



Impact of E-Waste Recycling on Water and Soil

Toxics Link
for a toxics-free world

About Toxics Link

Toxics Link is an Indian environmental research and advocacy organization set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together groups and people affected by this problem. Toxics Link's mission statement is 'Working together for environmental justice and freedom from toxics. We have taken upon ourselves to collect and share both information about the sources and the dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world.'

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A Report on

Impact of E-Waste Recycling on Water and Soil

By
Toxics Link

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Acknowledgements

We take this opportunity to thank all those who were instrumental in compiling and shaping this report.

Our sincere thanks to SPECTRO Analytical Labs Ltd., Okhla, for its support in sample collection and analysis. We are grateful to the people from Loni and Mandoli areas for their cooperation in helping us obtain samples and sharing site information with us.

We also acknowledge the support provided by Mr. Ronak Chowdhry and Ms. Sadhna Shukla, interns from Delhi School of Social Work, for their contribution in profiling and mapping the two sampling sites of Mandoli and Loni.

We express our sincere thanks to Swedish Society for Nature Conservation (SSNC) for their support towards this study.

We would also like to thank our other colleagues at Toxics Link who were equally helpful. Their comments and suggestions have been critical in understanding the issue.

Abbreviations

E-waste	Electronic Waste
μS/cm	Microsiemens Per Centimetre
Cd	Cadmium
CFL	Compact Fluorescent Light
COD	Chemical Oxygen Demand
Cr VI	Hexavalent Chromium
DNA	Deoxyribonucleic Acid
EC	Electrical Conductivity
ETC/RWM	European Topic Centre on Resource and Waste Management
Hg	Mercury
LPG	Liquid Petroleum Gas
mg/l	Milligrams Per Litre
Ni	Nickel
NTU	Nephelometric Turbidity Unit
Pb	Lead
PBB	Polybrominated Biphenyl
PBDE	Polybrominated Diphenyl Ethers
PCB	Printed Circuit Board
TDS	Total Dissolved Solids
UNEP	United Nations Environmental Programme
WEEE	Waste Electrical and Electronic Equipment
Zn	Zinc

... soil samples taken from

Loni & Mandoli

suggest that the soil characteristics have changed significantly

Executive Summary

Context of the study: Electronic waste is one of the fastest-growing waste streams globally and as per the United Nations Environment Programme (UNEP) estimates; total e-waste generation is expected to cross 50 million tonnes annually. This rapid growth is fuelled by planned product obsolescence, lowering prices and changing lifestyles. India too has been impacted by the digital revolution, with consumption of electronics growing at a rapid pace. Concurrently, waste generation is almost staggering at 15 per cent. Currently India generates approximately 800,000 tonnes of waste annually.

While such waste has been a source of livelihood for the urban and rural poor, it is often one of the major contributing factors for severe risks to human health and the environment. Most workers engaged in the waste sector are not even aware of the risks involved. The practices adopted in recycling waste and recovering materials are rudimentary, involving acid bath heating, open burning and indiscriminate use of chemicals without following any safety norms. These are often conducted in the bylanes of the city, making them dangerous and hazardous for the environment and human health.

There have been various reports documenting practices of recycling e-waste in the country and drawing an inference of the environmental impacts of such practices. However, there is negligible data to substantiate this correlation. This study attempts to understand the impacts of recycling practices on soil and water mediums of the neighbourhood areas and establish correlation between such practices and the resultant impacts thereof. The mediums of soil, water and air receive waste contaminants and are expected to reflect changes in their characteristics. Due to certain practical constraints, it was not possible to collect air samples. Hence only the medium of water and soil have been considered for testing in this study. The aim of this study is twofold:

- Document the recycling practices of e-waste and its consequential impacts on mediums of water and soil.
- Provide a quantitative assessment of selected pollutants and chemicals in water and soil at two prominent e-waste recycling sites, Mandoli and Loni, in and around Delhi.

Based on previous experience and knowledge of recycling practices in Delhi, two informal recycling areas around Delhi—Loni and Mandoli—were selected for this study. Both these sites have multiple recycling units, which engage in hazardous processes for recovery of materials from e-waste.

Loni is an industrial area to the west of Ghaziabad city on the borders of Ghaziabad district, in the state of Uttar Pradesh and the city of Delhi. The industrial area consists of around 40 operational units, which have been engaged in backyard recycling practices over a significant period of time. The methodology, tools and techniques used for recycling e-waste in these units are basic, such as heating by blow torch or stove, breaking with hammer, chemical stripping, melting and open burning, without any concern for the environment. Recycling waste circuit boards of compact fluorescent lamps (CFLs) to extract lead, aluminium and iron is the primary activity undertaken in the area. After dismantling and desoldering the circuit boards, the waste is collected in heaps and set on fire in open fields to extract copper, leaving behind large quantities of ash in these fields.

Mandoli is another area around Delhi, which was identified as one of the sites for testing water and soil samples. The area lies under Krishna Vihar Phase III, Ghaziabad, Uttar Pradesh. This area on the border of Delhi and Uttar Pradesh is home to a number of small and medium enterprises and is called 'Gaddha colony'. The Gaddha colony cluster consists of around 80 operational units, most of which are engaged in waste recycling activities. These units run in temporary, semi-constructed buildings with just four walls and a door, without any kind of roofing. E-waste recycling or processing of printed circuit boards (PCBs) is the most common activity in this area. These units use concentrated sulphuric and nitric acid for processing the circuit boards to recover copper. The spent acid is then discharged into open lands. Burning of PCBs is also common practice to recover copper and the residual ash is dispersed into open lands. Both the areas of Mandoli and Loni support these kinds of activities, which make them ideal locations for such a study and most suitable sites for picking up water and soil samples for testing heavy metals and other attributes of contamination.

Sampling

Samples of water and soil were obtained from both sites of Loni and Mandoli. The systematic random sampling method was followed for identification of locations, and 9 samples of water and 12 samples of soil were collected from Loni, and 6 samples of water and 10 samples of soil were collected from the Mandoli site. At both sites, one controlled area was also identified, which was at a reasonable distance from the recycling areas and which did not support any such recycling activity. At Mandoli, three effluent samples from recycling sites were also collected, two of these samples were from current recycling sites in operation and one sample from a non-operating site.

For water samples, the standard procedure of collecting the sample in clean 2-litre containers, after rinsing it with the sample water, was used. Most of the drinking water samples were taken from the working hand pumps which residents/workers of the area were using for their daily needs. The depth of these hand pump bores were between 60 and 120 feet.

For collecting soil samples, a tulip bulb planter was used on soft soil. The planter can take soil samples from 0 to 10 inches depth and is easy to use and decontaminate; it has a uniform diameter and sample volume; it preserves the soil core.

These samples were then sent to SPECTRO Labs (an accredited laboratory) in Delhi to test for heavy metals and other physicochemical attributes.

Results

Loni Water Quality The physicochemical characteristics of the samples collected at Loni were as follows.

The physicochemical characteristics of the samples collected at Loni were found to be at variance with Indian standards IS: 10500.

- The pH levels varied from 6.9 to 7.6 and were found within the desirable limit as per Indian standards (6.5 to 8.5).
- Electrical conductivity of the water samples varied from 302 to 1,360 µS/cm. Normally an electrical conductivity of 0–800 µS/cm in water is considered as safe for drinking purposes (provided there is no organic pollution and not too much suspended clay material). Out of all samples, one sample (sample no. 1)

was higher and all other samples were below 800 µS/cm. The average electrical conductivity was 497.8 µS/cm.

- The observed total hardness of the water samples varied from 184 to 325 mg/l. The average total hardness concentration was observed to be 238.8 mg/l. Out of all samples, one sample (sample no. 1) was higher and all other samples were below the desirable limit of Indian standards (300 mg/l).
- The observed turbidity level varied from <1.0 to 9.5 mg/l. The average concentration of turbidity was observed to be 2.53 mg/l. All locations were within the desirable limit of Indian standards (10 NTU) for turbidity.
- The observed levels of lead, cadmium, nickel and chromium (VI) were found within detectable limits.
- The mercury level observed in sample no. 6 (0.02 mg/l) was almost 20 times higher than the desirable limit of Indian standards (0.001 ppm). The other eight samples were below the detectable level.
- Zinc was observed in collected samples and varied from 0.05 to 0.32 mg/l. All locations were within the desirable limit of Indian standards (5 mg/l) for zinc.
- From the results obtained, it can be concluded that water quality in the Loni area has not been significantly impacted as only one sample reflects higher levels of mercury.

Loni Soil Quality In the Loni study area, sample no. 3 was considered as a control sample in the study as there are no heavy metal standards for soil in India. This sample no. 3 was located in the south-west side and was 460 metres away from the centre point. All analysed samples were found with very high levels of heavy metals as compared to the control sample.

- The lead levels varied from 95.74 to 4778 ppm; 100 per cent of the soil sample was found with very high lead levels as compared to the control sample (35.52 ppm). The highest lead level was almost 147 times higher than the control sample.
- The cadmium levels varied from <0.1 to 5.4 ppm; 27 per cent of soil samples, that is, three samples (sample nos 5, 9 and 11) were found with high cadmium levels. All other samples including the control sample were below the detectable limit (<0.1 ppm).
- The nickel levels varied from 13.38 to 57.62 ppm; around 82 per cent of the samples recorded high values as compared to the control sample (18.65 ppm). Two samples (sample nos 7 and 10) were found with nickel levels less than what

the control sample recorded. The highest nickel level was almost 6 times higher than the control sample.

