ASSESSING & MITIGATING HEALTH RISKS FROM STONE QUARRYING AND CRUSHING INDUSTRY IN BUNDELKHAND REGION OF CENTRAL INDIA

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1. Synthesis of Project

1.1 Rationale

Among the various small and medium enterprises (SMEs) in India, stone quarrying and crushing units play an important role in supporting local and national infrastructural requirements. Its growth has been rapid because of the increasing demands from the construction industry. This sector employs largely rural, migrant and unskilled workers (both men and women); provides them opportunities for primary employment as well as supplemental income for those involved in farming. However, the status of occupational & environmental safety and health in this sector is in need of considerable improvement. Stone quarrying and crushing involves a variety of processes that create potential for exposures to a wide range of physical, chemical and ergonomic hazards. Quarrying, drilling, blasting, breaking, loading and unloading, overhauling, crushing and screening represent a few such processes that are operational in all units regardless of their size. Emissions are also a health risk to inhabitants of local communities. The aim of the project was therefore to demonstrate the utility of adopting an "eco-health" framework to recommend, implement and create a framework for sustaining interventions that will contribute to reducing the magnitude of environmental and occupational health risks faced by this sector and the communities that support the same.

While stone quarries and crushing units are located in many states of India, the project was conducted in a cluster located within the Bundelkhand region (Tikamgarh district) in Central India to take advantage of technical support that could be made available by Development Alternatives (DA), the principal host institution, beyond the project period. DA has an office in the district and has been working with communities surrounding this area for other development related activities.

1.2 Objectives

A cluster of thirteen stone crushing units in an area of approximately one square kilometer was selected for the baseline assessment and subsequent design and implementation of select interventions. The communities in two adjoining villages that depend on these units for their livelihood were selected for the community level assessments. The main objectives of the project were:

1. To identify the major determinants of health viz. environmental, social, economic, cultural and political risks that are related to the industry and communities through participatory engagement of multiple stakeholders.

2. To assess environmental quality of air, water and soil to establish the baseline environmental status and contributions to population exposures and consequent health impacts.

3. To assess the baseline health status in a representative cross-sectional sample of workers and community residents to establish potential contributions from living, social, gender related and occupational environmental variables.

4. To develop and implement participatory intervention strategies that facilitates the adoption of short-term technical and operational measures to reduce environmental and health risks, and support long-term participatory interaction among stakeholders.

5. To evaluate the effectiveness of the participatory process by its ability to generate projects that make a tangible improvement in human health and social well-being and/or generates a series of "lessons learned" to serve as precedents for future programs.

1.3 Process

The project used a combination of classical environmental monitoring and epidemiological methods (such as environmental sampling, cross-sectional health assessments etc.) together with well established social science research methods (such as focused group discussions) to identify opportunities for interventions. Project objectives evolved with additional refinements being continuously made, on the basis of active engagement of stakeholders. Select project objectives had to be substantially modified based on limitations imposed by feasibility (such as installation and sustained operation of dust control systems) and/or requirements of legal notifications (such as reporting of occupational diseases). Most project objectives however, were fulfilled as anticipated.

1.4 Impact

The project allowed a comprehensive understanding of prevalence occupational and environmental risk factors, identified and prioritized risk factors for interventions and demonstrated the feasibility of select short-term and long-term interventions. The project also accomplished a significant degree of inter-institutional and local capacity building to enhance the sustainability of what was initiated by the project. Finally, the project enabled the researchers and the concerned stakeholders to jointly characterize risks so that risk communication could be structured in effective ways to support and sustain eco-health frameworks for many diverse sectors in the future.

2. Description of Research Problem

The main research questions addressed in the project were centered around *evolving a strategy to design, implement and sustain interventions for a hazardous occupational sector where in recognition of hazards was easy but yet risk management was tremendously complicated by maze of social, political, behavioural and economic factors*. The biggest challenge was in coming up with a framework wherein one could convincingly demonstrate the need for solutions without actually assessing impacts (i.e. assess health risks and not necessarily health impacts), "show how" effectiveness of interventions and have communities and workers engaged in a sustained dialogue for continual improvements in their community and work environments. Since "participatory" approaches were recognized to be central for addressing the research problem from inception, the logical framework for the project was centered on creating, implementing and supporting participatory processes that result in improvement of economic and environmental performance by the stone quarrying and crushing industry while enhancing the health and social structure of the communities associated with them in the identified project location.

The initial pilot refined the approaches to be adopted and most importantly avoided presumptions about which interventions are needed and likely to be adopted. A few findings from the pilot were key in framing the specific objectives for the project. For e.g. while owners were thought to be in total control and workers virtually bonded to these jobs for want of livelihood, it became clear during the pilot that skilled labour was not easy to find. Ironically, "quarry work" was not perceived as being "positive" in the community. Owners therefore were willing to adopt measures that would enhance their business continuity and profitability but admitted being passive about seeking "appropriate solutions". Specifically, dust abatement interested the owners a great deal provided they could be convinced of the cost-benefit from examples elsewhere. Castes and caste related issues played a dominant role in the communities and were central for positioning of intervention options. Health care providers were keen but hitherto had not engaged in preventive health services for the sector. That environmental deterioration was widespread and harming health was widely known within communities. Limited assessments of the environmental quality had been performed to understand the scale and extent of damage however. Based on the pilot, the research problem was addressed in six major dimensions as described below.

i. Participatory assessments for initial scoping of project components and subsequent refinement of project methodologies and implementation of interventions
ii. Baseline assessment of hazards in work environment
iii. Baseline assessment of environmental quality in the project area and creation of an eco-info-base
iv. Baseline health assessment for workers and the community
v. Implementation of select interventions and framing of "future" interventions (following a feasibility assessment)
vi. Capacity building

3. Project design and implementation

The project was executed as a consortium of activities broadly divided into six dimensions (as listed above) and anchored by some common threads. These threads were so woven as to link the various project dimensions, allow lessons learnt in each dimension to be freely exchanged and optimize utilization of financial and human resources. **The first such linkage was established through participatory assessments.** These allowed environmental/ clinical/economic assessments to be fed back iteratively into intervention selection, design and implementation. **The second such linkage was established through capacity building efforts at various levels.** This allowed better hazard recognition and contributed to on-going and future interventions at the community and work environments.

The study was carried out in two villages (labeled S and B in the report to protect identities) located within the Tikamgarh District in Madhya Pradesh (Central India). The villages are about 6km apart by road. There are 14 stone quarrying and crushing units in these villages of which 3 were chosen for on-site assessments and interventions for dust control were implemented in 1 unit. .

3.1 Participatory Assessments

These assessments were initially used to gather to develop an understanding of community's perceptions about their village, its problems, causes and effects of different factors and prepare a matrix for systematic hazard assessment. to design participatory interventions that pose immediate and long term impacts on their health conditions and overall quality of life. Following the assessment of environmental quality and health assessment, participatory approaches were continued in prioritizing and implementing select interventions. Finally, they were used to identify requirements for initiating/sustaining short and/or long-term interventions.

The assessments were made primarily through "Focused Group Discussions". The participants included men, women and youth in both the villages. The process of seeking participation was 'inclusive' meaning most of the exercises involved people from different socio-economic status, different age groups and different occupational environments (such as stone quarrying and crushing, agriculture etc.). The participatory exercises focused on different themes including

1. General information about the community
2. Agri input-output analysis to ascertain farm incomes of the community
3. Health seeking behaviour of the community
4. Access and control over infrastructure and facilities
5. Community perception of well being
6. Participatory action plans

Table 1: Select data collation tools used in the participatory assessments

Objective of village level participatory exercises	Data Collation Tool
To generate baseline information on demographics, occupational structure, literacy levels and other village information.	Secondary Literature Review and Household Survey
To develop an understanding on the health related problems concerning men/women/children , health care system utilization	Listing, Ranking, Matrix
To have an understanding of people's perception of 'well being' and the status of the village based on the perception.	Listing, Ranking
To determine changes which have come over in the village over the past few decades and develop an understanding on the factors lying therein and their impact	Historical Matrix
To develop an understanding on the different spheres of household expenditure and sources of income	Cake/Pie
To develop an understanding over peoples' access and control over resources	Venn

Figure 1: Participatory assessments in progress in the villages (Right panel shows a sample of village level mapping prepared by the residents)

Following data collation, a comparative analysis was performed. The same people who were involved in conducting these exercises were involved in the process of analysis to avoid any loss and / or misinterpretation of information or knowledge. The information collated was also triangulated with other key informants and reliable secondary data. In addition to participatory assessments, an elaborate stakeholder engagement process was developed and used to continuously inform the other components of the project. Some of the key stakeholders included **unit owners, unit owners' associations, the District Health Department, the Madhya Pradesh State Pollution Control Board, the State Agriculture department, the village Panchayat staff, private physicians and the National Research Center for Agro Forestry, Jhans**i. These interactions provided key inputs for the design and execution of assessment and intervention exercises in parallel with the village level assessments of community perceptions and needs.

3.2 Baseline assessment of hazards in the work environment

The scope of workplace monitoring was decided based on past documentation of hazards of this occupational sector, as well as pilot walk –through observations in the units. The parameters for primary sampling included

- Concentrations of respirable particulate matter and silica
- Noise exposure levels
- Safety and ergonomic hazard analysis

The participatory assessments lent support to the occupational hazard assessments in identification of suitable locations for sampling, providing logistical support in placing the instruments, providing labour and taking the responsibility to ensure the safety of the instruments.

Four sets of measurements were made for air quality between March 2007 and August 2008 in three participating stone crushing units. Of these, only one set of measurements was performed after the implementation of the dust control devices in one of the three units. This allowed a reasonable assessment of the range of dust exposures that could be expected for the workers given the variability across seasons and even across individual days with changes in meteorological conditions. A sub-set of samples were analysed for silica. Noise and safety hazards were assessed through one set of cross-sectional assessments.

Air quality measurements were made using high volume samplers (for ambient concentrations of respirable particulate matter) and low volume samplers for (area and personal exposure concentrations for PM_{10}, PM_4 and $PM_{2.5}$). Area and personal noise measurements were made within the units using area sound level meters and personal noise dosimeters, respectively. Safety and ergonomic assessments were carried out using a combination of checklists and questionnaires

Area particulate monitoring in the unit

Area noise measurements near primary crusher

Figure 2: Workplace hazard monitoring at the crushing units

3.3 Baseline assessment of environmental quality in the community and creation of eco-info-base

The participatory assessments, in particular the historical mapping exercises performed by the community provided the base for identifying environmental parameters that are likely to have been impacted through this occupational activity (i.e. stone quarrying and crushing). It also provided the justification for creation of the eco-info-base that tracked changes in ecology surrounding the project site using high resolution satellite imagery validated by ground truthing assessments. While the baseline assessments of environmental quality focused on parameters of relevance for public health, the eco-info-base covered parameters of relevance for the general ecology of the environment.

Environmental quality monitoring: Project area was reported and found to be water scarce, rocky and semi arid. Drinking water scarcity was reported to be a major concern for the people especially over the last few years. Water sampling was therefore conducted in selected stone crushing unit as well as nearby communities to establish water quality in relation to drinking water standards. Changes in agricultural productivity and patterns of cropping prompted soil sampling to see if the soil quality had been adversely impacted by the deposition of dusts coming out from the stone crushing and quarrying units.

Water quality monitoring was performed twice (once each year) during the project period in each of the villages. Samplings locations were decided through on –site observations and consultation with the local community. Most major water sources were included in the sampling. Water quality was tested for five main parameters viz. pH, fluoride, nitrate, total dissolve solids (TDS) and bacterial contamination (Coliform). Household water samples were however tested only for bacterial contamination to look into community hygiene practices. Water quality of Betwa river, adjacent to village B, was also tested.

Soil testing processes too were conducted in co-operation with the farming community of the area as well as the village development committee. Collected samples were tested for pH, electrical conductivity, organic carbon, total nitrogen, available phosphorous, extractable potassium and available micronutrients, according to protocols outlined by the Indian Agriculture Research Institute New Delhi, India.

Finally, ambient measurements of PM 10 were made in the villages using high volume samplers. Sampling covered locations close to (<500m) and somewhat farther away (>1000m) from the crushing units during days when the crusher was operational. In addition, low volume area samplers were used to measure levels of PM 10 and PM within household micro-environments (kitchen, bedroom, "just" outdoors etc.) indoors to ascertain contributions from crushing units as well from household solid fuel use (a relatively common occurrence in poor communities). A small subset of all samples were analysed for silica.

