pollution intensive industries, new entrepreneurs must be encouraged to go for environmentally sound technologies, wherever feasible.

The next issue is to treat the environmental problems emanating from the existing SSIs across the country. As the nature of technology, required labour skills and environmental problems differ between industries/clusters, the State Pollution Control Boards may conduct industry-wise/cluster-wise studies to suggest ways and means for pollution abatement and efficiency improvement.

Table 8.4: Comparison of SSI Cluster and a Typical Coal Thermal Plant
(All units are in Tonnes unless mentioned)

	Brick & Tiles (150 Units)	Silk Reeling (1500 Units)	Puffed Rice (600 Units)	Foundry (150 Units)	Total (Four Clusters)	Coal Thermal Power Plant
Capacity (MW)						210
Plant Load Factor (%)						68.2
Annual Generation (GWh)						1,255
Eucalyptus	62,960				62,960	
Firewood	33,210	38,912		5,533	77,655	
Coal		3,511		1,047	4,557	777,856
Sawdust		13,910			13,910	
Rice Husk			9,254		9,254	
Scrap Tyre			1,845		1,845	
Coke				12,090	12,090	
Furnace Oil (KL)				169.53	169.53	
Energy Consumption (TJ)	1,145	849.96	183.08	506.49	2,684	15,542
Ash	2,625	5,191	2,032	1,647	11,494	405,161
CO	1,141	794.08	144.06	145.27	2,224	642.97
CH_4	34.22	23.93	4.21	2.91	65.28	51.61
N_20	4.58	3.42	0.56	3.35	11.91	77.42
SO_2	78.76	64.95	29.36	286.20	459.28	11,353
NOx	115.37	95.79	38.98	85.35	335.48	4,774
TSP	593.31	415.97	92.89	53.58	1,156	1,295
CO_2		4,695	3,838	46,020	54,553	1,177,923

In fact, two strategies are currently under promotion by the Central Pollution Control Board (CPCB, 2001a): (1) Clean production, and (2) Waste minimization. Clean production (CP) is the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. Clean production is relevant particularly to SSIs where the resource utilisation efficiency is very poor (CPCB, 2001a). In most of the industries, it is expected that there is a potential of reducing the consumption of resources by 10 to 15 % (CPCB, 2001a).

The principal cleaner production technologies are: (1) Source reduction, (2) Recycling and reuse, and (3) Product reformulation or modification. Under source reduction, the suggested techniques are: (i) good house-keeping, and (ii) process change through either input material change, better process control, equipment modification or technology change. Under recycling and reuse, what is suggested is on-site recovery/reuse; and creation of useful by-products. For product reformulation or modification, a change in material inputs or equipments or processes is suggested. Of course, to implement these strategies, an in-depth knowledge of the industry or cluster is imperative.

Currently, the Ministry of Environment and Forests, Government of India has been promoting a scheme for adoption of clean technologies by SSIs through the provision of interest subsidy, apart from knowledge diffusion and database development. This is a welcome step and needs to be intensively pursued at the regional level.

But our study has revealed that the technology up-gradation alone will not result in efficient use of material and energy. The quality of human resource available with the SSI is also equality significant in determining the level of energy use. It is a possibility that the best technology used by untrained manpower producing bad products with inefficient use of resources. Therefore a perfect match between the technology and quality human resource is essential to optimize the resource use and thereby reduce the environmental impacts. Any technology up-gradation in a unit should be preceded by having quality workforce in place. Any government agency promoting technology up-gradation should ensure appropriate training to the existing manpower simultaneously. That is, the employee training should be made a part of the technology up-gradation package.

Waste minimization is a new and creative way of thinking about products and processes that make them. It is achieved by the continuous application of strategies to minimize the generation of wastes and emissions (NPC, 1996). Apart form reducing pollution load, waste minimization brings in many other benefits, which include resource conservation, improvement in work environment, etc. (CPCB, 2001a). The principles of waste minimization described by five points of action to be considered in a descending order of acceptability are: (1) Try to avoid or eliminate the production of a waste either by choosing an alternative process when designing a production unit initially, or by altering the process of an existing plant. (2) Try to reduce or minimize waste streams within an industry through a careful consideration of all the processes and activities, which give rise to wastes, (3) Recycle and reuse wastes, wherever possible, (4) If wastes cannot be eliminated or reduced or recycled, destroy them, (5) Only when all the above avenues are exhausted, then disposal of wastes into the environment should be considered.

The Ministry of Environment and Forests has already established Waste Minimization Circles (WMCs) for SSIs in 40 different industrial sectors all over the country. There is an urgent need to involve state governments and small industry associations at the regional level in the propagation among SSIs to go for waste minimization.