- Mercury levels varied from 0.01 to 2.69 ppm. Around 73 per cent soil samples were found with high mercury levels as compared to the control sample (0.39 ppm). Three samples (sample nos 1, 6 and 7) were found to be low as compared to the control sample. The highest mercury level was almost 7 times higher than the control sample.
- The hexavalent chromium levels varied from 3.7 to 15.45 ppm. Around 36 per cent soil samples were found with high levels of hexavalent chromium as compared to the control sample (5.32 ppm). Six soil samples (sample nos 1, 2, 5, 6, 7 and 12) were found with levels less than the control sample. The highest hexavalent chromium level was almost 3 times higher than the control sample.
- The zinc levels varied from 95.6 to 688.36 ppm. Around 27 per cent soil samples were found with very high zinc levels as compared to the control sample (118.27 ppm). Eight soil samples (sample nos 1, 2, 4, 6, 7, 8, 10 and 12) were found with zinc levels less than the control sample. The highest zinc level was almost 6 times higher than the control sample.
- Polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) was not detected in any sample.

The results obtained from soil samples suggest that the soil characteristics have changed significantly and the sample on the south-east side is reflecting higher levels of heavy metal content. The land gradient is sloping in the south-east direction and the results suggest that there is a higher concentration of pollutants in this direction and a relationship between activities and its impact on soil.

Mandoli Effluent Water Quality The physicochemical characteristics of the effluent water samples collected at Mandoli were compared with General Standards for Discharge of Environmental Pollutants of Indian standards IS: 10500.

- The pH levels varied from 1.19 to 8.24. The pH level of samples 1 and 2 were acidic (1.19, 4.23) in nature, while sample 3 was found within the prescribed safe limits, that is, 5.5–9.0, which is recommended as the general standard for discharge of environmental pollutanats for inland surface waters.
- Chemical oxygen demand (COD) levels of the effluent water samples varied from 3,657.6 to 29,195.2 mg/l; 100 per cent of the samples were observed with higher levels of COD. The highest level of COD was ~117 times higher as com-

pared with the recommended level of general standard for discharge of environmental pollutanats for inland surface waters.

- The lead levels were observed only in sample no. 1 (1.66 mg/l); it was ~17 times higher than the recommended level of general standard for discharge of environmental pollutanats for inland surface waters (0.1 mg/l). The other two samples were found below the detectable level.
- The nickel levels, observed only in sample no. 1 (1.36 mg/l), were found below the limit of general standard for discharge of environmental pollutanats for inland surface waters (3.0 mg/l). The other two samples were found below the detectable level.
- Cadmium chromium (VI) and mercury levels were found below the detectable levels in all the collected samples.
- Zinc levels were observed in all three samples and varied from 0.59 to 870 mg/l. The highest zinc level was ~174 times higher than the general standard for discharge of environmental pollutanats for inland surface waters (5.0 mg/l). The levels of zinc were ~174 and ~64 times higher in samples 1 and 2 respectively and in sample no. 3 (0.59 mg/l) it was lower as compared to the general standard for discharge of environmental pollutanats for inland surface waters (5.0 mg/l).

From the results obtained, it can be concluded that the the effluents being discharged from these units is high on heavy metals and other chemicals, much beyond the permissible limits as prescribed by the Indian standards (IS: 10500). It is also important to observe that there is a difference in the levels of heavy metals between the functional and non-functionl units, suggesting that the recycling activites are the source for such chemical and heavy metal contamination.

Mandoli Water Quality The physicochemical characteristics of the samples collected at Mandoli were found to be at variance with Indian standards IS: 10500.

- The pH levels varied from 7.46 to 8.16 and were found within the desirable limit as per Indian standards (6.5 to 8.5).
- Electrical conductivity of the water samples varied from 637 to 4,580 µS/cm. Normally an electrical conductivity of 0–800 µS/cm in water is considered safe for drinking purposes (provided there is no organic pollution and not too much suspended clay material). But in the Mandoli study area, 50 per cent of the samples, that is, sample nos 2, 3 and 6 were found with electrical conductivity above 800 µS/cm, while the rest of the samples were below 800 µS/cm. The highest electrical conductivity was almost 5 times higher than the normal level

and that was recorded in sample no. 6. The average electrical conductivity was 1,419.5 μS/cm.

- The observed total hardness of water samples varied from 152 to 568 mg/l. The average total hardness level was observed to be 286.7 mg/l. Out of all the samples, 33 per cent, that is, sample nos 2 and 3 were observed with total hardness levels above the desirable limit of Indian standards (300 mg/l).
- The observed turbidity levels varied from 2.5 to 12.9 mg/l. The average turbidity level was 6.18 mg/l. Out of all samples, 33 per cent, that is, sample nos 1 and 3 reported results above the desirable limit of Indian standards (10 NTU).
- The observed COD levels varied from 3.74 mg/l to 26.2 mg/l. The COD level for drinking water has not been mentioned in the Indian standards.
- The lead level observed in sample no. 1 (0.52 mg/l) was almost 11 times higher than desirable limit of Indian standards (0.05 ppm). The other five samples were found below the detectable level.
- The mercury level observed in sample no. 3 (0.71 mg/l) was almost 710 times higher than desirable limit of Indian standards (0.001 ppm). The other five samples were found below the detectable level.
- The nickel level observed in sample no. 1 (0.16 mg/l) was found below the desirable limit of Indian standards (3.0 ppm). The other five samples were found below the detectable limit (<0.01 mg/l).
- Cadmium and chromium (VI) were found below the detectable levels in all collected samples.
- Zinc was observed in collected samples and varied from 0.17 to 10 mg/l; 33 per cent, that is, two samples showed zinc levels above the desirable limit of Indian standards (5 mg/l).

From the results obtained it can be concluded that the water quality is undergoing change and there is presence of heavy metals in some samples.

Mandoli Soil Quality In India there are no heavy metal standards for soil, hence the collected soil sample were analysed and compared with the control samples, while some inference can be drawn from the standards of some other countries such as the USA, Canada and the UK.

In the Mandoli area, sample no. 10 was considered as a control sample in the study; it was located at the north-east side and was 700 metres away from the centre point. All the analysed samples were compared with sample no. 10 and were found with very high levels of heavy metals.

- The lead levels varied from 35.17 to 3,836 ppm. All the samples (~89 per cent), except sample 6, presented much higher values as compared to the control sample (37.31 ppm). The highest lead level was almost 102 times higher than the control sample.
- The cadmium levels varied from 1.24 to 22.76 ppm; 100 per cent of the samples were found with very high levels as the control sample was found below the detectable level (<1.0 ppm). Nickel levels varied from 13.47 to 112.47 ppm. All the samples (~89 per cent) except sample no. 8 presented higher values as compared with the control sample (18.65 ppm). The highest nickel level was almost 6 times higher than the control sample.
- The mercury levels varied from <1.0 to 8.71 ppm; 78 per cent samples were found to have high mercury levels. The other three samples, as well as the control sample, have shown mercury levels below the detectable limit.
- The hexavalent chromium levels varied from 1.02 to 140.95 ppm. Only one sample (sample 3) observed a high level, that is, 140.95 ppm, which was 6 times higher as compared to the control sample (24.15 ppm). The other eight samples were found with low levels of hexavalent chromium.
- The zinc levels in all samples varied from 1,148.04 to 6,258.72 ppm; 100 per cent of the samples were found with very high zinc levels as compared with the control sample (1,119.45 ppm). The highest zinc level was almost 6 times higher than the control sample.
- Polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) levels were not detected in any sample.

The results obtained from soil samples suggest that the soil characteristics have changed. All metals or chemicals that have a significant presence in the raw materials are also reporting high in test results of soil samples, thus suggesting that the change in soil characteristics is on account of recycling practices in operation in the locality.

Conclusion

E-waste is globally associated with environmental contamination and serious health issues due to its chemical constituents. In India, large volumes of such waste is handled in the informal sector and recycled without any environmental safeguards.

However, there is a paucity of data and evidence to correlate the activities of this sector and its impacts on the mediums of water and soil. This study has attempted to establish a relationship between the activities and impacts. The final findings of the study suggest the following:

1. The areas of Loni and Mandoli, both on the outskirts of Delhi, support extensive e-waste recycling.
2. Both sites discharge their effluents into open lands in the absence of drains.
3. They also dispose of their solid waste in open lands, while most residual matter is disposed by open burning.
4. The effluents discharged at Mandoli are acidic, with very low pH values and high levels of heavy metals. The levels of heavy metals and other physical parameters are much beyond the accepted limits for effluents as provided by Indian standards.
5. These effluents, heavy in pollutants, are being directly discharged into soil thus impacting the soil.
6. The water quality at Loni is better as compared to Mandoli. There is a wide variation in the levels of zinc and nickel, though within the standards for drinking water, suggesting change in water quality at various locations. High mercury levels in one of the samples are a reason for concern. This result throws up serious questions on the use of this water for drinking purposes and the need for further intensive studies.
7. Soil results at both sites confirm changes in soil parameters as compared to the respective control samples and also if compared to standards from other countries. The levels of heavy metals in soil are much higher in the Mandoli area as compared to Loni. Some of the metals found in the soil are the input materials or residues discharged into soil. There is clear evidence of changes in soil characteristics at both recycling sites and this directly relates to the activities and input materials of the waste recycling sector.

The report clearly indicates changes in soil quality in the recycling areas and this change is attributable to the recycling activities being conducted in these areas. The water quality at both sites also demonstrates some impacts of pollution but this requires further investigation. The study could not assess health impacts on the population engaged in recycling activities or living in the neighbourhood, but this is another impact that needs to be investigated.