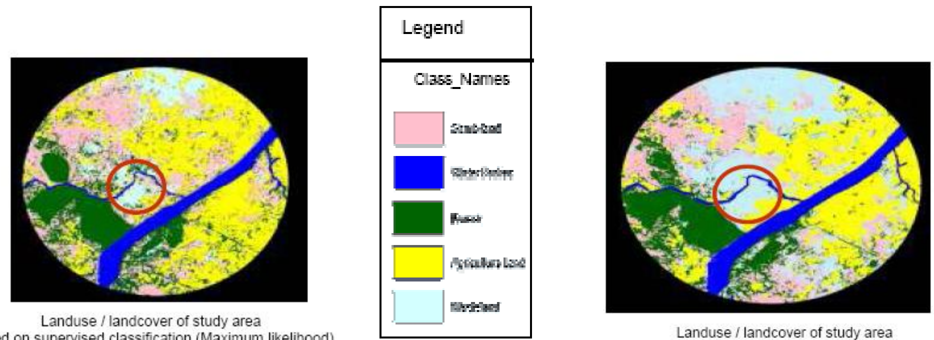
Generation of Eco-info-base:

Stone mining destroys or significantly alters all the physical features that influence the capabilities of the land. An Eco-InfoBase allows an understanding of existing resources, their status, spatial distribution and association with other resources and socio-economic situation. It also allows the user to track major changes in land use and land cover to evaluate impacts attributable to mining activities in the region.

Remote Sensing and Geographical Information Systems with limited ground truthing were used to perforrn a situation analysis and impact evaluation. The satellite data of 2003 and 2008 and topographical maps were procured from National Remote Sensing agency and survey of India for developing the eco-InfoBase and landuse/landcover maps. The landuse/landcover maps were developed by interpreting the satellite images of 2003 and 2008. The broad methodology used for carrying out the study was as follows:

Delineation of study area: Topographical maps on 1:50,000 scale were used to delineate the study area likely to be impacted by stone crusher units and mining. A buffer of 10 Kms was created and the area was extracted for the study. After finalising the delineated area, base map was prepared as a platform to project and analyse non-spatial data like demography, water quality, health status.

Preparation of spatial database: The base map comprising of physical features such as roads,rivers, habitation points, railway lines, forest areas & village location points were prepared in ArcGIS software. For this, survey of India toposheet (54-K/11) was used as reference materials. The permanent features were transferred in digital format through digitization. Initially, the survey of India toposheet was georeferenced using Geographic Latitude/ Longitude WGS 84 co- ordinate system. Merged satellite data (for the year 1989, 2003 and 2008) was used for preparing spatial database / thematic maps on landuse / landcover for detailed assessment of landuse and to evaluate temporal change in landuse/landcover from year 1989 to 2003 and 2003 to 2008 in the study area.



Landuse / landcover of study area
Based on supervised classification (Maximum likelihood)
IRS 1D – LISS – III, 2003

Landuse / landcover of study area
Based on supervised classification (Maximum likelihood)
IRS P4 – LISS – IV, 2008

Figure 3: Landuse / landcover maps for 2003 vs. 2008

Collection of Ground Truth information: Initially rapid traverse of the test site was made to identify the sampling points on the FCC image and in the field. The exact locations of such variable feature were noted with help of GPS for assigning the training samples during Digital Image Processing. Detailed field investigations were carried out in various physiographic units.

Digital Analysis of Remote Sensing Data: Supervised classification is the most important analytical tool used for the extraction of more information from remotely sensed digital image data. Supervised classification was performed using maximum likelihood classifier. In the present study, before starting this procedure the possibility of separation of each class was determined from various enhancement & unsupervised classification techniques. The digital data images of (IRS – IA: 1989, IRS- I D: 2003 & IRS P4:2008) were geometrically corrected & masked according to the boundary of study area (10 kms buffer). Supervised classification was performed using maximum likelihood classifier. Using satellite data interpretation, the study area of year, 2003 and 2008 was

classified into five different classes viz; Water bodies, Agricultural Land, Waste Land, Scrubland, and Forest. The area under different classes was then calculated for change detection analysis.

3.4 Baseline health assessment for workers and the community

Health assessments were conducted in both the villages in order to understand the prevalent general health status of the community in relation to the environmental quality (in the occupational and community environment). The health assessment was not designed to establish causal linkages to environmental exposures but to facilitate analyses of the cross-sectional data in a qualitative framework to identify known causal agents and opportunities for intervention.

The primary purpose of the health assessments was thus to (i) understand the status of community health in relation to the relative prevalence of multiple sets of determinants (ii) understand the level of community risk perceptions in relation known risk factors (iii) guide choice of interventions in terms of their relative contributions to current and or future health status and (iv) enable risk communication and capacity building efforts within the local medical community.

Health assessment: As was described for the previous components of the project, participatory involvement ensured that health concerns and perceptions of the community were captured in the health assessments too. The conduct of a baseline screening of the village population was requested by the communities and therefore this assessment became both an “assessment” and an “intervention” at the same time. As a result, there was a large voluntary turnout during the exercises and 472 people (nearly 72% of the total population of both the villages) were screened (children were not included for the health assessments). The participating villages also contributed in the form of providing a safe and private space in their houses at two locations (2 rooms at each location) for the total assessment period with basic amenities like electricity, tables, chairs and beds. Some opinion leaders from the village also shared responsibility for mobilization of community along with field staff resulting in good turn out of people particularly in village S. An informed consent (in Hindi, the local language) was obtained from all participants was obtained before the conduct of any health assessments.

Health assessments were conducted using questionnaires to record a clinical history, self-reported symptoms/disease and performing select clinical investigations (including biochemical tests and spirometry). We refrained from administration of chest X-rays for diagnosis of silicosis as the required infra-structure for reporting notifiable occupational diseases and follow up was not available in the project site. The sensitivities of the unit owners were also a factor behind dropping the said investigation. Audiometry could not be performed for want of adequate on-site facilities (such as a noise and vibration free room). Detailed information on household level environmental variables (such as source of drinking water, access to sanitation, use of solid fuels etc.) and lifestyle variables (including smoking, alcohol, nutrition etc.) were also recorded to allow stratified analysis. Of particular importance was also the recording of occupational history and occupational injuries.

3.5 Feasibility assessment and implementation of select Interventions

While the need for interventions in this vulnerable sector was always recognized, the assessments described in the previous sections served to explore feasibilities for required interventions. Clearly, many interventions were not what could be implemented and assessed within the project period and hence for most interventions a “needs assessment” for sustainability was also made. Based on an integrated technical, financial and socio-cultural feasibility assessment, a comparative ranking of risks and controls was prepared to differentially capture both the “risk assessment and risk management” components of this project

Technical feasibility assessment: Technical feasibility assessments were conducted for those issues that required engineering design and or control. Dust emissions and improvements in safety within crushing units and water quality improvement within communities were identified to be primary concerns requiring such a technical feasibility assessment.

Socio-cultural/economic feasibility assessment: For the engineering interventions feasibility was assessed through multiple discussions forums where in the owners provided inputs on their requirements, willingness to invest and the cost of the dust control systems. Many interventions also required a support network of human resources to implement and sustain interventions. The feasibility of how such networks may be created was examined through formation of village level groups that involved multiple target groups such as the youth, girl children, women etc. These groups were involved in pilot scale implementation or support of interventions to judge the relative feasibility of long-term efforts. Some degree of socio-cultural feasibility was also assessed through interactions with health care providers who provided the inputs for understanding the needs for capacity building to support the recognize and manage health risks in this community.

3.6 Capacity Building

The project engaged in a large number of capacity building exercises across a diverse group of stakeholders. These exercises allowed an understanding of the needs for the concerned parties and package a set of resource materials that could be used to sustain such efforts beyond the project period. Some key efforts in capacity building included organization of training programs for community residents on water and sanitation, for farmers on crop improvement, for village leaders on governance and management, youth groups on social awareness and health care providers on diagnosis, management and prevention of occupational and environmental diseases related to this sector. In addition, researchers from both implementing institutions benefited form cross-disciplinary training through joint field activities.

4. Research Findings from Project Components

4.1 General Profile of the Study Villages

Table 2: General descriptives of study population

	Village S			Village B		
Number of Households	112			65		
Household Size	5.0			5		
Proportion of Urban Population (%)	0.0			0.0		
Sex Ratio (females / 1000 males)	877			856		
Sex Ratio (0-6 years)	892			703		
Sex Ratio (SC)	820			1048		
Sex Ratio (ST)	857			0		
	P	M	F	P	M	F
Population – Total	597	318	279	336	181	155
Population – Rural	597	318	279	336	181	155
Population – Urban	0	0	0	0	0	0
Population (0-6 years)	123	65	58	63	37	26
Population (Scheduled Caste)	233	128	105	43	21	22
Population (Scheduled Tribe)	13	7	6	0	0	0
Proportion of SC Population (%)	39.0	40.3	37.6	12.8	11.6	14.2
Proportion of ST Population (%)	2.2	2.2	2.2	0.0	0.0	0.0
Number of Literates	315	207	108	198	123	75
Number of Illiterates	282	111	171	138	58	80
Literacy Rate(%)	66.5	81.8	48.9	72.5	85.4	58.1
Total Workers	277	179	98	99	93	6
Main Workers	188	165	23	95	91	4
Marginal Workers	89	14	75	4	2	2
Non Workers	320	139	181	237	88	149
Work Participation Rate (%)	46.4	56.3	35.1	29.5	51.4	3.9
Proportion of Main Workers (%)	31.5	51.9	8.2	28.3	50.3	2.6
Proportion of Marginal Workers (%)	14.9	4.4	26.9	1.2	1.1	1.3
Proportion of Non Workers (%)	53.6	43.7	64.9	70.5	48.6	96.1
Cultivators	145	86	59	35	31	4
Agricultural Labourers	39	4	35	1	1	0
Workers in Household Industries	0	0	0	0	0	0
Other Workers	93	89	4	63	61	2
Proportion of cultivators to total workers (%)	52.3	48.0	60.2	35.4	33.3	66.7
Proportion of agricultural labourers to total workers (%)	14.1	2.2	35.7	1	1.1	0
Proportion of workers in household industries to total workers (%)	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of other workers to total workers (%)	33.6	49.7	4.1	63.6	65.6	33.3

4.2 Participatory Assessments

4.2.1 Findings from village level social assessments

General

Village S has three socio-economic based hamlets wherein one of the hamlets (45 households) is entirely dependent on the stone crushing and quarrying units (most of them being landless as well) while those in the other two hamlets (67 households) are primarily involved in agriculture. Overall in village S 33% of the population is employed in stone quarrying and crushing (SQC) units. Village B has four socio-economic hamlets and almost 64% of the population is involved in. SQC jobs. However, they are also engaged in cultivation of wheat for self-consumption. In both villages, those involved in SQC's are largely involved at quarry sites for blasting, drilling, boulder breaking and as petty contractors for logistical support. The youth in both the villages, however, are reluctant to adopt livelihood opportunities in SQC units but are also constrained by lack of alternate livelihood opportunities

There are primarily three agricultural seasons in India viz. Rabi (winter crop), Kharif (monsoon crop) and Zayed (summer crop). In both the villages only the Rabi crop is cultivated due to unpredictability of monsoons and acute water scarcity during summers. Even in cultivation of the Rabi crop, the marginal, small and medium farmers (comprising 50% and 66% of households in Village S and B respectively) cultivate only wheat, because it is the staple crop of the region. This category of farmers has little produce left for sale in the market and sometimes even a cash loss is incurred. Farming communities in both villages had poor understanding about improved farming practices. Furthermore, due to limited cash incomes and resultant low disposable cash availability, people dietary intake is largely confined to cereals.

The communities in both the villages perceived of significant decline in forest cover and rains in the area over last two decades (about 90% degradation in forest cover and 80% deterioration in annual rainfall over last 30 years) resulting in proportionate decline in agriculture and livestock productivity (communities perceive 80% decline in agricultural productivity over last 30 years). One important cause-effect relationship that communities enumerated was the development of industrial area in 1984 and thereafter establishment of stone quarrying and crushing units.