The promotion of clean technologies, skill up-gradation and awareness training to the workforce and waste minimization techniques along with strengthening the State Pollution Control Board with adequate staff would go a long way in achieving the objective of pollution abatement and environment friendly small industry development.

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ANNEXURE I

BRICK INDUSTRY CLUSTER IN MALUR

Rural Clamp Kiln

IDK Firing Chamber

Brick Moulding

Intermittent Downdraught Kiln

Brick Units Cluster in Malur

Fuel for Brick Kilns

SILK REELING CLUSTER IN RAMANAGARAM

Cocoon Boiling

Silk Reeling in Charakha

Silk Reeling in Charakha

Silk Reeling in Cottage Basin

Raw Silk Winding

Silk Reeling in Multi-End Units

PUFFED RICE IN DAVANAGERE

Paddy Boiling in a Drum for Puffed Rice Making

Drying of Boiled Paddy

Mixing of Rice with Salt Water

Pouring Salt Water Mixed Rice into a Vessel Containing Hot Sand

Gathering Puffed Rice with the help of a Sieve

Air Pollution in the Cluster

Air Pollution in the Cluster

FOUNDRY CLUSTER IN BELGAUM

Cupola for Producing Molten Metal

A Mould

Mould ready for Pouring

Different Prepared Moulds

Blower of the Cupola

Annexure II

Unit address - Brick and Tile Cluster, Malur

Sl. No.	Company	Address
1	Balaji Bricks Works	Bavanahalli Cross, Malur -563130
2	Sri Nanjundeshwara Bricks And Tiles	Dyapsandra Road, Malur - 563130
3	Ramakrishna Bricks And Tiles	Old Masthi Road, Malur - 563130
4	Jai Maruthi Bricks Works	Kolar - Malur Road, Cikkadahthur, Malur - 563130
5	Srinivasa Tiles	Old Masti Road, Malur - 563130
6	Thirupathi Brick Works	Channakal Masti Road, Malur - 563130
7	Aruna Bricks	Hulimangala Hoskote Gate, Hosur Road, Malur – 563130
8	B.P.B Bricks	Masti Road, Mylandahall, Malur - 563130
9	Sri Manjunatha Tiles And Bricks	Erabanahalli, Madivala Post, Malur - 563130
10	Sri Raghavendra Brick Works	Dyapsandra Road, Malur - 563130
11	Manjunatha Bricks Works	Hosur Road, Malur- 563130
12	Sri Vinayaka Brick Works	Hosur Road, Malur- 563130
13	Ambabhavani Brick Industries	Dypsandra Road, Malur- 563130
14	Mohan Tiles And Brick Works	Masti Road, Malur- 563130
15	Srinivasa Brick Works	Harohalli Kasaba, Malur- 563130
16	Sri Vinayaka Bricks	Tekal Road, Malur- 563130
17	Sri Byraveshwara Brick Works	Erabanahalli, Bangalore Road, Malur- 563130
18	Maruthi Brick Services	Chikkonahalli, Malur - 563130
19	Noor Brick Works	Yashawantpura Cross Bangalore, Malur - 563130
20	Hanuman Tiles And Bricks	Masti Road Malur- 563130
21	A.L.K Brick Works	Masti Road, Malur - 563130
22	Sri Laxmivenkateshwara Tile Works	Masti Road, Malur - 563130
23	Sri Vinayaka Brick Works	Kolar Road, Malur - 563130
24	D.B.W	Kolar Road, Malur – 563130
25	Sri Gopal Bricks	Bangarpet Road, Malur- 563130
26	Raghavendra Tiles And Bricks	Hosur Road, Malur - 563130
27	Narasimha Bricks	Masti Road, Malur - 563130
28	Maruthi Bricks And Tile Works	Santhenahalli Cross, Malur - 563130
29	Srinivasa Tiles	Masti Road, Malur- 563130
30	Srikantha Tiles And Bricks	Kolar Road, Malur - 563130
31	Srinidhi Brick And Tiles	Mylandahalli, Malur - 563130
32	Mukambika Bricks Unit	Hosur Road, Malur - 563130
33	Bharath Tiles And Bricks	Hosur Road, Malur - 563130
34	V.R Tile Works	Hosur Road, Malur - 563130
35	Sri Ramakrishna Tiles Works	Masti Road, Malur - 563130
36	Sri Shankara	Bangarpet Road, Malur - 563130
37	Mahalaxmi Tile And Bricks	Hulimangala, Hosakote Gate, Malur - 563130