... the Central Pollution Control Board (CPCB)

in 2004

estimated India's e-waste generation at 1.47 lakh tonnes or 0.573 MT per day

1

Introduction

Electronic waste is the fastest-growing waste stream comprising computers, mobile phones, televisions, consumer durables and other electrical and electronic products. The UNEP estimates suggest that globally 50 million tonnes of e-waste is generated annually.[1] Planned product obsolescence, globalization, lowering of production costs and changing lifestyle have been responsible for an increased consumption of electrical and electronic products and consequently an exponential high rate of waste generation. It is not only the volume of waste but also its nature that is extremely complex on account of a multitude of materials which are present in these products. Precious and rare metals as well as a bouquet of heavy metals and complex chemical compounds pose serious challenges in managing such large volumes of this complex waste. Processing such waste and recovery of materials by recycling it without any adverse impacts on the environment can pose serious challenges.

India generates significantly large volumes of e-waste; the Central Pollution Control Board (CPCB) in 2004 estimated India's e-waste generation at 1.47 lakh tonnes or 0.573 MT per day.[2] A study released by the Electronics Industry Association of India (ELCINA) at the electronics industry expo 'Componex Nepcon 2009' estimated the total e-waste generation in India at a whopping 4.34 lakh tonnes by end 2009.[3,4] While domestic generation of e-waste comprises a major portion of the total waste generation, a significant volume of waste is also received from some developed countries. For emerging economies, these material flows from waste imports not only offer a business opportunity, but also satisfy the demand for cheap second-hand electrical and electronic equipments. In addition, the lack of national regulation and/or lax enforcement of existing laws are promoting the growth of a semi-formal or informal economy in India. An entirely new economic sector has been evolving around

1 http://www.un.org/esa/dsd/resources/res_pdfs/publications/trends/trends_Chemicals_mining_transport_waste/ch4_waste_management.pdf
2 Lok Sabha Unstarred Question no. 650, dt. 28.07.2010.
3 Sandeep Joshi, 'Growing E-waste Is Causing Concern', The Hindu, 28 February 2009.
4 http://rajyasabha.nic.in/rsnew/publication_electronic/E-Waste_in_india.pdf

trading, repairing and recovering materials from redundant electronic devices. While this sector is a source of livelihood for the urban and rural poor, it is often one of the major contributing factors for severe risks to human health and the local environment. What makes it worse is that most participants in this sector are not even aware of the risks. The practices in recycling waste and recovering materials are rudimentary and lack the use of appropriate technology, making them dangerous and hazardous.

1.1 Rationale for the Study

The informal sector engaged in handling e-waste operates as a well-oiled machine, with an extensive reach for such waste. It handles almost 90 per cent of the total waste generated in the country, recovering materials and refurbishing products. There are pockets in some of the cities which have been documented for recycling of e-waste, with clusters specializing in particular processes such as dismantling of computers or mobile phones, segregation of parts, refurbishments of old products and recovery of metals. There is a well-established hierarchy of material flows and networks between diverse actors for smooth functioning of all players engaged in such activities.

The recyclers, however, continue to use rudimentary processes and practices such as open burning, acid baths and heating of circuit boards, resulting in emissions and release of toxic elements into the environment. These clusters have been operational for many years and have been handling extensively large volumes of e-waste without any pollution-control devices or measures to capture the pollutants being released into land and water sources in and around the area. The spent acid with residual metals is discharged into open land and finally absorbed by soil and surface water.

Currently there is very little or negligible data generated from such recycling sites in India to understand the relationship between such activities and its impacts on the environment and human health. This study is an effort to develop a correlation between such recycling activities undertaken by the informal sector and its impact on its surroundings and environmental mediums such as soil and water. While sincere efforts were made to study the impact in the medium of air too, this could not be undertaken due to the challenges inherent in such a study where the recycling community perceives such studies as a threat to their livelihoods.

The findings of the study could be indicative due to the limited sample size, but they can open up many opportunities for further research and data that can be useful in the decision-making process for safeguarding the environment and human health.

1.2 Material Composition of WEEE

When e-waste is disposed of or recycled without any controls, there are certain predictable negative impacts on the environment and human health. E-waste contains more than 1,000 different substances, many of which are toxic, such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium and flame retardants. About 70 per cent of the heavy metals (mercury and cadmium) in US landfills come from electronic waste and consumer electronics make up 40 per cent of the lead in landfills.[5] These toxins are known to cause brain damage, allergic reactions and cancer.

E-waste contains considerable quantities of valuable and precious metals. Recycling e-waste has the potential to be an attractive business, and companies such as Boliden (Sweden), WEEE AS (Norway) and Citiraya (UK) are investing in the area.

Given the diverse range of materials found in waste electrical and electronic equipment (WEEE), it is difficult to give a generalised material composition for the entire waste stream. However, most studies examine five categories of material: ferrous metals, non-ferrous metals, glass, plastics and others.

According to the European Topic Centre on Resource and Waste Management (ETC/RWM),[6] iron and steel are the most common materials found in electrical and electronic equipment and account for almost half of the total weight of WEEE. Plastics are the second largest component by weight, representing approximately 21 per cent of WEEE. Non-ferrous metals, including precious metals, represent approximately 13 per cent of the total weight of WEEE, with copper accounting for 7 per cent. It is interesting to see that, over time, the metal content has remained the dominant component, well over 50 per cent, as compared to pollutants and hazardous components, which have seen a steady decline.

1.3 Objectives of the Study

The study has the following aims:

- Generating data on the environmental impacts of the informal sector engaged in recycling e-waste in India

5 J. Puckett and T. Smith, 'Exporting Harm: The High-Tech Trashing of Asia', The Basel Action Network, Seattle 7 Silicon Valley Toxics Coalition, 2002.

6 ETC/RWM is part of the European Environment Information and Observation Network (EIONET), 2003, http://waste.eionet.eu.int/waste/6

- Documenting the recycling practices of e-waste and its consequential impacts on medium of water and soil
- Quantitative assessment of selected pollutants and chemicals in water and soil at two prominent e-waste recycling sites, Loni and Mandoli, in and around Delhi

1.4 Heavy Metals in the Environment and Their Health Effects

Heavy metals have a density of 6.0 g/cm^3 or more (much higher than the average particle density of soils which is 2.65 g/cm^3) and occur naturally in rocks. But their concentrations are frequently elevated as a result of contamination. Among the most common heavy metals which are potentially hazardous and are known to contaminate soils are cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), zinc (Zn) and nickel (Ni).[7] The sources of heavy-metal pollutants are metal mining, metal smelting, metallurgical industries and other metal-using industries, as well as waste disposal, corrosions of metals in use, agriculture and forestry, fossil fuel combustion and leisure activities. Hot spots of heavy-metal pollution are located close to industrial sites, around large cities and in the vicinity of mining and smelting plants. Peri-urban areas are especially more vulnerable to such pollution loads in India due to indiscriminate dumping of waste and effluents. This can also adversely impact agricultural practices in these areas due to uptake of heavy metals in crops, thus contaminating the food chain.[8] More details are presented in Annexure 1.

1.4.1 Heavy Metals in Soil

Soil is a particularly difficult matrix for environmental pollution studies as it is generally composed of a multitude of geological and biological materials resulting from weathering and degradation, including particles of different sizes with varying surface and chemical properties. There are many different soil types categorised according to the content of biological matter, from sandy soils to loam and peat soils, which make analytical characterisation even more complicated. Soil sampling for environmental monitoring of pollutants, therefore, is still a matter of debate in the community of soil, environmental and analytical sciences. Mining, manufacturing and the use of synthetic products (for example, pesticides, paints, batteries, industrial waste and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils. Potential contamination of soils may occur at old landfill sites (particularly those that accepted industrial wastes), old orchards that used insecticides containing arsenic as an active ingredient, fields that

7 http://pac.iupac.org/publications/pac/pdf/2002/pdf/7405x0793.pdf
8 http://soil-environment.blogspot.in/2009/07/heavy-metals-and-their-health-effects.html

had past applications of waste water or municipal sludge, areas in or around mining waste piles and tailings, industrial areas where chemicals may have been dumped on the ground and areas downwind from industrial sites.[9, 10] Excess heavy-metal accumulation in soils is toxic to humans and other animals.

1.4.2 Polybrominated Biphenyls (PBBs) and Polybrominated Diphenyl Ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are an important class of flame retardants, widely used in a variety of consumer products such as plastics, electrical and electronic equipment, upholstered furniture, non-clothing textiles and foam products. Because PBDEs are added to products rather than chemically bound into them, they can be slowly and continuously released from the products during their manufacture, while in use or after their disposal. Exposure occurs, in particular, through food intake and the indoor environment. Infants and toddlers have the highest body burden, due to exposure via maternal milk and through house dust. Tetra-, penta- and hexa-BDEs are the congeners most commonly found in humans. Recent concerns on possible adverse health effects of PBDEs have focused on their potential endocrine disrupting effects and on developmental neurotoxicity. Relatively recent reports have indicated that exposure to low concentrations of these chemicals may result in irreparable damage to the nervous and reproductive systems. Virtually no studies have been done assessing the health effects of people exposed to PBBs and PBDEs.[11]

1.5 Groundwater

Groundwater is rain water or water from surface water bodies, like lakes or soaks into the soil and bedrock, and it is stored underground in the tiny spaces between rocks and particles of soil. Groundwater pollution occurs when hazardous substances come into contact with and dissolve in the water that has soaked into the soil. If rain water or surface water comes into contact with contaminated soil while seeping into the ground, it can become polluted and can carry the pollution from the soil to the groundwater. Groundwater can also become contaminated when liquid hazardous substances soak themselves down through the soil or rock into the groundwater.[12]

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9 http://soils.usda.gov/sqi/management/files/sq_utn_3.pdf

10 Wenjie Fan and Hongjiang Zhang, 'The Comparison of Heavy Metals in Soils from the North and South Regions of the Tianshan Mountains', *Journal of Food, Agriculture & Environment,* 11 (2): 915–17, 2013.