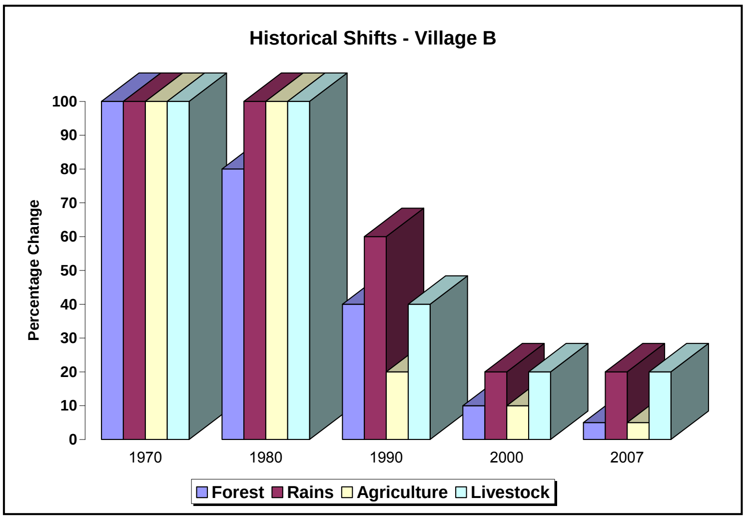


Figure 5: Historical mapping of villager's perception of ecological changes in Village B

According to the communities, that led to massive destruction of forests and hence sudden decline in rains, water crisis, poor agriculture productivity and consecutive years of drought. This also led to increase in rural migration to urban hubs.

There is mixed opinion among communities in both the villages on SQC units. While some feel that they destroyed the ecological strength of the area, others also acknowledge them for providing assured incomes and also for resultant infrastructure development works in their villages.

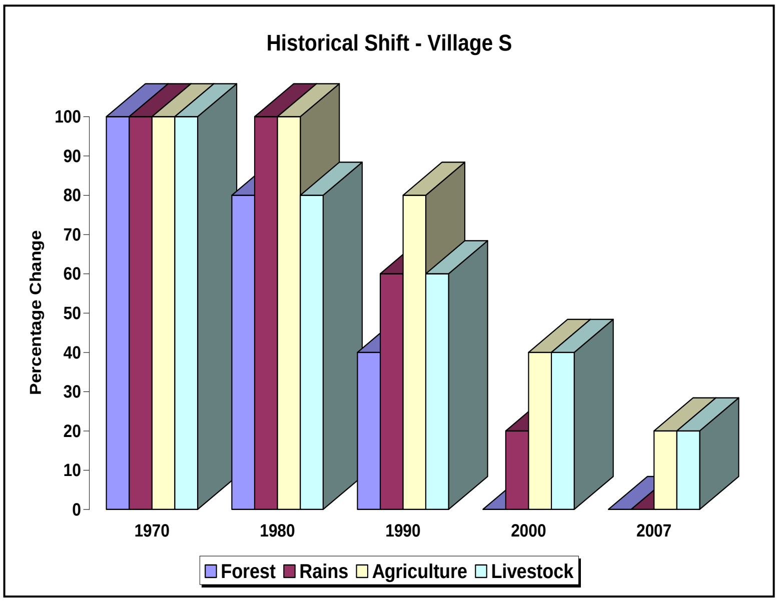


Figure 5: Historical mapping of villager's perception of ecological changes in Village S

Health and well-being

Communities in both the villages were unaware about their health status but got heavily sensitized and inquisitive about their health issues after participatory exercises. People were either dependent on home remedies or quacks as the first level of health service access for nearly all categories of general ailments with the formal health care system being accessed only for critical conditions. Faith and trust in government operated health services were at best poor amongst all sections of the society. Children were accorded the highest priority for health related expenditure followed by men. Women's health often merited the least amount of attention.

Participants from both the villages identified common attributes such as Good Health, Good Education, No Alcoholism, Good Agriculture, Toilet Facility, LPG Connection, High Income and Water Availability as defining well being.

Lack of access to clean drinking water (both in terms of water quality and availability was identified as an important concern in both villages. Women valued water availability higher than men (perhaps because of the larger effort exerted by women in fetching water for the family).

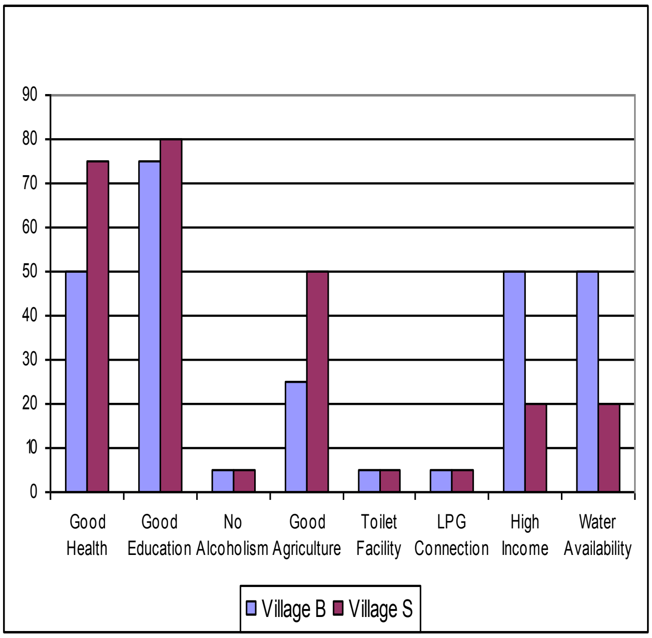


Figure 6: Attributes of well being identified by villagers

Good Education was valued highly and relatively high percentages (as compared to other marginalized rural communities) of the population in the villages are literate. However, girl children in general were not allowed to continue their education after 8th grade as this entailed movement outside village boundaries. With regard to Good Health, 50% of participants from village B reported feeling healthy whereas in village S, 75% people reported feeing healthy. However, upon being questioned about their health seeking behavior, several ailments and diseases were reported to be prevalent among men, women and children (perhaps reflecting a general lack of perception on what "being healthy" (meant). Access to sanitation facilities was very low in both villages. As in the case of water, women valued availability of a "toilet" highly (again reflecting substantially greater hardships for women when toilets are not available). Use of solid fuels was highly prevalent with limited LPG (clean fuel) use.

Gender related issues

Gender related differences in perception and status were identified at the individual, household and community levels as described below

At individual level

- Women in both the villages don't feel the need to be aware of the development programmes running in villages and are negligent about their own health. They are mostly confined to household chores and agriculture related activities.
- As compared to the men, literacy levels among women are low (about 35%). But mostly women in the middle age and old age group are illiterate, while the literacy levels are much higher amongst younger women.

At household level

- Women bear most of the burden of household chores including time-consuming chores such as fetching water and collecting household fuel. This burden has worsened over the last few years with increasing scarcity of water and deforestation in the neighbourhood.
- High rate of alcoholism among men was found to be one of the main reasons for incidences of domestic disputes.
- Women have little say in major household decisions even if they are the earning members.
- It is a not socially acceptable for women to go out of the village alone
- Barring two or three families, most of the household do not have toilets and bathrooms and villagers have to go off to far off places to relieve themselves. This could be the cause of some serious health related problem for women due to low intake of water.

At community level

- Even in meetings that seldom happen, the participation level of women in both the Village Collectives (Gram Sabhas) is extremely low as the environment at such meetings is not friendly for women – they find difficult to voice their opinion in front of men and their suggestions are neither taken seriously nor implemented (ironically the Head of the local Village Council (Sarpanch) is a woman but never participated in meetings). Most women members were not even aware of the meetings and therefore there was no/low participation in such events.

Socio-economic status related issues

Both the villages have fragmented societies largely divided by their socio-economic status resulting in low levels of collaborative thinking and action to mitigate common concerns. This was found to be more pronounced in case of women. Both the villages lack disciplined institutional systems to interact with other institutions for their operational and strategic needs.

The need for credit in both the villages is largely for immediate health related expenses and for customary and traditional practices (like marriages, deaths, festivals etc.). The credit is primarily sought from local money lenders at exorbitant interest rates (3-12% per month) most of the times on collaterals like jewellery. For minor health ailments and immediate domestic needs credit is sought from the SQC unit owners and is repaid as deductions in installment from their weekly payments. Credit borrowings from formal financial institutions is abysmally low due to lengthy procedures for credit disbursement that is often too little and late as perceived by the communities. However, other reason for banks being reluctant to offer credit to most of the households in these villages is a poor repayment track record. Women from both the villages accuse that men forcefully use their savings meant for repayment for alcohol resulting in defaults and indebtedness.

Different institutions like panchayats, Government line departments lack motivation in delivering services expected out of them and people in these villages also are poorly informed to access these services.

4.2.2 Contributions of participatory research processes to other project components

In addition to the village level assessments that provided the most intense degree of participatory interactions, a range of other participatory assessments were conducted through engagement with a number of stakeholders. These assessments provided a diverse range of inputs for the design and execution of all sub-components of the project. They are broadly summarized in Table 3.

Table 3: Inputs from participatory assessments for other project components

Project Sub-Component	Input Providers	Key Inputs
Assessment of work related hazards	Unit owners State pollution Control Board Workers	Monitoring was permitted on site under the condition that the identity of units are not disclosed in any form Logistic assistance for placement of samplers, identification of work areas/processes/jobs with excessive dust exposures and work-shift information was provided Demonstration of engineering interventions was permitted at one or two units Walk-through assessments for safety hazards were permitted under the condition that workers are not provoked or alarmed unduly about prevalent hazards Pollution Control Board staff participated in several on-site visits to assess efficacy of the dust control equipment
Assessment of Environmental Quality & Eco-Info-base generation	Community groups	Profile of village residents with respect to occupation, socio-economic status, farm productivity, ecology of village surroundings and environmental quality was created through the use of tools listed in table 1 Support was provided for identification of sampling locations for environmental measurements within the community
Health Assessments	Community groups Local district health officials	Health screenings had never been performed at the village level and therefore was requested and overwhelmingly supported by village residents Village residents recognized and reported perceptions regarding the prevalence of many health problems and health seeking behaviour Village residents ranked environmental and health concerns for use in the subsequent intervention phase Physician resources were limited. Diagnosis of notifiable occupational diseases (especially silicosis) was identified to be problematic as support infra-structure for follow-ups/notification was not available. To avoid anxiety and disruption of community dynamics , these assessments were not included
Feasibility Assessment & Implementation of select interventions	Unit owners Community	Cost was identified as the single biggest factor for adoption of interventions. However, effectiveness was also accorded priority Except for dust control devices, readiness for other workplace related controls was low Drinking water, greenbelt development and soil fertility improving interventions was supported by active participation by village residents
Capacity Building	Health care providers Village level Groups	Local physicians from both the Govt. and private sectors were willing to commit time to acquire additional skills for recognition and management of occupational diseases Village level groups especially the youth are eager to involve in low cost efforts that improve the environmental quality of their surroundings

4.3 Baseline assessment of hazards in the work environment

4.3.1 Measurement of respirable dusts

Measurements of respirable dusts at the workplace were done for two size fractions viz. PM_{10} and PM_4 to allow comparisons to relevant health based standards. PM_{10} measurements were performed using high volume samplers to allow comparisons to National Ambient Air Quality Standards. PM_4 measurements were performed using low volume samplers to measure area concentrations within the breathing zone of workers and compare to workplace. Personal exposure concentrations were also monitored for a select group of workers.

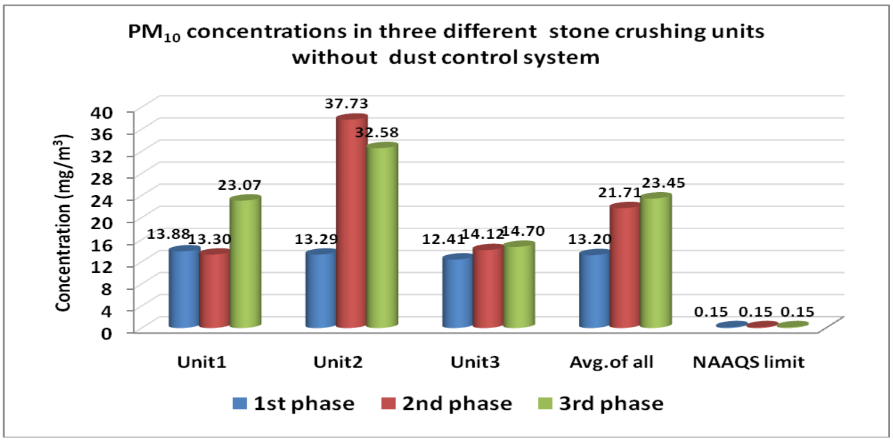


Figure 7: Average concentrations of PM_{10} recorded in the 3 crushing units prior to installation of dust control devices for three different periods (two winter and one summer period respectively).

As can be seen 24-hr concentrations of PM 10 exceed national guideline values by nearly 100 fold. The area area concentrations of PM 4 too exceeded the guideline values in many locations across units as shown below.