38	Sri Venkateshwara Brick And Tiles	Narasapura Road, Hungenahalli, Malur - 563130
39	Sri Vasavi Tiles And Bricks	Bangarpet Road, Malur- 563130
40	Sri Venugopal Tiles Works	Dyapsandra Road, Malur - 563130
Sl. No.	**Company**	**Address**
41	Anjanadri Bricks	Masti Road, Malur -563130
42	Hanuman Brick Works	Chokkandahalli, Bangalore Road, Malur - 563130
43	B. B. C.	Masti Road, Malur - 563130
44	Tirumala Tiles And Bricks Works	Hosur Road, Malur - 563130
45	Radhakrishna Bricks Works	Myalandahalli, Kudayanur Post, Malur - 563130

Unit address – Silk Reeling Cluster, Ramanagaram

Sl. No.	Unit owner	Address
1	Vazeer khan	Ghousia Nagar, Ramnagaram
2	Mohammad Farooq	M.F.R Silk industry, Moti Nagar, Ramnagaram
3	Mr. Ayub Pasha Bin Akbar Saab	Moti Nagar, Ramnagaram
4	Munier Ahmed	Tipu Nagar, Ramnagaram
5	S. A. A. Silk Reeling	Thopkhana Mohalla, Ramnagaram
6	Hasgar Khan	Tipu Nagar, Ramnagaram
7	Sabeena Jay	Mehaboob Nagar, Ramnagaram
8	Vazeer Khan	Salambandwadi, Ramnagaram
9	Daulat Sharif Bin Abdul Bashir	Mehaboob Nagar, Ramnagaram
10	Nasim Banu	C/o Syed Kuddas, Mehaboob Nagar, Ramnagaram
11	Shamim Unnisa	C/o Javed Pasha Mehaboob Nagar, Ramnagaram
12	Samiyulla Khan	Vezoor, Ramnagaram
13	Rahim khan	Masidi Mohalla, Ramnagaram
14	Rashid khan	Extension Mohalla Ramnagaram
15	Asif pasha	Thopkhana Mohalla, Ramnagaram
16	Samayalla Khan	Vezoor, Ramanagaram
17	Zia Ulla Baig	Masidi Mohalla, Ramnagaram
18	Shaukat Ali Khan	Mehaboob Mohalla, Ramnagaram
19	Banir	Nalbandwadi, Ramnagaram
20	Anwar Pasha	3308, Mehaboob Nagar, Ramnagaram
21	Khalander Ali Baig	Moti Nagar, Ramnagaram
22	Basha	Ghousia Nagar, Ramnagaram
23	Munir Pasha	Nalbandwadi, Ramnagaram
24	Syed Ibrahim	Ghousia Nagar Ramnagaram
25	Imitiaz Pasha	Extension Mohalla 3rd cross Ramnagaram
26	Syed Ziaulla	Khumandar Mohalla, Ramnagaram
27	Shoukath Ali Khan	Khaneshumari, 1269/1437, Madar Khan Mohalla,

		Ramnagaram
28	Habeeb Khan	Railway Station Road, Behind Post Office, Ramnagaram.
29	Syed Aju Pasha	Kummtna Mohalla, Ramnagaram.
30	Abdul Rauf	Kummtna Mohalla Ramnagaram
31	Riyaz pasha	Masidi Mohalla Ramnagaram
32	Mohammad Rijwan	Moti Nagar Ramnagaram
33	Chotte Saab	Mehaboob Nagar Ramnagaram
34	Riyaz Amjad	Mehaboob Nagar, Ramnagaram.
Sl. No.	**Unit owner**	**Address**
35	Syed Mustafa	Salambandwadi. Ramnagaram.
36	Syed Usman	New Muslim Block, 1696, Ramnagaram.
37	Jaffer Shareif	s/o Ahmed Sharief, Salambandwadi, Ramnagaram.
38	M D Imam Pyare Saab	63, Kathipura, Ramnagaram.
41	Nazeer Ahmed	s/o Ameer Jan, Moti Nagar, Ramnagaram.
42	Syed Rasool	4354, Shettihalli, Ramnagaram.
43	Imtiyaz Ibrahim	Vezoor, Ramnagaram.
44	Syed Anwar	1824, Vezoor, Ramnagaram
45	Rafiq Amjad	Balageri, Ramnagaram
46	Mukthar Amjad	No.170 Tipu Nagar, Ramnagaram
47	Khaleel Khan	Mehaboob Nagar, Ramnagaram
48	Akbar Ali Khan	Moti Nagar, Ramnagaram
49	Abdul Salam	Mehaboob Nagar, Ramnagaram
50	Sabjan Pakyarthi	Moti Nagar, Ramnagaram
51	Nazir ulla Khan	Ghousia Mohalla, Ramnagaram
52	Basha Saab	Madar Khan Mohalla, Ramnagaram
53	Basha	Yarab Nagar, Ramnagaram.
54	Syed Peer	Madar Khan Mohalla, Ramnagaram.
55	Md. Iqbal Pasha	Salambandwadi, Ramnagaram