11 http://www.waterboards.ca.gov/rwqcb2/water_issues/programs/stormwater/MRP/2013_AR/BASMAA/BASMAA_2012-13_MRP_AR_POC.pdf

12 http://www.epa.gov/superfund/students/waststite/grndwatr.htm

...Loni & Mandoli

are located on the fringe of the city and are known for supporting multiple units engaged in such hazardous practices for significantly long period of time

2

Locations

2.1 The Sampling Sites

The issue of site selection for this study was of critical importance as there are multiple sites where recycling activities, like dismantling, segregation of parts and refurbishment using different kinds of input materials, are undertaken. These activities are carried out in the open, without any pollution control measures, which possibly could have impacts on environment. Hence there was a need for this study to identify a suitable cluster with a longer history of highly toxic and potentially hazardous activities.

We decided to select Loni and Mandoli on account of the most visible hazardous nature of processes being practised in these clusters for recovery of materials. Both these sites are located on the fringe of the city and are known for supporting multiple units engaged in such hazardous practices for significantly long period of time.

Both these locations are home to multiple facilities which are engaged with PCBs to recover copper and other metals from these using acid baths and burning processes. The detailed descriptions of both these sites are as follows:

2.1.1 Loni

2.1.1.1 About the Area

The Loni industrial area lies to the west of Ghaziabad city on the borders of Ghaziabad district, in the state of Uttar Pradesh and the National Capital Region. This industrial area can be approached from both Delhi and Ghaziabad and is home to many informal e-waste recycling units. The land in the area is privately owned and was being used for agricultural activities but since the last few years, the land is being used for recycling of electronic waste (Figure 1). The area being on the fringe of both the cities of Ghaziabad and Delhi still continues to be relatively less expensive and at a distance from the glare and direct scrutiny of regulators. Relatively low land prices, better transport connectivity and the ease of availability of waste have been some key factors in the growth of recycling facilities in this area. Some families engage all family members in e-waste recycling work (Figure 2). The recycling area is located adjacent to agricultural fields. Details of activities, processes and workers at Loni area are presented in Annexure 2.

FIGURE 1
Heaps of electrical (mainly CFL circuit boards) lying in Loni for recycling

FIGURE 2
All the household members engaged in e-waste recycling work

2.1.1.2 Geographical Profile

The general geography of the area can be explained with reference to nearby colonies and small landmarks for the ease of understanding. To the north of Loni, there is a big water tank and in the west lies the State Highway No. 57; in south lies Laxmi Cinema, while to the immediate east is an open area. The coordinates of the location (centre point) are 28^0 45′ 12″ N and 77^0 18′ 11″ E. General elevation of the area is around 677 ft, where maximum height is 680 ft (NW) sloping towards the SE. Geographically, this area is approximately around 1 square kilometre.

There is no municipal water supply available in the area, hence people use ground water from hand pumps, and the ground water level has gone down to around 100 ft.

There is no proper arrangement for drainage, but by studying the given gradients one can conclude that general flow of water is in the SE direction. Rainfall and wind patterns of the area are almost the same as Delhi in general.

Here is a brief discussion regarding the different types of metals that are extracted out of e-waste in the units operational in the area and the process of their extraction.

Lead Lead is extracted by heating the circuit board with the help of a gas burner; lead used in circuit boards is exfoliated and collected separately.

Iron After extracting lead, the remaining part of the waste is burnt for around ten to twelve hours. After burning, it is allowed to cool down and then iron is removed with the help of a magnetic plate.

Aluminium After extracting iron, aluminium is extracted by picking up the small pieces of aluminium left behind from the heap of burnt circuit boards. Locals call it ‘silver’ due to its silver-like appearance.

Copper Copper is extracted from transformers by cracking the outer cover made up of plastics with help of a hammer and then the (copper) wire is stretched out manually with bare hands.

2.2.1 Mandoli

2.2.1.1 About the Area

This area lies under Krishna Vihar Phase III, Ghaziabad, Uttar Pradesh. The land is owned by residents of the nearby Tilla Shabajpur village. Prior to any kind of commercial use, the land was used for agriculture. However, rising prices of property and increased vigilance by regulatory authorities in the metropolis of Ghaziabad and Delhi pushed some of the industrial processes and activities into this area. Details of different types and number of industries operating in this area are presented in Table 1. E-waste recycling in the informal sector is presented below in Flow Chart 1 and the step-wise extraction of copper from printed wiring boards is presented in Figure 3.

This area, adjoining the border of Delhi and Uttar Pradesh, is home to a number of small and medium enterprises and is called Gaddha colony. Details of activities, processes and workers in the Mandoli area are presented in Annexure 2.

FIGURE 3
The extraction of copper from printed wiring boards (PWBs)

1. Manually removing varnish
2. Recovering copper sulphate after submerging PWBs for 12 hours in sulphuric acid, followed by boiling off H2O using PWB residues as a fuel

3. Manually segregating the copper layer and glass fibres after burning multi-layered PWBs, which are resistant to acid
4. Scrap iron is added to the remaining liquid to react with the dissolved copper,
5. Fallen out copper slime is a third product bringing the total to 1 to 2 t of copper per month
6. Such a small and medium enterprise (SME) creates about 12 jobs, though at high external costs

2.2.1.2 Geographical Profile

The general geography of the area can be explained with reference to nearby colonies for the ease of understanding. To the east of Gaddha colony is the adjoining village of Tilla Shabajpur and to the north across the road lies the Mandoli industrial area housing many industrial units engaged in several recycling processes and activities. In the west is a residential area called Amit Vihar, while the immediate south of Gaddha colony is an open area. The coordinates of the colony are 28^0 43′ 19.92″ N and 77^0 19′ 0.57″ E.

General elevation of the area ranges between 690 ft to 708 ft, south sloping towards the NW where the average elevation is around 680 ft.

This area is not considered as developed and its legal status is disputable. The area does not have a definite drainage system. Waste water and other effluents are generally discharged into the open and vacant land, and based on the gradient of the land most effluents tend to flow in the NW direction. The effluents are absorbed by the soil and percolate down to lower levels. Rainfall and wind patterns of the area are almost the same as Delhi in general.

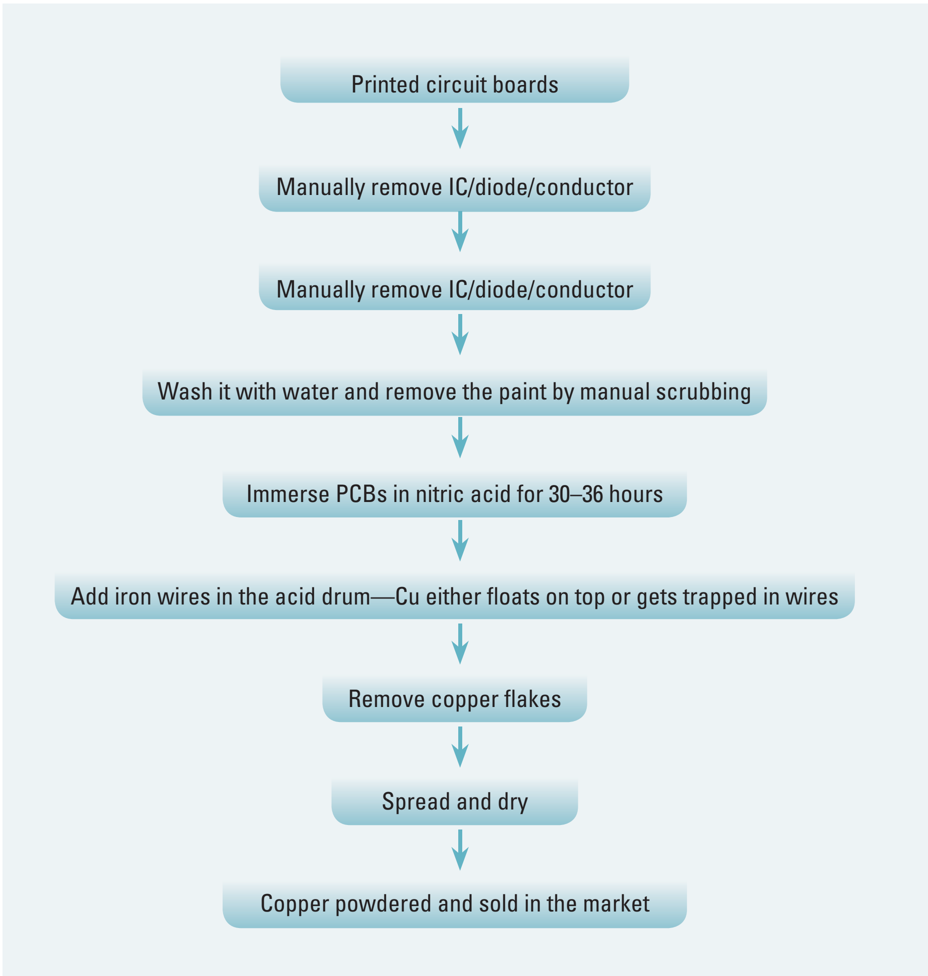
TABLE 1
Type and number of industrial units in Mandoli area

Type of unit	Input material	Output Material	No. of operational units
Mild steel	Raw steel; silver	Processed steel	2
Metallic waste reprocessing	Keet (metallic waste)	Iron and copper	1
Footwear segregation	Unsorted, out-of-use footwear	Sorted footwear (Suitable for burning)	3
Glass units	Unsorted waste glass, both colourless and coloured; acids HCl and HNO3; caustic soda	Colourless glass	1

Type of unit	Input material	Output Material	No. of operational units
Denim washing	Water; these units have closed	Washed denims	3
Television dismantling	Out-of-use TV sets	Segregated TV parts	1
Copper extraction	Circuit boards, acids HCl and HNO3, caustic soda	Copper with around 20% of impurities	64

FLOW CHART 1
E-waste recycling in the informal sector, Mandoli, Delhi

Process of precious metal recovery from printed circuit boards



3

Methods

3.1 Sampling Methods and Protocol

The snapshot sampling was done in order to explore the extent of contamination of surrounding soils and ground water reservoirs, which are being used by the residents of the localities for drinking and other daily needs. Samples were collected from these two sites where the recycling of e-waste has been done for the last 10 years.