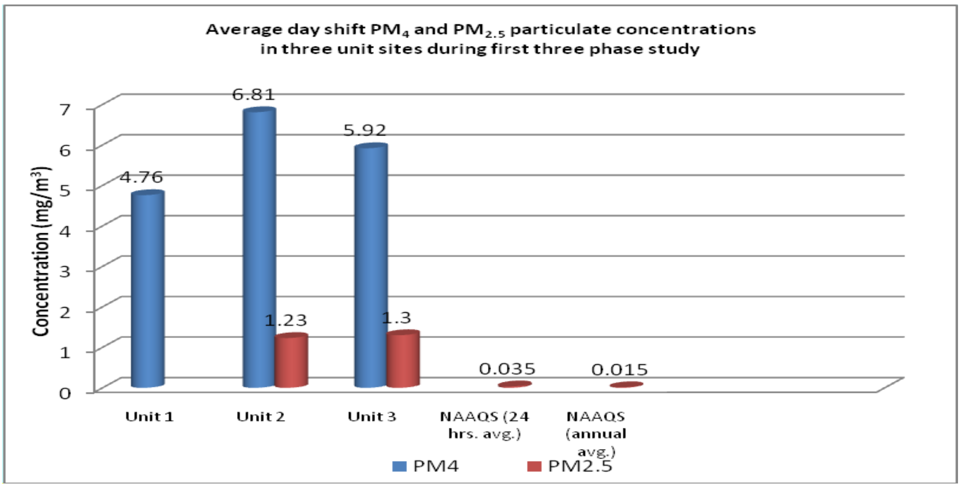


Figure 8: Average concentrations of PM_4 recorded across multiple locations in the 3 crushing units prior to installation of dust control devices for three different periods (two winter and one summer period respectively).

Worker exposures were monitored for a few categories of workers viz. male and female helpers and loaders. These workers are likely to receive the highest levels of exposure during specific periods of operation that are best captured using personal samplers. Because of the inconvenience of wearing the samplers for extended periods of time, a full shift exposure could not be recorded. However short-term exposure concentrations indicated that these workers receive some of the highest exposures to respirable dusts. The peak levels for PM 4 recorded ranged from 2 to 60 mg/m^3 (the guideline value for a full shift exposure is 3 mg/m^3). Details of exposure monitoring are furnished below.

Table 4: Exposure Concentrations for select categories of workers prior to installation of dust control systems

Monitoring Phase	Worker	UNIT – I			UNIT - II			UNIT - III		
		Sampling time (hrs.)	Elapsed time (min)	Exposure conc (mg/m^3)	Sampling time (hrs.)	Elapsed time (min)	Exposure conc. (mg/m^3)	Sampling time (hrs.)	Elapsed time (min)	Exposure conc. (mg/m^3)
First phase	Helper	14:26-17:08	74	*59.17	11:35-17:31	331	*1.37	12:00-15:00	180	*4.85
Day 1	Helper	14:31-17:08	155	#31.71	11:32-17:28	315	*1.84	12:00-15:50	188	*6.84
	Loader	14:35-17:15	160	*2.78	14:34-17:30	338	*2.85	11:55-16:40	198	*1.78
[march 07]										
	Helper	12:25-17:10	319	*2.40	Workers not interested			10:40-13:10	140	*3.69
Day2	Helper	12:44-16:35	90	#4.13				11:40-12:56	18	*7.85
	Loader	12:34-15:41	141	*1.95				10:35-13:30	167	*7.14
Second phase	Helper1	15:05-17:38	148	*16.46	13:50-17:37	216	*5.13	14:03-19:00	295	#10.23
Day 1	Helper2	15:09-16:38	81	*20.40	14:05-15:03	168	#1.92	14:00-19:27	286	#2.29
	Loader	15:10-17:09	115	#10.8	13:53-18:02	236	*2.76	13:55-19:02	187	*17.40
[Dec. '07]										
	Helper1	13:00-17:03	132	*8.73	09:45-12:07	137	*2.21	11:19-13:48	137	*4.10
Day 2	Helper2	13:05-15:40	152	#22.6	10:57-12:03	66	#0.80	11:23-13:48	140	*8.88
	Loader	15:00-17:06	61	*5.95	09:38-12:18	153	*1.22	11:26-13:47	147	*1.33
Third phase	Feeder1	13:30-17:50	246	*5.00	-	-	-	16:45-21:08	214	*15.46
Day 1	Feeder2				-	-	-	16:45-20:15	151	*3.31
	Helper1	14:55-17:49	167	*4.30	12:35-17:30	167	#10.44	16:55-21:11	251	*1.73
[Feb. '08]	Helper2		-	-	12:55-17:32	226	#3.58	-	-	-
Day 2	Feeder	Unit was shut down			12:45-14:01	76	*8.83	Workers not interested		
	Helper				12:45-17:55	116	#5.63			
	Loader				12:50-17:58	68	*2.44			
Fourth phase	Feeder1	14:25-17:57	214	0.136	14:40-16:00	100	0.19	10:30-12:15	86	0.016
	Feeder2	14:02-18:08	233	2.477	13:0-14:50	114	0.62	-	-	-
Day 1	Helper1				13:00-14:38	116	0.27	12:22-13:11	51	0.200
	Helper2				12:15-16:19	15	3.69	-	-	-
[Aug. '08]										
	Feeder	14:25-17:52	39	2.217	19:47-21:40	90	0.54	Not done		
Day 2	Helper	-	-	-	12:18-17:02	14	1.46			
	Helper2	14:32-15:00	28	0.602	17:00-17:15	19	3.05			
	Loader1	Not available			14:52-16.05	101	0.80			
	Loader				17:04-17:20	19	0.99			

**** Stands for male worker and # stands for female worker exposures,***

["ACGIH (American Conference of Governmental Industrial Hygienists) believes that even biologically inert, insoluble, or poorly soluble particles may have adverse effects and recommends that airborne concentrations should be kept below 3 mg/m^3, for PM 4, until such time as a TLV is set for a particular substance."---2008, TLVs and BEIs, ACGIH]. It is to be noted that the dust from stone crushing is not inert and is rich in mineral especially silica content.

4.3.2 Measurement of crystalline silica

Because of the reason that silica in the respirable dust fractions may be the biggest health hazard for the crushing unit workers, silica levels were ascertained in fraction of the PM 4 samples. As can be seen in the figure below, respirable silica levels exceed permissible exposure limits recommended by OSHA (occupational Safety and Health Administration, USA) and The ACGIH (American Conference of Govt. Industrial Hygienists and The Indian Factories Act.). It is to be noted that the limit values are set differently by different agencies to accommodate slightly different protocols of measurement but in general the ACGIH limit values are considered to reflect more recent scientific thinking/evidence for health impacts though the guideline may not be legally binding.

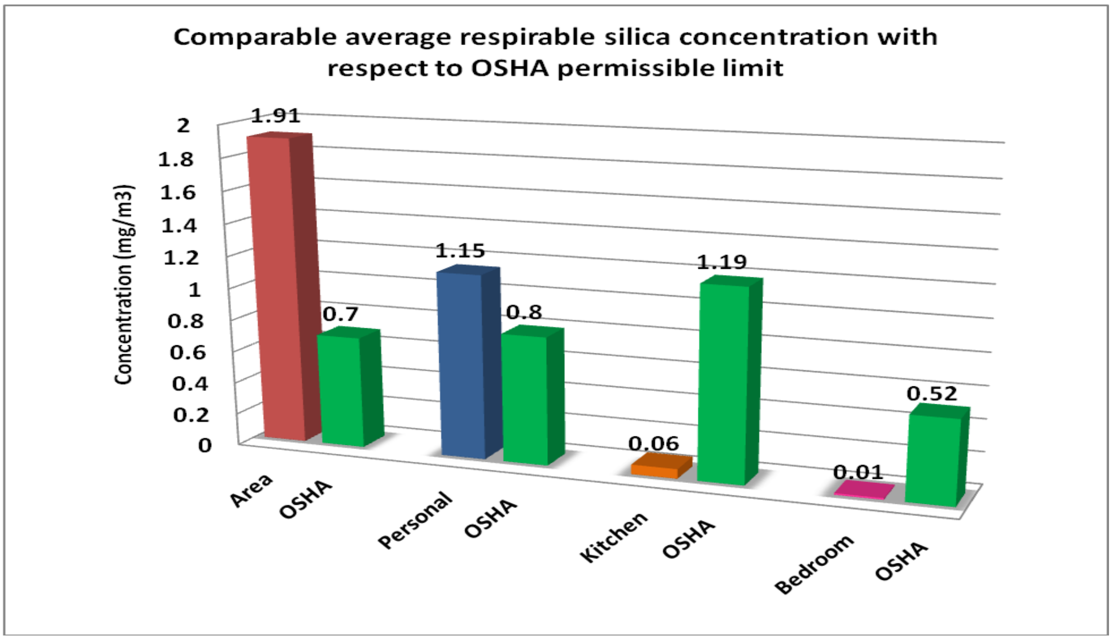


Figure 9: Respirable Silica concentrations in workplace/community locations prior to installation of dust control systems

4.3.3 Measurement of noise in the work environment

Distribution of area noise was measured in all three units prior to intervention as shown in Figures 10-12. Colours indicate range of noise levels (such as <75 dB, 75 – 80 dB, >80 – <85 dB, 85 – 90 dB and >90 dB units). The red zones indicate intensities higher than 90 dB (the permissible limit as prescribed by the Indian Factories Act.

In all three units, noise intensities of > 90 dB were observed in the vicinity of the primary crushing unit, secondary crushing units and vibrators. Occasionally high noise levels were recorded in other peripheral areas due to the noise coming from adjacent crushing units and frequent running of trucks within the units (for unloading boulders on the top of the primary crushers, loading chips from three different sized zones, collecting dust from the hopers, carrying requisite accessories for the units etc.).

Distribution of area noise level within the unit - VM (without intervention)

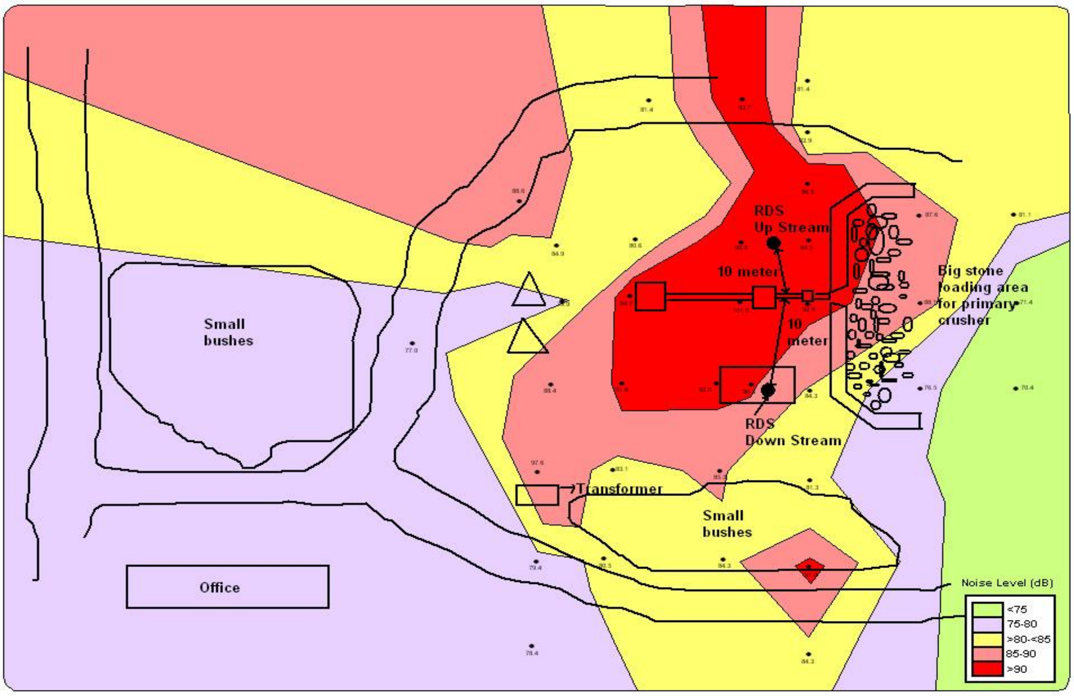


Figure 10: Noise level contours for Unit I

Distribution of area noise level within the unit - JJ (without intervention)