Unit Address – Puffed Rice Cluster, Davangere

Sl. No.	Name of the Owner	Address
1	A. B. Habeebulla	Maganahalli Road, Azad Nagar, Davangere
2	Samiullakhan	Maganahalli Road, Azad Nagar, Davangere
3	K. Samiullakhan	Maganahalli Road, Azad Nagar, Davangere
4	Simiullakhan	Maganahalli Road, Azad Nagar, Davangere
5	Zahru	Maganahalli Road, Azad Nagar, Davangere
6	Zahru	Maganahalli Road, Azad Nagar, Davangere
7	A. B. Habeebulla	Maganahalli Road Azad Nagar, Davangere
8	Habibulla	Maganahalli Road, Azad Nagar, Davangere
9	A.B Habeebulla	Maganahalli Road, Azad Nagar, Davangere
10	Zahru Saab	Maganahalli Road, Azad Nagar, Davangere
11	Samimulla Khan	Maganahalli Road, Azad Nagar, Davangere
12	Samimulla khan	Maganahalli Road, Azad Nagar, Davangere
13	Samimulla khan	Maganahalli Road, Azad Nagar, Davangere

14	Samimulla Khan	Maganahalli Road, Azad Nagar, Davangere
15	Samimulla Khan	Maganahalli Road, Azad Nagar, Davangere
16	H.H Anwar Saab	Maganahalli Road, Azad Nagar, Davangere
17	Zahru	Maganahalli Road, Azad Nagar, Davangere
18	Zahru	Maganahalli Road Azad Nagar Davangere
19	Hidayathulla	Maganahalli Road, Azad Nagar, Davangere
20	Zahru	No-16, Maganahalli Road, Mandakki Layout
21	Zahru	Maganahalli Road, Azad Nagar, Davangere
22	Anwar Saab	Maganahalli Road, Azad Nagar, Davangere
23	Anwar Saab	Maganahalli Road, Azad Nagar, Davangere
Sl. No.	**Name of the Owner**	**Address**
24	Habeebulla	Maganahalli Road, Azad Nagar, Davangere
25	A. B Habibulla	Maganahalli Road, Azad Nagar, Davangere
26	Anwar Saab	Mandakki Layout, Davangere
27	Zahru Saab	Mandakki Layout, Davangere
28	Samiulla Khan	Mandakki Layout, Davangere
29	A B Habbebulla	Mandakki Layout, Davangere
30	A B Habeebulla	Mandakki Layout, Davangere
31	A B Habeebulla	Mandakki Layout, Davangere
32	Anwar Saab	Mandakki Layout, Davangere
33	A B Habeebulla	Mandakki Layout Davangere
34	H. H. Anwar Saab	Mandakki Layout, Davangere
35	H. H. Anwar Saab	Mandakki Layout, Davangere
36	H. H. Anwar	Maganahalli Road, Azad Nagar, Davangere
37	H. H. Anwar	Maganahalli Road, Azad Nagar, Davangere
38	H. H. Anwar Saab	Mandakki Layout, Davangere.
39	Samiulla Khan	Mandakki Layout, Davangere.
40	A. B. Habeebulla	Mandakki Layout, Davangere.
41	A. B. Habeebulla	Mandakki Layout, Davangere.
42	A. B. Habeebulla	Mandakki Layout, Davangere.
43	A. B. Habeebulla	Mandakki Layout, Davangere.
44	A. B. Habeebulla	Mandakki Layout, Davangere.
45	Hidayathulla	Mandakki Layout, Davangere.
46	H. H. Anwar Saab	Mandakki Layout, Davangere.

Note: There are about 600 puffed rice units located in one single cluster of Davangere. In many a case, individual owners own multiple number of units. Accordingly, our coverage also comprises multiple units under a single owner's name.