Systematic random sampling is a useful and flexible design for estimating the average pollutant concentration within grid cells, and is sometimes also referred to as stratified random sampling (Figure 4). The area of concern is subdivided using a square or triangular grid and then samples are collected from within each cell using the random selection procedure. Systematic random sampling allows for the isolation of cells that may require additional sampling and analysis. Figure 4 illustrates a systematic random sampling approach.

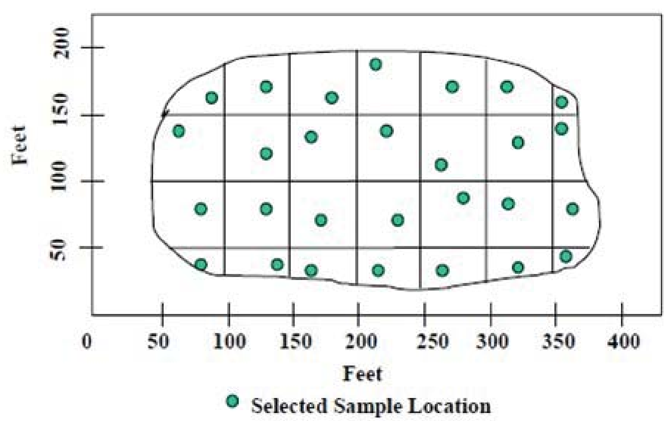


FIGURE 4 Systematic random sampling

For water samples, the standard procedure of collecting the sample in a clean 2-litre container, after rinsing it with the sample water, was used. Most of the drinking water samples were taken from the working hand pumps, which residents/workers of the area have been using for their daily needs. The depth of these hand pump bores were between 60 and 120 ft (Figure 6).

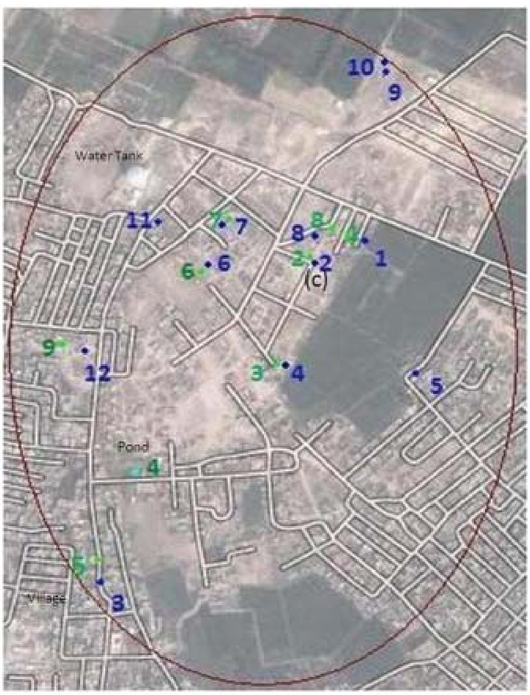
For collecting soil samples, a tulip bulb planter was used on soft soil. It can take soil samples from 0–10 inches depth and is easy to use and decontaminate; it has a uniform diameter and sample volume; it preserves the soil core (Figures 7 and 8).

These samples were then sent to SPECTRO Labs (an accredited laboratory) to test for heavy metals and other physicochemical attributes.

3.1.1 Sample Collection at Loni

All water and soil samples were collected around centre points (marked as C) of the location in Loni area (Figure 5). A total of 9 samples of water and 12 samples of soil were collected from different directions of point C (Table 2). The control sample for soil was collected from a nearby village within 1 km range and located at SW direction of the point C.

FIGURE 5 Sampling locations at Loni



Note: All green dots 1–9 in the map are the sampling locations for water in Loni area. Blue dots on the map of Loni represent sampling locations (1–12) for soil. Soil sample 3 is located SW of the centre point C, which is the control sample for soil in Loni and is located within the village area at a distance of 461 metres from the centre point C (Table 2).

TABLE 2
Description of samples collected from e-waste recycling sites in Loni area, Uttar Pradesh

Sample	Directions	Distance in metres	Latitude	Longitude	Remarks
WS – 1	East	57.10	28°45`09.23``	77°18`16.04``	From identified working hand pump
WS – 2	North-east	2.00	28°45`09.10``	77°18`16.28``	
WS – 3	South-west	137.93	28°45`09.74``	77°18`16.23``	
WS – 4		333.36	28°45`09.95``	77°18`16.41``	From the pond on the other side of road
WS – 5	South-west	443.24	28°45`09.79``	77°18`16.14``	Control sample
WS – 6	West	168.95	28°45`10.87``	77°18`10.26``	From identified working hand pump
WS – 7	North-west	155.37	28°45`09.19``	77°18`18.16``	
WS – 8	North	96.63	28°45`09.24``	77°18`16.16``	
WS – 9	West	337.50	28°45`06.75	77°18`04.36``	
SS – 1	East (downstream) of ref. point	56.19	28°45`09.34``	77°18`16.16	Includes one sample from the drench
SS – 2		Centre unit	28°45`09.15``	77°18`16.22``	
SS – 3	Village	461.07	28°45`09.87``	77°18`16.36``	Control sample
SS – 4	South	137.79	28°45`05.59``	77°18`13.92``	Includes one sample from the drench
SS – 5	South-east (downstream) of C	154.11	28°45`10.75``	77°18`18.15``	
SS – 6	West	166.95	28°45`11.73``	77°18`17.55``	
SS – 7		158.59	28°45`11.50``	77°18`10.91``	
SS – 8	North	89.90	28°45`09.17``	77°18`16.14``	Includes one sample from discarded site
SS – 9	North-east	233.11	28°45`16.86``	77°18`17.30``	
SS – 10		244.55	28°45`09.31``	77°18`16.20``	
SS – 11	North-west	224.16	28°45`09.24``	77°18`16.26	
SS – 12	West	324.56	28°45`06.57``	77°18`04.75``	

Note: WS – water sample; SS – soil sample.

3.1.2 Sample Collection at Mandoli

All water and soil samples were collected around centre points (marked as C) of the location in Mandoli area (Figure 9). Some locations were chosen around dumping

FIGURE 6
Drinking water sample collection in Loni area

FIGURE 7
(Left)
Soil sample collection in Loni area

FIGURE 8
(Right)
Soil sample collectin from open burning site, Loni area

sites and e-waste recycling units (Figures 10 and 11). A total of 3 samples of effluent water, 6 samples of water and 10 samples of soil were collected from different directions of point C (Table 3, Figure 12). The control sample for soil was collected from a nearby village within 1 km range and located at east direction of the point C.

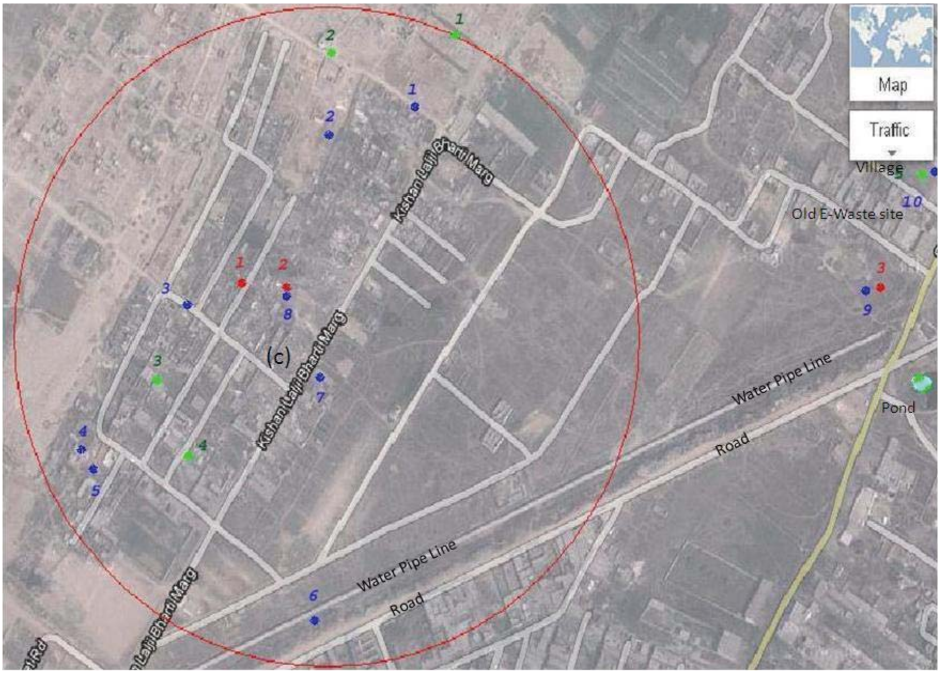


FIGURE 9
Sampling locations at Mandoli

Note: The red dots on the map of Mandoli represent the location for effluent samples. These are 1 and 2, which are NW and N to C respectively, and 3, which is NE to the centre point C. Blue dots 1–10 represent the location for soil samples from Mandoli area. Sample 10 is the control sample for soil and is approx. 734 metres to NE of the point C and is in the village.