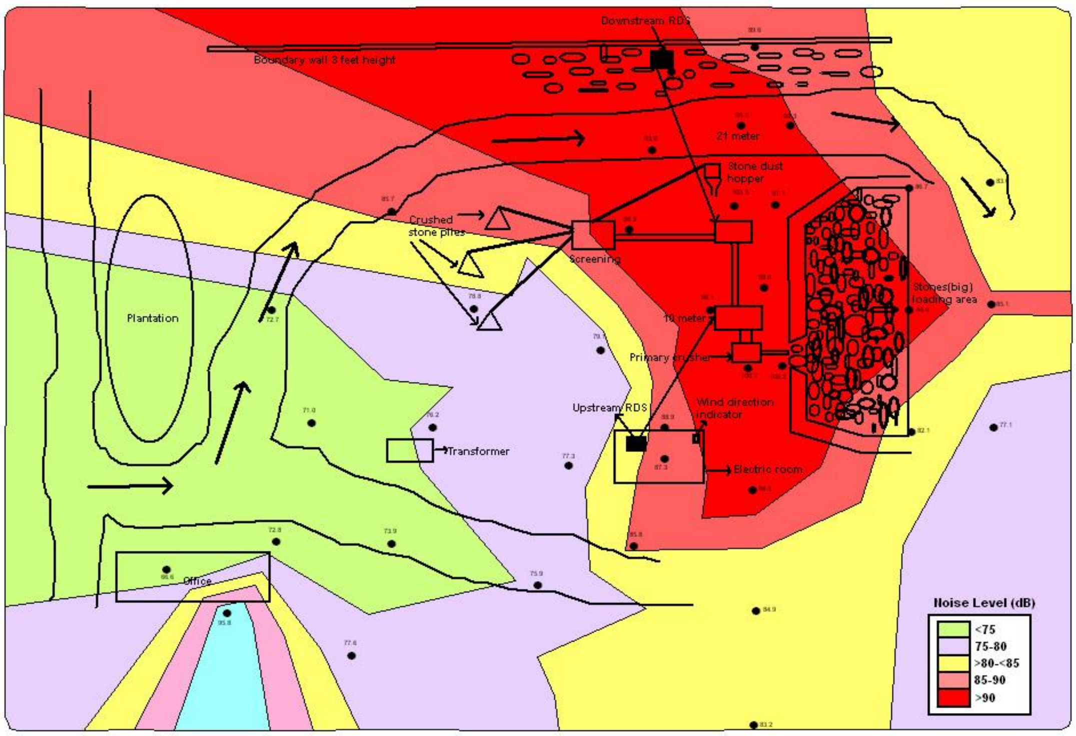


Figure 11: Noise level contours for Unit II

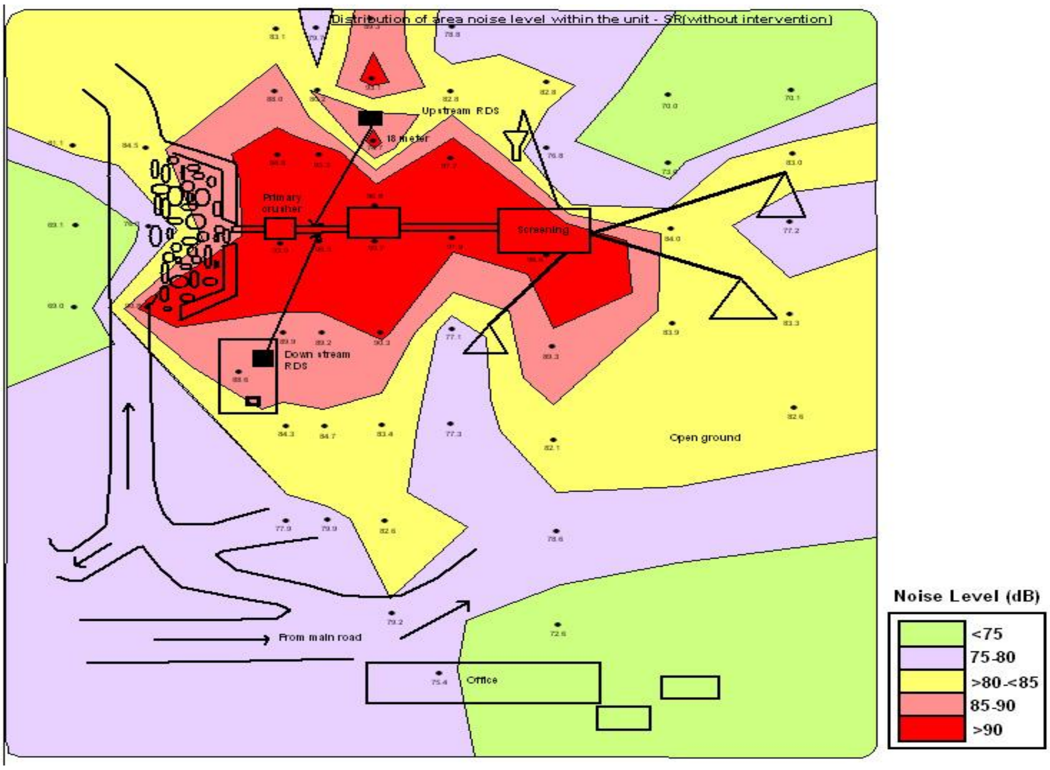


Figure 12: Noise level contours for Unit III

Twenty two workers were also monitored in the three units using personal noise dosimeters. The results of these measurements were compared to PELs (Permissible Exposure Limits) as stipulated in the Indian Factories Act and the TLVs (Threshold limit values) recommended by the ACGIH for 8 hour exposure to noise, which were 90dB(A) and 85dB(A), respectively. Except for only two values conducted for a male loader in Unit 1-JJ, all other values crossed recommended permissible limits (Table 5).

Table - 5: Personal noise exposure:

Phase	Unit 1 (VM)		Unit 2 (JJ)		Unit 3 (SR)	
	Exposure time (min)	Average LAs eq (dBA)	Exposure time (min)	Average LAs eq (dBA)	Exposure time (min)	Average LAs eq (dBA)
1st phase	166	*88.4	137	#81.3	220 231	#102.4 *99.2
2nd phase	150 305	*99.12 *93.93	139 207	#86.78 *95.64	243 148	#92.3 *104.23
3rd phase	255 171	*101.66 ^102.43	180 204 145	##88.91 **95.81 *93.23	266 268	^106.06 ^91.83
4th phase	199	#88.5	305	#83.1	230	^89.9
	33	◎90.5	18	◎92.1		

PEL (dBA):90, TLV_TWA (dBA): 85

*** Male helper, # Male loader, ** Female helper, ## Female loader, ^ Male feeder ◎ Male Supervisor**

4.3.4 Integrating noise and dust exposure assessments

A typical worker time-activity profile is shown in the picture below to recognize the potential of exposure for the same worker to multiple hazards.

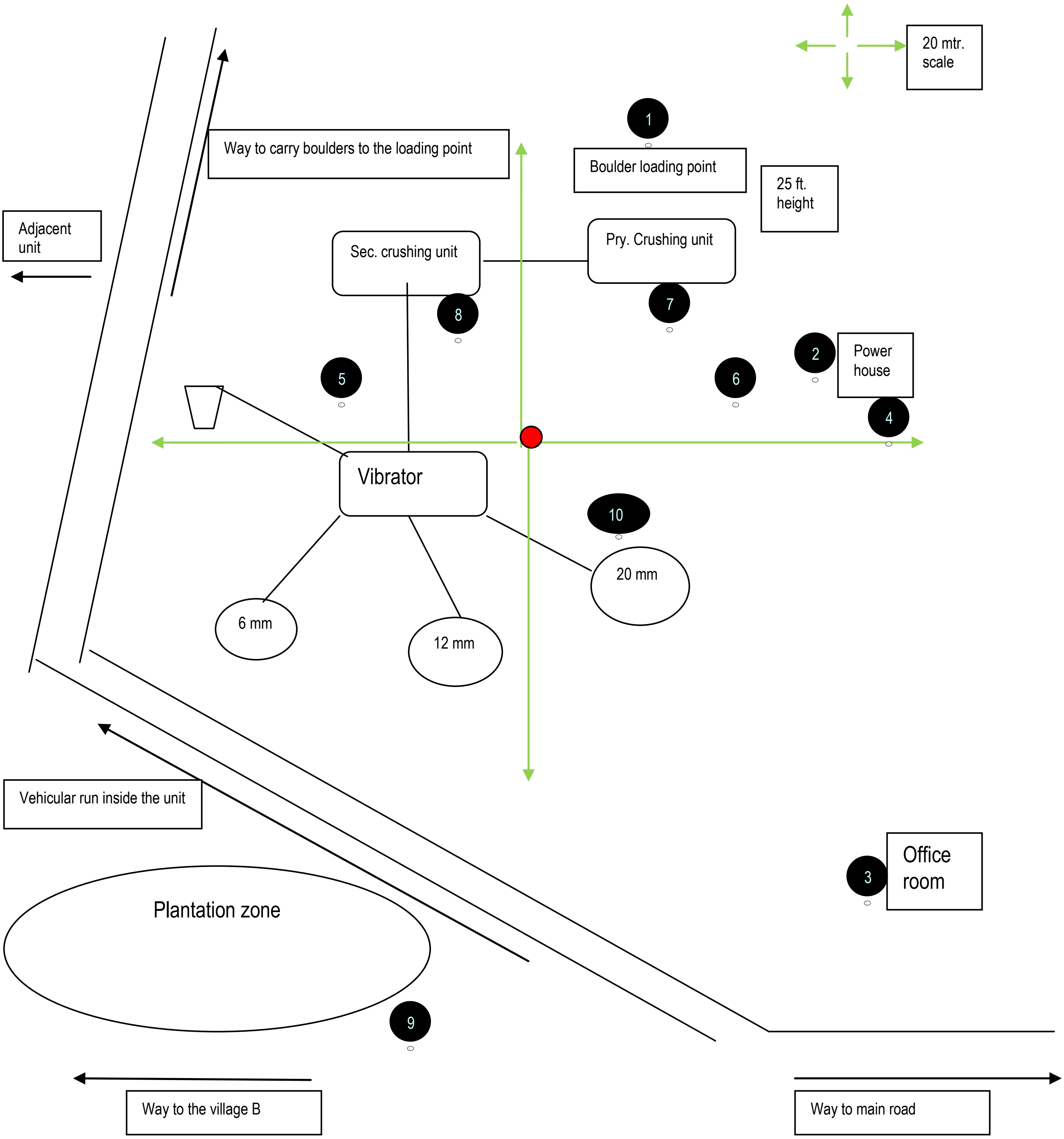


Figure 13: Typical worker (helper) time activity patterns in the crushing units

- Numbers within black circles indicate the position of the helper during 9 am to 5 pm work shift.
- Following are the circle numbers depicting the time spent by the worker during assigned activities of the day:

1. 10 min., **2**. 5 min., **3**. 10 min. **4**. 5 min., **5**. 50 min. **6**. 10 min., **7.** 130 min., **8.** 125 min. **9.** 45 min. **10.** 90 min..

Job-exposure reconstructions such as these clearly indicate that workers spend a considerable part of their work-shift within a 20 meter distance from the central point (red circle) of the unit. But considering dust emitting sources, 50 % of the black circles are located within 10 meter distance from either near primary crushing unit, secondary crushing unit, chips loading point, boulder loading point, or between vibrator and hopper. This also represents a zone where some of the safety hazards abound as well. Some categories of workers such as helpers thus are at risk of injuries and health effects from multiple hazards.

4.3.5 Assessment of safety hazards in the work environment

A comprehensive safety hazard analysis was performed in all three crushing units to inventorise hazards and possible intervention options. Since a very large number of specific safety issues were identified, they are detailed in a separate annexure. Findings and recommendations of the safety audits are also being brought out in the form of a safety guidance manual for this sector. The audit allowed recognition of all hazards and prioritization of intervention efforts in terms of feasibility, cost and effectiveness.

4.4 Assessment of baseline environmental quality and creation of the eco-info-base

4.4.1 Assessment of ambient and indoor air quality in villages S and B

Since stone crusher emissions are of importance not only for workers within units but also for community residents in adjoining areas, we monitored PM 10 levels through high volume sampling in both villages S and B and analyzed a subset of samples for silica. As shown in Figure below the levels of respirable dusts exceeded the National Ambient Air Quality Guidelines as well as the recently issued WHO guidelines. However, the levels of silica were not a major concern within the community.