Unit Address – Foundry Cluster, Belgaum

Sl No	Company	Address And Phone
1	Techno Castings	Plot No 146,147 Udyambag, Belgaum-590008. Ph no: 441002
2	Shivram Founders	Plot No 8-1, Site No 333, Udyambag, Belgaum-590008, Phone: 440739/442449
3	Kalyani Founders	Plot No 703, Hangirgekar Compound,

		Udyambag, Belgaum-590008, Phone: 440266
4	Jineshwar Malleable and Alloys	B-14, Angol Industrial Estate, Chennammanagar, Belgaum-590008, Phone: 441055
5	Padma-Akshay Alloy Pvt Ltd	Plot No 24 And 39, Site No 605, Machhe Industrial Area, Belgaum-590008, Phone: 411274/411324
6	The Allied Founders Pvt. Ltd.	Plot No. N-3, Industrial Estate, Udyambag, Belgaum 590008, Ph No. - 440924,441057
7	M/S Rohan Metals	Sy.No. 698 Plot B-29, B 36, Udyambag, Belgaum-590008, Ph No. 442027
Sl No	**Company**	**Address And Phone**
8	Renuka Metal Industries	Plot no. N-12, Industrial Estate, Udyambag, Belgaum 590008
9	Grihalakshmi Metal Industries	Udyambag Belgaum-590008, Phno: 441542
10	Prithvi Metals Private Ltd	Plot No 685, Udyambag, Belgaum-590008, Ph No:441550
11	Shanthi Iron And Steel	Plot No 690, Udyambag, Belgaum –590008, Ph no. 440972
12	Sai Alloys	165 Udyambag, Belgaum –590008, Ph no: 440747
13	Vishal Iron and Steel	129/141,Udyambag Belgaum-590008, Ph: 441032
14	Margale Engineering Works	133/B, Udyambag, Belgaum –590008, Phno: 441346
15	Vikrant Iron and Steel	74, Udyambag Belgaum-590008, Phno: 440019
16	Godeera Metals Pvt Ltd	153 Udaymbag Belgaum-590008, Ph: 440859
17	Atlantic Ferro Castings	Machhe Industrial Area, Belgaum-590008, Ph: 446909
18	Essen Aluminium	M42, Industrial Estate, Udyambag Belgaum-590008, Ph: 440526
19	Trident Steels	40,Machhe Industrial Area, Belgaum-590008 Ph: 411936
20	Sai Founders and Engineers	48/694, Udyambag Belgaum-590008, Phno: 442376
21	Gajanana Founders	Plot No 53 Udyambag Belgaum-590008,
22	Hindustan Engineers	11,S No 341/2,Udyambag Belgaum-590008, Ph: 441780
23	Amey Founders and Engineers	C-23/24, Industrial Estate Udyambag Belgaum-590008, Ph: 441298
24	Harsha Enterprises	81/2,Machhe Indl Estate, Belgaum-590008, Ph: 411835
25	Amijeet Founders	182 Udyambag, Belgaum-590008
26	K.T.N Metals	78/1,B Plot No. 149-50-51, Udyambag, Belgaum-590008, ph No: 441561

27	Victor Enterprises	M/N 16 Industrial Estate, Udyambag, Belgaum-590008, Phno: 440444
28	Vimal Enterprises	53,Machhe Industrial Area, Belgaum-590008, Ph: 411520
29	BKI Foundries	690,Indl Area Udyambag, Belgaum-590008, Ph: 442127
30	Arun Foudries and Fabrication	690,Udyambag, Belgaum-590008, Ph: 440288
31	AKP Foundries PVT LTD	689 Udyambag, Belgaum-590008, Phno. 440164
32	Mahesh Iron and Steels	29,Machhe Industrial Area, Belgaum-590008, Ph: 411039
33	Sai Steel	30/45,Machhe Industrial Area, Belgaum-590008, Ph: 463717
Sl No	**Company**	**Address And Phone**
34	Mangal Founders	631/1,Jamboti Road, Machhe, Belgaum – 590008, Ph: 411455
35	Vinmar Diesels	57,Machhe Indl Area, Belgaum-590008, Ph: 411510
36	Shreyas Castings	112,Machhe Indl Area, Belgaum-590008, Ph: 411525
37	Abhishek Alloys Pte Ltd	58,Machhe Indl Area, Belgaum –590008, Ph: 411040
38	Finecast Metals	634/1,Pn No 4,Jamboti Road, Machhe Belgaum-590008, Ph: 411624
39	United Metal Works	75,Khanapur Road, Tilakwadi, Belgaum-590008, Ph: 441538
40	Venkatesh Industries	46, Machhe Industrial Estate, Belgaum – 590008, Phno: 411665
41	Sai Metals	Plot No 11& 20, Machhe Industrial Estate, Belgaum-590008, Ph No: 411367
42	Protech Founders	739, Khanapur Road Udyambag, Belgaum – 590008, Ph No: 441953
43	Pooja Alloys	No 33, Macche Industrial Estate, Belgaum-590008 ph No: 443106