TABLE 3 Description of samples collected from e-waste acid bath recovery of copper metal at disposal sites in Mandoli area, Delhi

Sample	Directions	Distance in metres	Latitude	Longitude	Remarks
WS – 1	North	273.50	28°43`25.66``	77°19`05.01``	From identified working hand pump
WS – 2		257.30	28°43`25.61``	77°19`02.20``	
WS – 3	West	112.74	28°43`17.95``	77°18`55.42``	
WS – 4	South-west	109.10	28°43`16.11``	77°18`55.97``	
WS – 5	North-east	734.68	28°43`26.17``	77°19`24.51``	Control sample
WS – 6	East	561.79	28°43`17.57``	77°19`21.75``	From the pond on the other side of road
EWS – 7	North-west	39.63	28°43`19.22``	77°18`57.84``	From effluents
EWS – 8	North	75.50	28°43`19.26``	77°18`59.99``	
EWS – 9	East	530.72	28°43`19.81``	77°19`18.06``	
SS – 1	North	211.15	28°43`23.90``	77°19`03.70``	Includes one sample from discarded site
SS – 2		154.30	28°43`23.12``	77°19`00.92``	
SS – 3	West	86.61	28°43`19.47``	77°18`56.41``	Includes one sample from the drench
SS – 4	West (downstream) of ref. point	181.28	28°43`16.08``	77°18`53.36``	
SS – 5		185.73	28°43`15.09``	77°18`53.75``	
SS – 6	South	224.76	28°43`11.76``	77°19`00.59``	
SS – 7	East	66.25	28°43`17.67``	77°19`00.70``	
SS – 8	North	74.74	28°43`19.27``	77°18`59.97``	
SS – 9		521.77	28°43`19.82``	77°19`17.88``	Includes one sample from discarded site
SS – 10	Village	734.00	28°43`25.54``	77°19`24.52``	Control sample

Note: WS – water sample; EWS – effluent water sample; SS – soil sample.

FIGURE 10
Dumping site in Mandoli area

FIGURE 11
E-waste recycling unit in Mandoli area

FIGURE 12
Effluent water and soil sample collection from the industrial shed

3.2 Analysis

The sampling was done in the month of October and November 2012. For water, waste water and soil sampling, different methods were adopted, which are listed in Table 4. Bottles with 2 litre water and 2 kg of soil samples each were collected from different areas of the sites. The collected samples were sent to an accredited laboratory for analysis. Standard operating procedures/methods (Table 4) were used to analyse the samples.

TABLE 4
Methods used to identify parameters

IS: 3025 (part 11) : 1984	pH
APHA – 2510 B	Conductivity
APHA – 2340 C	Total hardness
IS: 3025 (part 10) : 1984	Turbidity (NTU)
APHA – 5220 (COD) C	COD
AAS/ICP	Lead, nickel
AAS/ICP	Zinc, cadmium, mercury
APHA – 3500 – Cr – D	Hexavalent chromium

Note:
**APHA: American Public Health Association*
**AAS: Atomic Absorption Spectrometry*
**ICP–ES: Inductively Coupled Plasma–Emission Spectrometry*
**IS: Indian Standards*

Results and Discussion

4

4.1 Water Analysis

4.1.1 Loni Water Quality

The physicochemical characteristics of the samples collected at Loni are presented in Table 5 and compared with Indian standards IS: 10500 (Annexure 3).

TABLE 5 Detailed physicochemical and heavy metals analysis of Loni water samples (1/11/2012)

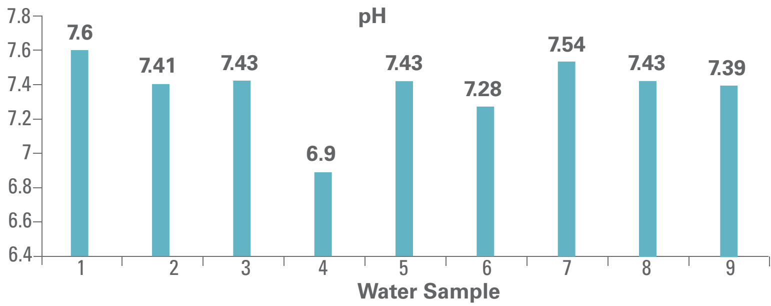
Sample description	pH	Electrical conductivity	Total hardness	Turbidity	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc
		(µS/cm)	(mg/l)	NTU	(mg/l)					
WS – 1	7.6	1360	325	<1.0	<0.01	<0.01	<0.01	<0.01	<0.01	0.09
WS – 2	7.41	389	264	1.32	<0.01	<0.01	<0.01	<0.01	<0.01	0.05
WS – 3	7.43	405	284	2.96	<0.01	<0.01	<0.01	<0.01	<0.01	0.34
WS – 4	6.9	536	200	9.5	<0.01	<0.01	<0.01	<0.01	<0.01	0.06
WS – 5	7.43	360	232	1.4	<0.01	<0.01	<0.01	<0.01	<0.01	0.17
WS – 6	7.28	331	184	2.4	<0.01	<0.01	<0.01	0.02	<0.01	0.58
WS – 7	7.54	302	200	1.7	<0.01	<0.01	<0.01	<0.01	<0.01	0.19
WS – 8	7.43	495	256	1.4	<0.01	<0.01	<0.01	<0.01	<0.01	0.39
WS – 9	7.39	302	204	1.1	<0.01	<0.01	<0.01	<0.01	<0.01	0.97
Min.	6.9	302.0	184.0	<1.00	–	–	–	–	–	0.05
Max.	7.6	1360.0	325.0	9.50	–	–	–	0.02	–	0.97
Average	7.4	497.8	238.8	2.53	–	–	–	–	–	0.32
IS: 10500	6.5–8.5	–	300	5	0.05	0.01	–	0.01	0.05	5

Note: Description of samples:
Water samples 1–4 and 7–9 are hand pumps located to the west of the centre point, which are in use by people for their day-to-day activities. The water sample 1 is from a hand pump, which is 57 metres NE of the reference point and is not in use all the time.
Water sample 5 is from the village hand pump located 443 metres in SW direction from the reference point marked as C in the map.
Water sample 6 is 169 metres west of the reference point marked as C.

4.1.1.1 pH and Electrical Conductivity (EC)

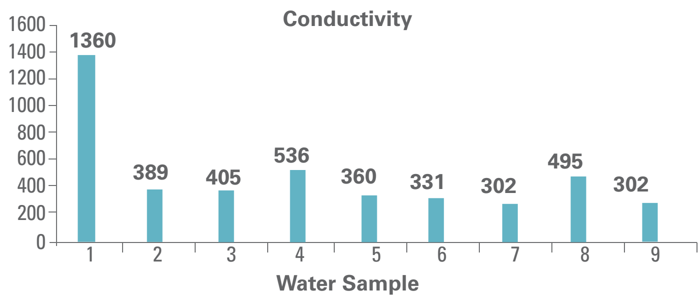
The pH levels varied from 6.9 to 7.6 and were found within the desirable limit as per Indian standards (6.5 to 8.5) (Graph 1).

GRAPH 1
pH levels of water samples at Loni area



Electrical conductivity of the water samples varied from 302 to 1,360 µS/cm. Normally an electrical conductivity of 0–800 µS/cm in water is considered as safe for drinking purposes (provided there is no organic pollution and not too much suspended clay material). Out of all samples, one sample (sample no. 1) was higher and all other samples were below 800 µS/cm. The average electrical conductivity was 497.8 µS/cm (Graph 2).

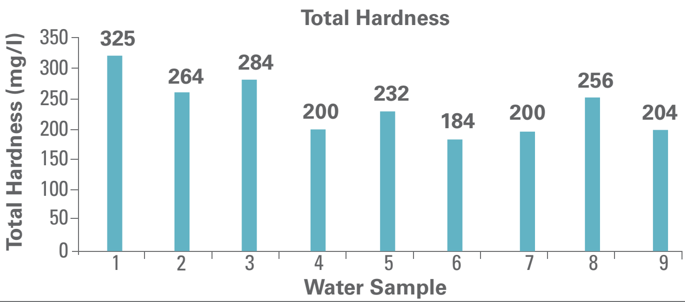
GRAPH 2
Conductivity levels in water samples at Loni area



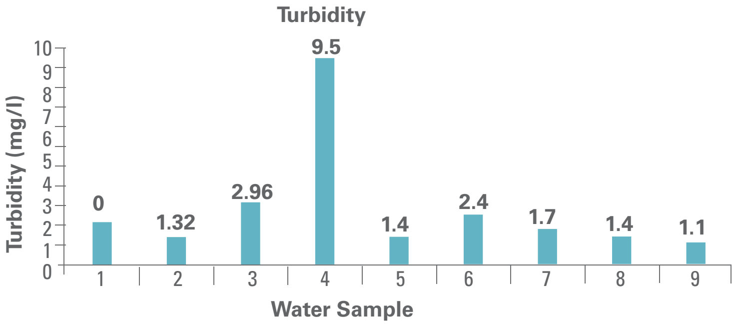
4.1.1.2 Hardness and Turbidity

The observed total hardness of the water samples varied from 184 to 325 mg/l. The average total hardness concentration was observed to be 238.8 mg/l. Out of all samples, one sample (sample no. 1) was higher and all other samples were below the desirable limit of Indian standards (300 mg/l) (Graph 3).