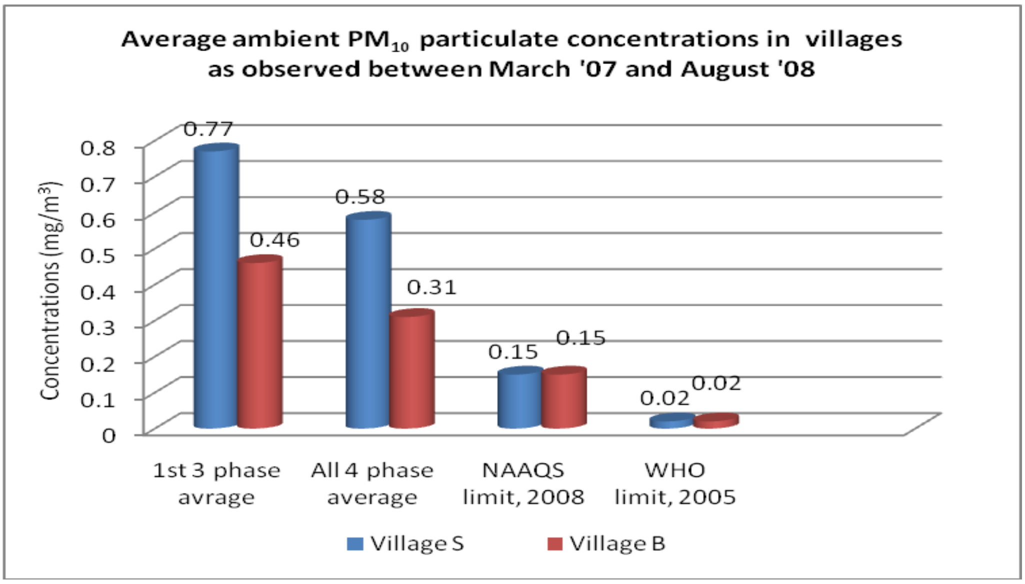


Figure 14 PM 10 levels in adjacent villages

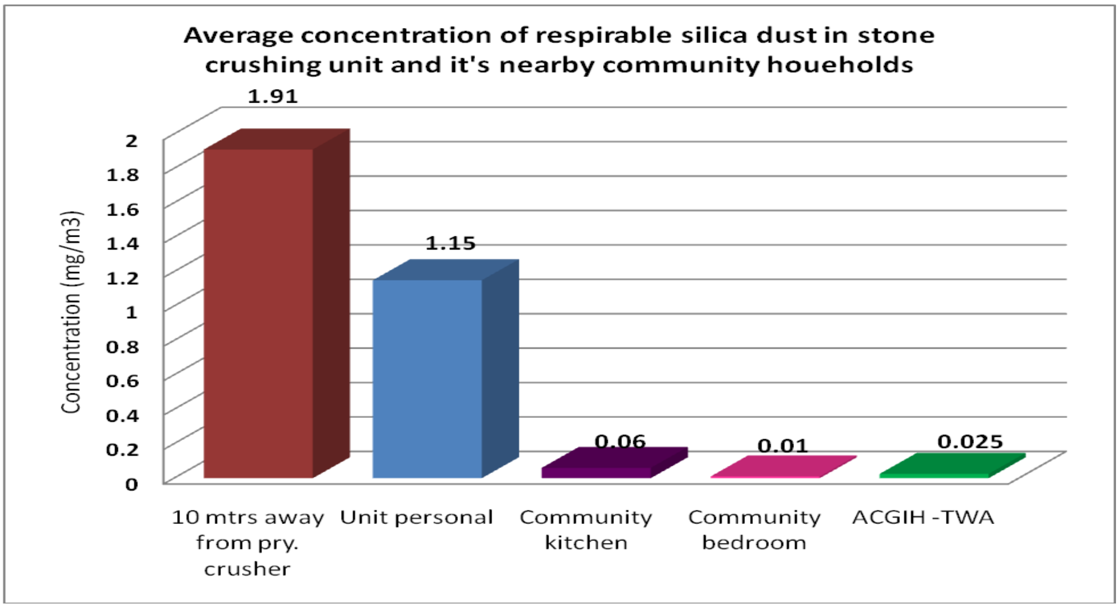


Figure 15: Respirable silica levels in environmental samples in relation to workplace levels

It is to be noted that no recommended guideline values are available for the ambient (outdoor/indoor) environment and in general ambient guidelines are substantially lower than occupational guidelines to provide an adequate margin of safety for all age groups.

Finally, since emissions from indoor use of solid fuels in this community is also likely to be a major health hazard for women, indoor levels of particulates were also monitored through area measurements within households. As has been reported elsewhere in India, the levels indoors were significantly higher than the PM 10 and PM 2.5 standards although no separate indoor standard is available. Results are shown in Figure below

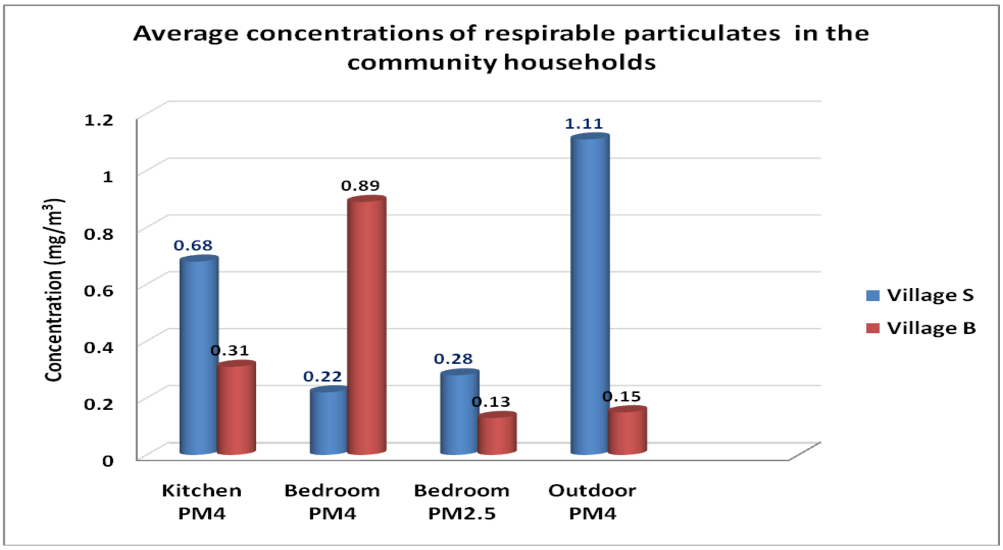


Figure 16: Respirable particulate levels in household micro-environments

4.4.2 Assessment of water quality in villages S and B

Water sampling and analysis were done in two different phases of a year. In the first phase a total of 42 water samples were analysed, which included all usable 13 water sources and 29 households samples. All 13 source samples were found contaminated with single chemical parameters or in multiple quality problems like TDS, nitrate, and fluoride. In terms of bacterial contamination, 10 out of 13 sources were found coliform positive (including one stone crushing unit premises sample). On the other hand, all 17 Household samples which were tested for bacterial contamination only, found coliform contamination positive. During second phase, a total of 33 water samples, consisting 18 source samples (including 1 stone crusher unit premises and 1 river water) and 15 samples from different households, across the village were collected and tested. Eleven water sources out of eighteen, were found contaminated with chemicals like Total Dissolve Solids, Nitrate, and Fluoride whereas, in household category twelve samples were found contaminated with coliform. Before the second phase of sampling, the study area witnessed excellent rain fall. The sampling results for physico-chemical parameters between the phases were however not significantly different to attribute any changes as being due to changes in water table. Hygiene and sanitation conditions of water sources and water storage at households were observed to be most likely reasons for bacterial contamination in the water samples. Details of water sampling results are provided in the environmental monitoring Annexure

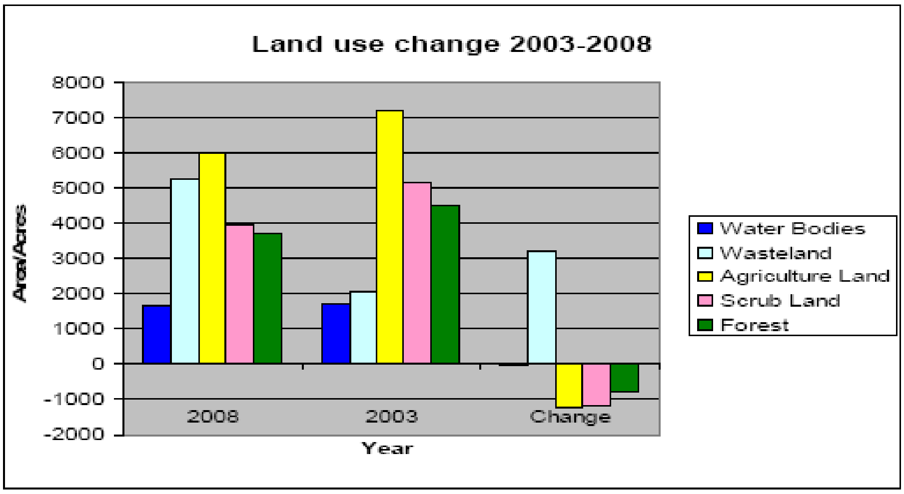
4.4.3 Assessment of soil quality in villages S and B

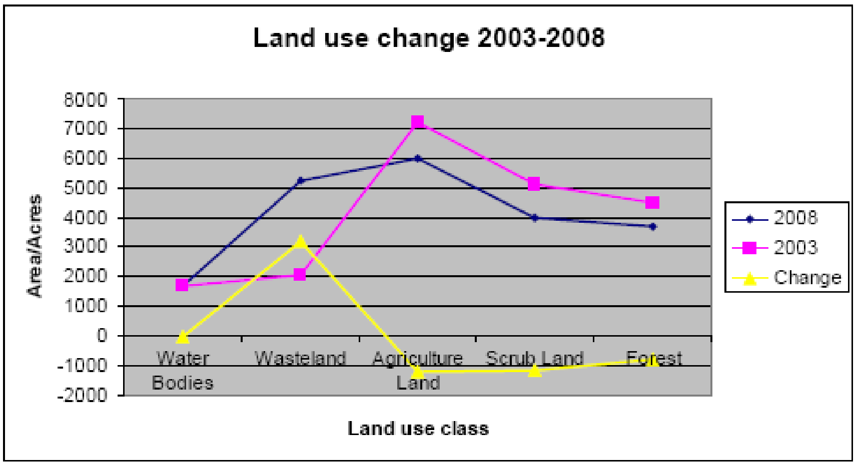
Soil sampling was done in two separate phases. In the first phase, agricultural soil samples were collected from village B whereas in second phase samples were collected from village S. Seven samples were collected for testing from both the village fields.

Soil samples were found moderately gritty and soil texture could be classified as sandy loam that would lead to excess porosity making lesser water holding capacity. Electrical conductivity indicated that soil was not saline in nature. High salinity would affect proper germination of seeds. Phosphorous content of the soils was found to be within satisfactory range but the pH values revealed that soils were near to alkalinity which may contribute to secondary micronutrient deficiency (phosphorous availability decrease between pH 7.5 to 8.5 due its precipitation). Micronutrients contents of soils were more or less shown normal values. Extractable potassium content was found within recommended ranges suggesting limited fertilizer application. Substantially low organic carbon and total nitrogen contents of all soil samples resulted low humus content. Water scarcity resulted in the land frequently being kept fallow and was accompanied by large-scale deforestation resulting in soil erosion The detailed results of all soil parameters are provided in the environmental monitoring Annexure 4.

4.4.4 Detection of land use change using the eco-info base

Figure below shows the major changes in land use over the period 2003 to 2008.