The observed turbidity levels varied from <1.0 to 9.5 mg/l. The average concentration of turbidity was observed to be 2.53 mg/l. All locations were within the desirable limit of Indian standards (10 NTU) for turbidity (Graph 4).



GRAPH 3
Total hardness levels in water samples at Loni area



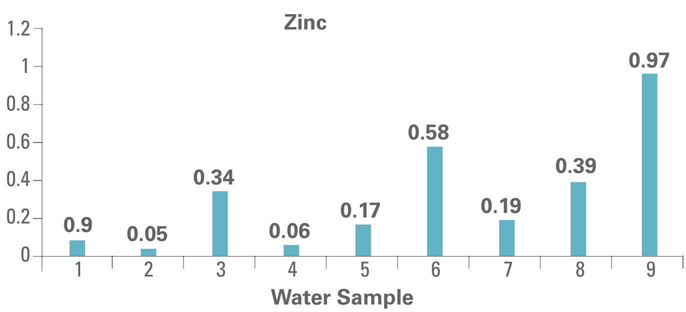
GRAPH 4
Turbidity levels in water samples at Loni area

4.1.1.3 Heavy Metals

The observed levels of lead, cadmium, nickel and chromium (VI) were found below detectable limits.

The mercury level observed in sample no. 6 (0.02 mg/l) was almost 20 times higher than the desirable limit of Indian standards (0.001 ppm). The other eight samples were found below the detectable level. A slight increase in mercury content can cause severe problems such as damage to the nervous system, kidneys and brain.

Zinc was observed in collected samples and varied from 0.05 to 0.32 mg/l. All locations were within the desirable limit of Indian standards (5 mg/l) for zinc (Graph 5).



GRAPH 5
Zinc levels in water samples at Loni area

From the results obtained, it can be concluded that water quality in the Loni area has not been significantly impacted as only one sample reflects higher levels of mercury.

4.1.2 Mandoli Effluent Water Quality

The physicochemical characteristics of the effluent water samples collected at Mandoli is presented in Table 6. These results were compared with Indian Standards (IS: 10500) (Annexure 4).

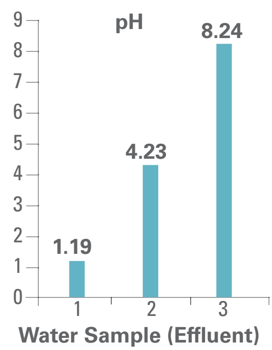
TABLE 6 Detailed analysis of Mandoli effluent water samples (18/10/2012)

Sample description	pH	COD	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc
		(mg/l)						
EWS – 1	1.19	29195.2	1.66	<0.01	1.36	<0.01	<0.01	870
EWS – 2	4.23	3657.6	<0.01	<0.01	<0.01	<0.01	<0.01	320
EWS – 3	8.24	27550.4	<0.01	<0.01	<0.01	<0.01	<0.01	0.59
IS: 10500	5.5–9.5	250	0.1	2.0	3.0	0.01	0.1	5.0

4.1.2.1 pH

The pH levels varied from 1.19 to 8.24 (Graph 6). The pH level of samples 1 and 2 were acidic (1.19, 4.23) in nature, while sample 3 was found within the prescribed safe limits of Indian standards (Annexure 4).

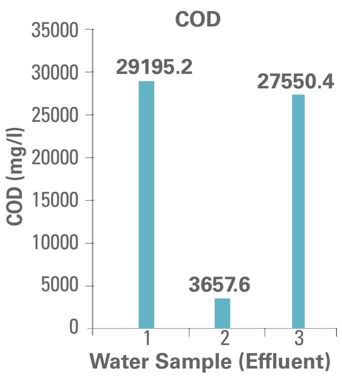
GRAPH 6 pH levels in effluent water samples at Mandoli area

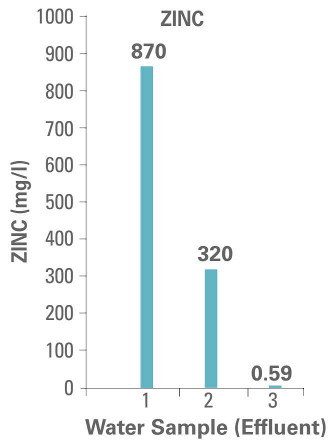


Sample nos 1 and 2 are from currently operational facilities that are using acids, while sample 3 is from a closed facility not engaged in e-waste recycling. The pH value clearly indicates the presence of acids in the effluents being discharged and suggests a relationship with input materials.

4.1.2.2 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a measure of the total quantity of oxygen required to oxidise all organic material into carbon dioxide and water. COD is an important parameter of measuring the quality water and determining the load of organic matter present in it. The higher the COD, the higher the amount of pollution in the test sample.





GRAPH 7
(Left)
COD levels in effluent water samples at Mandoli area

GRAPH 8
(Right)
Zinc levels in effluent water samples at Mandoli area

In the Mandoli area, COD levels of the effluent water samples varied from 3,657.6 to 29,195.2 mg/l (Graph 7); 100 per cent of the samples were observed with higher levels of COD. The highest level of COD was ~117 times higher than Indian standards (Annexure 4).

4.1.2.3 Heavy Metals

The lead level was observed only in sample no. 1 (1.66 mg/l); it was ~17 times higher than the limit of Indian standards, that is, 0.1 mg/l (Annexure 4). The other two samples were found below the detectable level.

The nickel level was observed only in sample no. 1 (1.36 mg/l) and was found below the limit of Indian standards, that is, 3.0 mg/l (Annexure 4). The other two samples were found below the detectable level. Cadmium chromium (VI) and mercury were found below the detectable levels in all collected samples.

Zinc levels were observed in all three samples and varied from 0.59 to 870 mg/l (Graph 8). The highest zinc level was ~174 times higher then the limit of Indian standards, that is, 5.0 mg/l (Annexure 4). The levels of zinc were ~174 and ~64 times higher in samples 1 and 2 respectively and in sample no. 3 (0.59 mg/l) it was lower as compared to the Indian standards.

On close scrutiny and analysis of the results, it can be infered that the presence of lead and zinc in effluents is directly linked to the nature of activities being practised in these units, hence establishing a correlation between input source and its consequential effects. The input materials used in copper recovery are concentrated acids and the test results of the effluents showing low pH values clearly indicate a linkage between the input materials and the output.

Sample no. 3 is from a unit that has since been closed down and the results from this sample for all parameters are lower as compared to samples 1 and 2.

The acidic pH, increased levels of COD and presence of some heavy metals in samples no. 1 and 2 suggest a relationship between the input materials and the effluents. The quality of effluents being discharged into open drains is likely to impact the mediums of both surface water and soil and alter their characterstics.

From the results obtained, it can be concluded that the the effluents being discharged from these units are high on heavy metals and other chemicals much beyond the permissible limits as prescribed by the Indian standards (IS:10500). It is also important to observe that there is a difference in the levels of heavy metals between the functional and non-functionl units, suggesting that the recycling activites are the source for such chemical and heavy metal contamination.

4.1.3 Mandoli Water Quality

The physicochemical characteristics of the samples collected at Mandoli are presented in Table 7 and found to be at variance with Indian standards (IS: 10500) (Annexure 3).

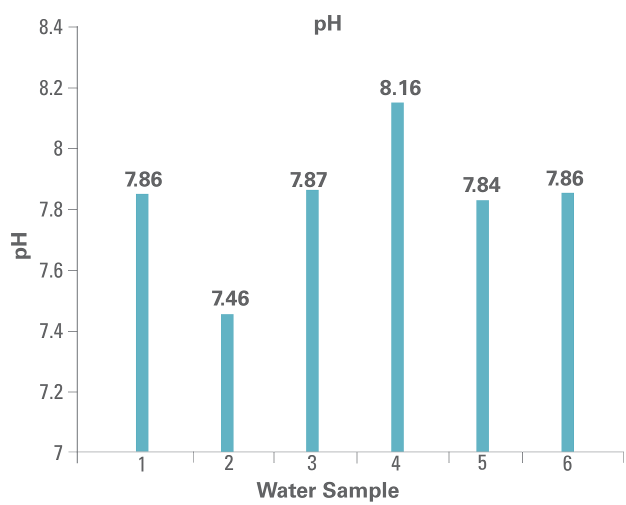
TABLE 7 Detailed physicochemical and heavy metals analysis of Mandoli water samples (18/10/2012)

Sample description	pH	Electrical conductivity	Total hardness	Turbidity	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc
		(µS/cm)	(mg/l)	NTU	(mg/l)					
Water sample 1	7.86	637	180	12.9	0.52	<0.01	0.16	<0.01	<0.01	9
Water sample 2	7.46	721	568	3.4	<0.01	<0.01	<0.01	<0.01	<0.01	1.32
Water sample 3	7.87	1,060	308	12.8	<0.01	<0.01	<0.01	0.71	<0.01	5

Sample description	pH	Electrical conductivity	Total hardness	Turbidity	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc
		(μS/cm)	(mg/l)	NTU	(mg/l)					
Water sample 4	8.16	837	268	2.5	<0.01	<0.01	<0.01	<0.01	<0.01	7
Water sample 5	7.84	682	152	2.8	<0.01	<0.01	<0.01	<0.01	<0.01	10
Water sample 6	7.86	4,580	244	2.7	<0.01	<0.01	<0.01	<0.01	<0.01	0.17
Min.	7.46	637	152	2.5	–	–	–	–	–	0.17
Max.	8.16	4,580	568	12.9	0.52		0.16	0.71	–	10
Average	7.84	1,419.5	286.67	6.183	–	–	–	–	–	5.415
IS: 10500	6.5–8.5	–	300	5	0.05	0.01	–	0.01	0.05	5

4.1.3.1 pH and Electrical Conductivity (EC)