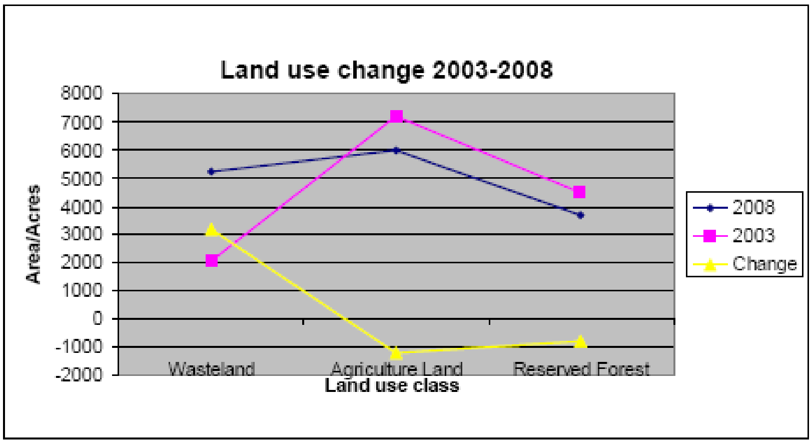


Figure 16: Results of change detection

4.5 Baseline health assessment

472 people from Village S and B participated in the health assessment exercises with equal participation by both men (N=269) and women (N=203). The distribution of ages of both men and women was normal around a mean of 30years. The health assessment was performed in three stages. First a detailed questionnaire was administered to the participants to self report parameters that are likely to have a bearing on their health. Following this a detailed physical examination was performed by a physician. Finally, select investigations (including basic biochemical parameters and spirometry) were performed on study participants. The results are summarized below

Table 6: % prevalence of select health determinants and self reported illness in the study population as determined by questionnaire administration

Occupation types		SQC	Farming	SQC + Farming	Others (incl. Homemakers	Student		
Village	Village S	22	31	10	22	13		
	Village B	35	28	10	22	5		
Gender	Male	40	23	15	2	19		
	Female	6	40	4	50	-		
Smoking	Men	37						
	Women	3						
Alcohol	19							
Self reported illness requiring significant expenditure	Stones 15	Malaria 4	Typhoid 3	Respiratory Diseases 2	Diarrhea <1	Jaundice <1		
Self-reported Symptoms	Back Pain 14	Cough with sputum 14	Urinary Infection 11	Abdominal Pain 17	Dry Cough 6	Insomnia 8	Fever 7	Miscellaneous 30
Accidents	Male 28	Female 7						
	SQC workers 37	Others 16						
History of vaccination	Yes 47	No 21	Don't know 32					
Family size	1-2 members 21	3-4members 79						
Earning members	1 56	>1 44						
Diet patterns	Vegetarian 42	Meat included 58						
Fuel use	Biomass 89	LPG 11						
Access to sanitation	No access 93	Available 7						
Mosquito Control Use	No controls 90	Some controls 10						
Annual Medical expenditure	<Rs.500 80	Rs.500-1000 14	>Rs.1000 3	Not known 3				

Table7: % prevalence of various findings assessed through clinical examination and/or investigations

BMI	18				
Anaemia	Male Mean Hb% 13.2 % Anaemia 15				Female Mean Hb% 11.5 %Anaemia 12
Hypertension	Male 7				Female 4
	Smokers		Non Smokers		
	SQC 5	Others 6	SQC 13	Others 2	
Elevated Liver Enzymes	Male				Female
	History of Alcohol use		No history of alcohol use		
	SQC 42	Others 36	SQC 43	Others 22	
Abnormal lung function as assessed by spirometry across occupations	SQC 15	Farming 17	SQC + Farming 4	Homemaker 17	Student 3
Abnormal lung function as assessed by spirometry in men across occupations	Smoker		Non-smokers		
	SQC 13	Others 14	SQC 10	Others 3	
Abnormal lung function as assessed by spirometry in men and women across occupations	SQC		Others		
	Male 11	Female 31	Male 5	Female 22	
Abnormal lung function as assessed by spirometry in women across fuel /kitchen types	Biomass 25		LPG 5		
	Separate Kitchen 25	No separate kitchen 31			

Following are some of the key findings made in the health assessments

- The questionnaire assessments indicated the relative high prevalence of a few determinants of health such as lack of sanitation, mosquito controls, smoking and non-availability of vaccinations. The self – reported symptom/illness findings were not strikingly remarkable as one may have anticipated in such a hazardous community setting
- There was a great deal of consistency between responses recorded through questionnaires and the informal responses provided during the focused group discussions except on reported alcohol use. Alcohol use was cited as being widely prevalent, while the questionnaires recorded a mere 20%, likely indicating under-reporting by the study participants
- The clinical assessments identified some important associations that may be of relevance for future health based interventions viz.
    - Both men and women were undernourished (low BMI) suggesting the nutritional supplementation. Surprisingly, the prevalence of anemia among women was similar to that of men and not significantly different from the national rural average

- Prevalence of hypertension amongst non-smoking men was significantly higher amongst SQC workers as compared to workers in other sectors. This suggests that while differences across occupations may be masked by smoking, work related habits such as prolonged standing, lifting heavy workloads and extreme physical exertion may contribute to cardio-vascular morbidity.
- Similarly, pulmonary function assessments too show that amongst non-smoking men the prevalence of respiratory impairments are significantly higher amongst SQC workers. Thus, while smoking may mask the differences across occupations, work place dust exposures are likely to contribute to severe respiratory morbidity amongst SQC workers.
- Pulmonary function assessments amongst women revealed an important association. Prevalence of respiratory impairments in women were significantly higher than in men despite the fact that a much higher proportion of men were smokers and were employed in SQCs . This indicates an important household source of air pollution namely the use of biomass fuels. The prevalence of biomass use is close to 90% in this community and women are likely to be at risk from dual hazards of indoor air pollution and occupational/outdoor air pollution in such a community setting.
- Although elevation of liver enzymes could be attributed to multiple risk factors, the community level reporting of rampant alcohol use and the relative uniform prevalence of liver enzyme elevations in groups that reported/did not report alcohol use suggests that there is considerable underreporting of alcohol use and that alcohol use may be a major risk factor for liver abnormalities in this community setting.

- The level of medical expenditure recorded through the questionnaire seems to indicate that this may be a considerable drain on family savings. Lack of access to good medical care at the public health facilities was widely cited during the participatory discussions and is likely responsible for the high levels of health expenditures.

4.6 Implementation of Interventions

4.6.1 Engineering interventions

Designing and installation of suitable engineering dust control system was one of the planned interventions in the project and also emerged as one of the recommendations of the environmental assessments. During the interaction with unit owners and the Pollution Control Board representative, four criteria were laid out for the team to develop suitable dust abatement systems viz. – the system should not interfere with the current operating processes, should be energy efficient and operate within surplus power available, should not consume water (as the region is water scarce) and preferably not exceed an investment of INR 400,000 (CAD 10000).

The team worked on two systems that were installed at two participating units. Before initiating the designing of system, the team members studied different systems under operation at other locations like Punjab, Rajasthan and Kerela. Thereafter, the system based on set conditions was designed that was then shared with the unit owners and their suggestions and inputs were integrated into the final product. Both the systems are decentralized dry systems with cyclones (suction based) as main component installed primarily to suck dust from sieves and material output chutes. Comparative tabulation of features of the two systems is furnished below.

Table 8: Comparison of performance of dust control units installed during the project

	System 1	System 2
Contribution by owner	10%	20%
Basic design element	Decentralized dry dust extraction cum suppression system having cyclone with blower (suction capacity of 7500 and 6000 cft/hr) that finally leads to chimney fitted with bag filters to combat finer particle dispersion.	Decentralized dust extraction cum suppression system with dry and wet arrangements having cyclone with blower (suction capacity of 7500 and 12000 cft/hr) that finally leads to water tank (for sedimentation of finer dust) and chimney.
Major operational difficulties	Poorly maintained unit Limited training was feasible Visible dust reduction was not accompanied by expected reductions in respirable dust	No operational difficulty being faced as the system is being run by the unit owner
Performance in terms of dust reduction	A 30% to 40% reduction in respirable dusts was achieved but limited assessment of sustained efficacy could be performed as unit was operational for few days during the time the monitoring team was available on-site	Could not be assessed

As mentioned above the performance assessment of the second installed system could not be performed therefore the final packaging of the technology – technical with financial for its promotion is yet to be completed.

Dust control system at Unit 1-VM

Figure 17: Dust Control system at Unit 1

4.6.2 Greenbelt Development

Green belt development around stone crushing units was taken up as a follow up of the recommendation of air quality monitoring. Green belt is believed to be a highly feasible technique for the stone crushing industries, not only as a precautionary method in environmental protection, but also in reducing the harmful impacts of the industry on environment and human health. To facilitate this process first, interactions were held with all the participating unit owners to explain the purpose and benefits of green belt development. The unit owners welcomed the idea and assured of extending all support and cooperation. Next, secondary information was collected on the geology of the area, climatic conditions like seasonal temperature, relative humidity and wind directions. Suitable species were identified also on the basis of soil type, required canopy, height and age of the plant. The species selected for the purpose are *Leucaena leucocephala* (locally known as Subabool); *Azadirachta indica* (locally known as Neem) and *Dalbergia sissoo* (locally known as Shisham).

Saplings of above identified plants were planted in three rows, first (Shisham), middle (Neem) and third rows (Subabool). The green belt was developed at three sides of the crushing unit to act as a wind breaker and dust absorbent. The alignment of medium height and large height tree was designed in a zigzag manner so that it helps in retarding the wind flow and dispersion of the dust. The methodology deployed for green belt development was also shared with experts from National Research Center for Agroforestry (NRCAF), Jhansi and their suggestions were incorporated. About 370 saplings were planted in two out of 3 participating units. Women Self Help Groups provided tree guards for safety of the saplings and provided some additional income streams for these women. The growth and survival rate of about 60% indicates the suitability of the species selected.

4.6.3 Community level interventions

A number of interventions were carried out at community level as described below.

4.6.3.1 Formation of community based institutions

As a part of community institution building in village B and village S, a Village Development Committee (VDC) was formed in both villages (consisting of around 11 members). The VDC functioned like a village level representative institution that liaisons with diverse development agencies, particularly the Government. The members were selected in participatory manner wherein the field staff of DA acted as meeting facilitators and all the decisions came from the community. The community understood the importance of having a mix of representatives such as from hamlets of different socio-economic status; men and women, literate and illiterates and different age groups. The committee was perceived to be able to take decisions that benefit one and all. Most notably while both villages had women members, a woman was also designated to function as the secretary of the VDC. In Village S many other need based institutions were formed as a part of the project, while in Village B the team could not procure the same level of participation and were not pursued as it became difficult to mitigate the conflict among different groups and hamlets in the village. The status of community institutions in Village S can be summarized as:

Table 9: Formation of community based institutions

<table>
<tr><th>Name of Institution</th><th>Number of Members</th><th>Purpose of their Formation</th><th>Their Contribution to the Project</th></tr>
<tr><td>Ekta Yuva Mandal (1 Youth Club)</td><td>17</td><td rowspan="2">○ Need based
○ Discipline communities by bringing spectrum of sub-groups within communities into institutional framework
○ Sustain initiated developmental processes</td><td>○ Community mobilization for health assessment
○ Contribution mobilization for installation of hand pump and other need based interventions. Eg. Mobilised Cash of INR 4020 (approx CAD 100) for handpump installation
○ Operation and management of village literacy and computer education centre (So far 31 women have turner literate and 50 youth enrolled in computer education)</td></tr>
<tr><td>Balaji and Ekta Kishori Mandal (2 Adolescent Girls Group)</td><td>Balaji: 10
Ekta : 09</td><td>○ Participate in Anganwadi activities and mobilize women and girls to access services of Anganwadi.
Motivate school dropouts (especially girls) to get enrolled into schools. Eg. Motivated 7 girls and their parents for re-enrollment</td></tr>
</table>

2 Farmers Club (Pragati and Ram Raja Kisan Club)	Pragati: 11 Ram Raja: 10		○ 7 members start vermin compost units after participating in training programme on Organic Composting ○ 20 members exposed to improved farming practices and have started practicing mixed cropping, horticulture and floriculture.
Multiple groups of girls and boys in School	Total Children Covered: 80		○ Initiated plantation in school campus and manage trees in small groups ○ Survival rate of plants estimated at 70%

4.6.3.2 Other need based interventions

Several need based interventions were carried out as a result of environmental assessments (air, water and soil); social assessments and interactions with diverse stakeholders. Some of the prominent interventions in Villages B and S are described below.

Cleaning and covering of open well in village B: This was jointly done by the community, DA and the Panchayat. The communities invested in a pump to pump out water and hired labour for cleaning and bleaching of the well. DA supported the laying of a mesh over the well with project funds.

Installation of Handpump in Village S: Village S has acute water

scarcity. The village had only one community handpump and this used result in a rush for fetching water. The women in particular were severely affected due to this problem. It was decided in consultation with Panchayat (local self government body) and the community that a water resistivity survey be carried out to identify potential water sources in the village. The survey was conducted through resources from the project that led to identification of only one potential source in the village with low discharge suitable only for hand pump installation. The panchayat agreed to dig a bore well at the identified site (a relatively high cost activity, about 428 CAD and 17000 INR). After the bore was dug at the site, water discharge tests were performed and resources were mobilized from community for installation of hand pump. The community contributed in form of Rs. 4020 (equivalent to 100 CAD), which is about 30% of the installation cost in cash. The hand pump was thus installed and village community especially the women are very happy about it. Seeking community contribution created ownership over the resource.

Sensitisation programme on sanitation in Village B: A one day sensitization programme on sanitation was organized in village B. About 40 women from the village participated in the training programme. The trainers covered issues related to water storage and handling at household level and utilization of low cost water purifiers like household filters and community filters.

Tree plantation and Rain Water Harvesting at School in Village S: Plantation of tree saplings in school premises in village S was carried out with active participation of the school children and teachers. To carry out the activity, permission of the Block Education Officer was sought. Thereafter, the students were split into different groups (that were named after leaders of the country) to dig the pits for plantation and also were entrusted the job of managing and maintaining the saplings. The sapling plantation was initiated in the form of a ceremony which was attended and presided over by the Block Education officer. The purpose of the activity was to inculcate the sense of tree plantation among students and the benefits of the same apart from making the school campus green and clean. A prize for management and maintenance of the plants was also institute. Two water filters have also been installed at the school premises so that the school children have access to clean drinking water. The same is also expected to have demonstration value to motivate other village communities to opt for these low cost household level water filters. The hand pump in school premise was defunct and the school children were facing problems in fetching water and therefore used to consume less water. Therefore a rain water harvesting structure was established in the school that finally led to availability of water in school premise. This is now the only school in the entire Orchha region with such facility in place and discussions are on with District Education Officer to replicate the same in all other schools in the district.

4.7 Capacity Building Exercises

A number of capacity building programmes were conducted during the project duration. The capacity building programmes were a mix of training programmes and exposure visits to different successful models. The capacity building initiatives are summarized below:

Table 10: A listing of capacity building exercises

Capacity Building Programmes	**Number of Programmes**	**Outputs**
Community Level Training Programmes		
Health and Sanitation	14 (eg: Health and Hygiene, De-worming, vaccination for pregnant women, family planning, eye camp, malaria prevention, safe drinking water)	○ 60 households in Village S start using **long sticked** containers to store water ○ 180 school children de-wormed ○ All the pregnant women covered (7 at the time of project) for vaccination and pre-natal check up. ○ 5 kids found to be myopic were facilitated

		with spectacles with support from local PHC
Farming (Agriculture and Livestock)	7 (Seed Production, Organic Composting, Soil Management, Livestock management, Kitchen Garden)	○ 7 vermi compost units established ○ 2 farmers start seed production in association with National Seed Corporation ○ 12 kitchen gardens established
Governance and Management	5 (Interface with Panchayat, Leadership, Book Keeping)	○ Youth club exercises Right to Information Act to ensure timely attendance of teachers in school ○ Youth club gets office space from the Panchayat ○ Gram Sabha meetings streamlined in village S with improved participation of women ○ All community institutions maintaining their books
Skill Based	3 (Food Processing, Computer Education and Community Radio Reporting)	○ Computer education centre established ○ 3 community reporters engaged with community radio station in Bundelkhand
Issue Based	3 (International Women's Day, International Population Day, World Environment Day)	==
Training of Health Care Providers		
Training of physicians	2 (Recognition and management of occupational and environmental diseases; Hands on training on spirometry and audiometry)	• A diverse group of stakeholders including practicising general and chest physicians, block health officers, dermatologists and family physicians were sensitized about environmental and occupational diseases of specific relevance for this community • Many relevant organizations / associations including Jhansi Medical College, Local Indian Medical Association Chapters were sensitized about the importance of recognition and surveillance of occupational diseases

		• A select group was also provided hands-on training on spirometry and audiometry and trained specifically on diagnosis and management of silicosis
Training of para-medical personnel	2 (General introduction to occupational and environmental diseases)	• Para-medical personnel were sensitized about recognizing and referring occupational/environmental diseases to the health care system
Exposure Visits		
Agriculture and Livestock Based	4 (to Women Managed Cowshed; IGFRI, Jhansi; DDU Research Institute Chitrakoot and TARAgram Pahuj)	
Water based	2 (Village Hastinapur and Rund Karari)	
Income Generation	1 (Women Managed Food Processing Centre)	

5. Dissemination of project outputs

The dissemination of project outputs has taken place in a variety of modalities. Some were organized at specific stages of the project while many outputs were communicated during informal and continuous exchanges with stakeholders. Listed below are some key outputs

a. Manuals for Spirometry, Audiometry & Safety available on SRU/DA website as well as free print copies
b. Video on Eco-Health Project available as a DVD
c. Stakeholder discussions with unit owners, Pollution Control Board Officials, community organizations, community residents and health care providers were used to discuss and obtain feedback on project results
d. Demonstration projects such as installation of dust control devices, greenbelt development and formation of community level partnerships served as a medium to heighten sensitivities for hazards related to this sector.
e. Research communications (currently under preparation) in peer reviewed literature will allow the dissemination of research results across multiple scientific groups

6. Project Impacts

The project yielded positive impacts for both the project investigators (and their respective organizations) as well as the study community. A stratified listing of impacts is provided below.

6.1 Impacts on Project Implementing Personnel and Organisations

- Both SRU and DA developed an in depth appreciation and built technical skills on the " Eco-Health" framework for community oriented action research projects
- By virtue of the multi-disciplinarity of the approach, the project achieved considerable inter-disciplinary skill building across institutions
- The project allowed the investigators to recognise the complexity in making "Eco-Health" projects work on a sustainable basis and make recommendations that duly address these complexities
- The project investigators have refined many field assessment methodologies based on insights gained from on-site monitoring activities. These methods have enriched the technical skills of investigators.

6.2 Impacts on Study Community

- The study communities were provided with the first ever interaction platform to discuss about their environment and it's linkages to their own health
- While many previous studies in other vulnerable sectors have been executed from the point of view of a formal scientific investigation, this project provided a unique setting wherein the assessments and recommendations stemming out of them were enormously weighted by what the "communities wanted" and not by what the "investigators wanted". Once the rationale for an assessment was provided and agreed upon by the community, the feasibility for a full fledged scientific assessment was greatly enhanced by their own co-operation. This iterative framework provided a fertile opportunity to discuss study recommendations and as a result the community is quite likely to sustain many pilot efforts that were initiated during the project.
- Women and youth in particular have been sensitized and mobilized a great deal on many aspects of simple environmental management methods that promote their health and well-being. This has provided a sense of empowerment that in turn is likely to contribute to sustainability.
- Detrimental impacts on air, water and soil quality are now better perceived and understood in greater detail by the communities as a result of participatory involvement.
- The baseline health assessment provided the villagers a sense of confidence that such assessments are useful and removed some reservations about seeking assistance for health care.

- While the institutions concerned with providing basic civic amenities, education and health care have been operational in the area, their success has been limited in the past as a result of lack of efforts to improve the community's understanding on their linkages to health. The project has facilitated substantial awareness generation so that available facilities are likely to be utilised optimally and/or additional facilities demanded to fulfill community needs.

6.3 Impacts on other stakeholders

- Amongst multiple stakeholders, impacts on stone quarry owners were one of the most significant. This was a group very resistant to any form of communication and consultative engagement for any reforms within the sector. The project managed to bring them to the discussion table. While in the initial stages, even permissions to execute short term monitoring in the workplace was not granted, eventually they consented to participate in implementation and operation of controls. Although, dust emission reduction remained their singular concern, they were sensitized about all workplace hazards. The safety manuals to be made available in local language is likely to facilitate future interventions with continued support from DA or other organizations involved with this community.
- The impact on community and the community groups (like youth groups, farmers' groups) has been significant and they have strongly contributed to the research processes. Their contribution has ranged from intellectual to physical and financial. This has been possible largely because of frequent interaction with them that would not have been possible without research institution's long term commitment for the region and the community with strong physical and infrastructural presence in the region.
- The health care providers represented another important stakeholder where lack of clinical skills and motivation had precluded them from taking a more active role in recognition and management of occupational diseases. The capacity building exercises provided by the project has catalysed this process. With some additional assistance from the health care systems, the local physicians may be co-opted to initiate surveillance on key disease conditions such as silicosis, noise induced hearing loss and work-related musculo-skeletal disorders.
- Many other stakeholders from governmental institutions Like Department of Health, Department of Agriculture, Agriculture Universities, the District Rural Development Authority etc participated in project discussions and have found the project to be an important vehicle to make progress on environmental management.

7. Recommendations and Conclusions

The project represents a maiden effort by the investigators to develop a holistic understanding of a very complex social setting where management of environmental risks involves a complex interplay of social, economic and political frameworks. Prior to this effort, limited attempts have been made to integrate perspectives of key stakeholders. Further more, efforts have not been directed at energising channels of communication between the stakeholders in such a manner that these perspectives are not held in tight "silos" but discussed and debated. Against this backdrop, no single short-term project could be expected to actually find all possible solutions for the concerned communities. The recommendations made by the project thus represent substantive improvements in understanding the feasibilities of alternative interventions and may be viewed as an evolving framework that will need to be revisited periodically even after the completion of the project.

Recommendation No 1: Improve compliance to existing air quality regulations by unit owners

Rationale provided by study: The project demonstrated partial success with dust control strategies. However, it also demonstrated that "cost feasibility" may not be compatible with "effectiveness". Air emissions from processes related to this sector are too high in volume and too hazardous in content to be controlled effectively by the current low cost engineering technologies being assessed. The project invested enormous amounts of human resources to design, install and support the operation of a relatively modestly priced device. It was clear from the quantitative environmental assessments that such devices are unlikely to work consistently to achieve health based air quality standards at neither the workplace nor the community. This limitation needs to be taken cognizance of by both unit owners and the regulatory agencies to reframe the strategy for compliance. We recommend that a major consultative exercise be undertaken to provide a design based guideline for dust control devices based on lessons learnt from this project (and integrating past national efforts) and examine alternative cost-subsidization mechanisms to bear the expense of an effective device as opposed to being restricted by current feasibility.

Recommendation No 2: Improve household sanitation and drinking water quality status

Rationale provided by study: Lack of access to sanitation and clean drinking water is not unique to this community setting and is encountered in virtually every rural habitation in India. The project provided convincing evidence that, communities around such occupational sectors do not receive any welfare benefits despite contributing to substantive profits to unit owners. Although the sector is not typically included under the "organized corporate sector" in terms of work organization, in terms of profits and revenue turnover the sector resembles many other organized sector industries. While "corporate social responsibility" is increasingly being adopted by companies and even advocated by regulators, provision of such welfare amenities may be considered for inclusion in the "consent to establish/operate" (that unit owners are required to obtain from the state pollution control board) prior to launch of quarrying activities.

Recommendation No 3: Enhance community awareness on health determinants

Rationale provided by study: The community showed keen interest in learning about their own health status. They were aware about the contributions from some determinants but largely accepted their status as an inevitable consequence of their socio-economic setting. The project allowed demonstration of some low cost interventions but sustained efforts are needed to enhance their awareness on multiple risk factors for their health and co-opt them into a process of first seeking health care and then subsequently engaging in avoiding / minimizing certain exposures. The important one is nutritional security that calls for improvements in natural resource base and revitalizing agriculture in the region. DA and SRU explore opportunities for continuing to support such awareness generation activities.

Recommendation No 4: Augment capacities of healthcare providers

Rationale provided by study: Health care access was at best poor in both villages. Even basic health services such as vaccinations and nutritional supplementation had limited penetration within the communities. Poor quality of health care services combined with poor access and poor affordability has set in a vicious cycle of ill-health and poverty. Available health care providers need to be further sensitized in order to change the prevailing situation. Most importantly, health surveillance in the community is likely to provide the most convincing evidence of continuing health impacts in this sector which in turn could be used to further mobilize future intervention efforts. While some sensitization was accomplished during the training exercises, we anticipate that through continued interactions with the local health systems, the project results will allow DA and SRU to persuade follow up efforts to initiate and maintain surveillance for key occupational diseases at the very least.

Recommendation No 5: Empower youth and community action groups to understand and implement their rights and responsibilities

Rationale provided by the study: While all the four preceding recommendations have been focused on a "top down approach" wherein a service provider/external stakeholder has to initiate improvements for the community, the project provided substantive evidence that empowering the youth and community action groups may be the most effective way for lowering "acceptable risks" within this setting. Both these groups were receptive to being trained, enjoyed the support of the communities and represent a vibrant but yet "untapped resource" for community level improvements. DA's continued presence in Taragram is likely to be the best vehicle to take periodic improvement programs and find means of making these services financially viable as well.

In conclusion, although as scientists, the investigators have put forth this set of recommendations, the sobering reality is that, unless the current system is thoroughly revamped, tangible improvements in the health of the community could hardly be expected. The most vulnerable within this setting are too poor and/or uneducated to engage in any sustained behavioral change to reduce exposures. The existing workplace environmental conditions may be even described as "unfit for human entry". From basic safety to toxic exposures, hazards abound in every step of the process. No amount of scientific investigation can adequately capture the complicated matrix of social, economic, administrative factors that result in such an exposure situation and adjudge consequent health and environmental impacts. Investigators would therefore like to request that the estimates of morbidity and the limited assessment of environmental quality be interpreted with "tempered scientific humility" duly recognizing the uncertainties in proposing the recommendations.

While it is unlikely that health risks alone would determine the future course of how this sector is managed, an in depth understanding of the potential for health risks is crucial for ensuring that the most vulnerable poor communities amongst us are not required to endure years of suffering, before development can "catch up" with them. Indeed if human development is the goal, addressing health risks are an important mechanism of ensuring equity in quality of life amongst populations and it is hoped that the information presented here represents a small incremental step towards achieving the same.

List of Annexures

1. Additional results from individual project components
2. Methods/Data forms/questionnaires used in the study
3. Project management (including listing of team meetings)