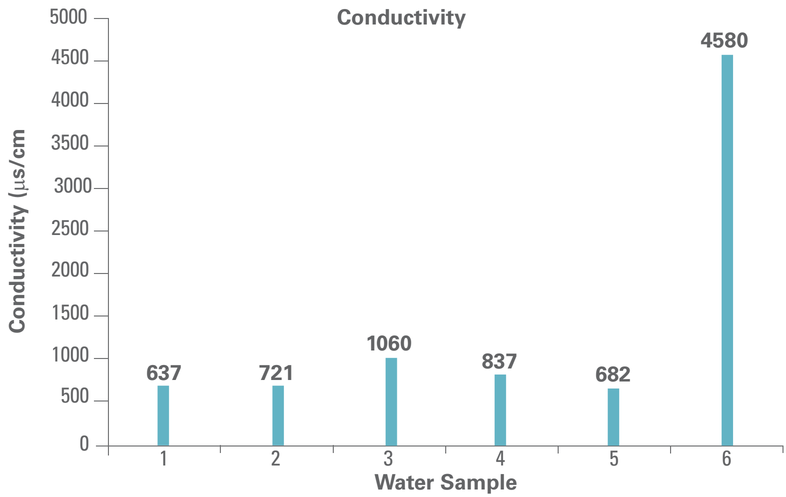
The pH levels varied from 7.46 to 8.16 and were found within the desirable limit as per Indian standards (6.5 to 8.5) (Graph 9).



GRAPH 9
pH levels in water samples at Mandoli area

Electrical conductivity of the water samples varied from 637 to 4580 μS/cm. Normally an electrical conductivity of 0–800 μS/cm in water is considered safe for drinking purposes (provided there is no organic pollution and not too much suspended clay material). However, in the Mandoli study area, 50 per cent of the samples, that is, sample nos 2, 3 and 6 were found with electrical conductivity above 800 µS/cm, while the rest of the samples were below 800 µS/cm. The highest electrical conductivity was almost 5 times higher than the normal level and that was recorded in sample no. 6. The average electrical conductivity was 1,419.5 µS/cm (Graph 10).

GRAPH 10
Conductivity levels in water samples at Mandoli are

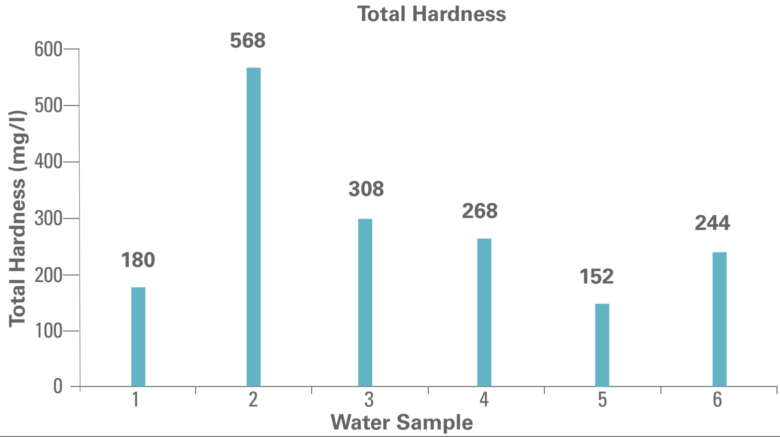


4.1.3.2 Hardness and Turbidity

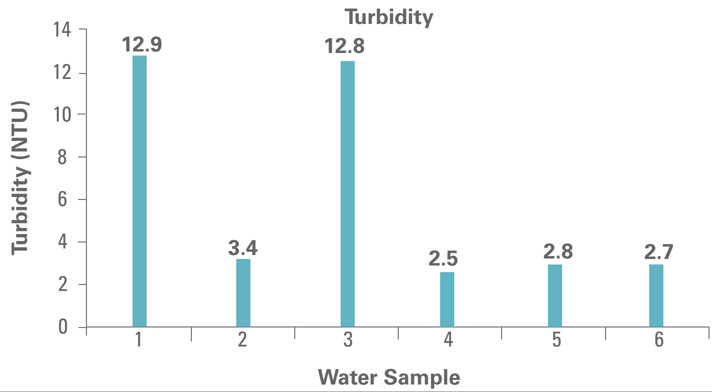
Water hardness is the traditional measure of the capacity of water to react with soap; hard water requires considerably more soap to produce lather. Hard water often produces a noticeable deposit of precipitate (for example, insoluble metals, soaps or salts) in containers, including a 'bathtub ring'. It is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cations, although other cations (for instance, aluminium, barium, iron, manganese, strontium and zinc) also contribute. Hardness is most commonly expressed in terms of milligrams of calcium carbonate equivalent per litre.

The observed total hardness of water samples varied from 152 to 568 mg/l. The average total hardness level was observed to be 286.7 mg/l. Out of all the samples, 33 per cent, that is, sample nos 2 and 3 were observed with total hardness levels above the desirable limit of Indian standards (300 mg/l) (Graph 11).

The observed turbidity levels varied from 2.5 to 12.9 mg/l. The average turbidity level was 6.18 mg/l. Out of all the samples, 33 per cent, that is, sample nos 1 and 3 reported results above the desirable limit of Indian standards (10 NTU) (Graph 12).



GRAPH 11
Total hardness levels in water samples at Mandoli area



GRAPH 12
Turbidity levels in water samples at Mandoli area

4.1.3.3 Heavy Metals

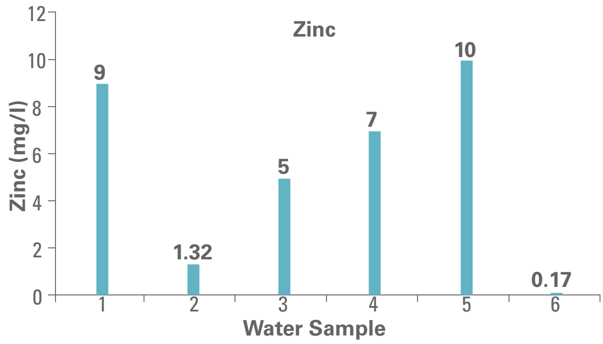
The lead levels observed in sample no. 1 (0.52 mg/l) were almost 11 times higher than the desirable limit of Indian standards (0.05 ppm). The other five samples were found below the detectable level.

The mercury levels observed in sample no. 3 (0.71 mg/l) was almost 710 times higher than the desirable limit of Indian standards (0.001 ppm). The other five samples were found below the detectable level.

The nickel level observed in sample no. 1 (0.16 mg/l) was found below the desirable limit of Indian standards (3.0 ppm). The other five samples were found below the detectable limit (<0.01 mg/l).

Cadmium and chromium (VI) were found below detectable levels in all collected samples.

GRAPH 13
Zinc levels in water samples at Mandoli area



Zinc were observed in all collected samples and varied from 0.17 to 10 mg/l; 33 per cent, that is, two samples showed zinc levels above the desirable limit of Indian standards (5 mg/l) (Graph 13).

From the test results, the overall observation is that the drinking water samples do conform to some of the parameters of pH, hardness and conductivity. The results of turbidity were high, suggesting higher presence of suspended materials. Presence of lead, nickel and zinc in water samples that are in close vicinity to the recycling area does give an indication of changes in the water quality. Lead and nickel found in drinking water samples are also input materials in the recycling facilities, hence the correlation between them and the impact on water quality.

From the results obtained, it can be concluded that the water quality is undergoing change and there is presence of heavy metals in some samples.

4.2 Soil Analysis

4.2.1 Loni Soil Quality

The characteristics of soil samples collected from the Loni area is presented in Table 8.

There are no prescribed standards for the acceptable level of heavy metals in soil in India; hence we looked at some other countries for such standards. Through secondary research, we identified standards for a few other countries and find that there is a wide variation in the standards for these metals among these countries (Table 9). In such a situation, it may not be logical to compare our results with any one country standard. However, these country standards do give us a possible range for comparison.

TABLE 8
Detailed analysis of Loni soil samples (01/11/2012)

Sample description	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc	PBB*	PBDE**
	Ppm							
Soil sample 1, PVC East	238.02	<0.1	23.8	0.24	5.13	110.17	0	0
Soil sample 2, CFL waste contaminated	171.56	<0.1	21.81	2.69	4.31	103	0	0
Soil sample 3	32.52	<0.1	17.74	0.39	5.32	118.27	0	0
Soil sample 4	95.74	<0.1	21.35	0.49	9.18	112.93	0	0
Soil sample 5	1,666.8	3.33	57.62	0.78	3.77	575.02	0	0
Soil sample 6	177.2	<0.1	27.05	0.24	4.98	111.43	0	0
Soil sample 7	148.43	<0.1	15.33	0.01	4.74	113.3	0	0
Soil sample 8	156.21	<0.10	23.56	0.72	6.11	112.96	0	0
Soil Sample 9	723.24	2.72	18.84	0.86	6.41	292.57	0	0
Soil sample 10	191.2	<0.1	13.38	0.4	15.45	95.6	0	0
Soil sample 11	4,778	5.4	54.33	0.61	5.12	688.36	0	0
Soil sample 12	142.32	<0.1	23.06	1.47	3.7	117.29	0	0

TABLE 9: Country standard for heavy metals in soil for industrial or land use (ppm)

TABLE 9
Country standard for heavy metals in soil for industrial or land use (ppm)

Metal	USA	Canada	UK	EU	Taiwan	India
Pb	220	2000	750	–	2000	–
Hg	9	10	26	–	10	–
Cd	36	20	230	15	20	–
Cr (total)	135	800	5000	800	250	–
Ni	1850	500	1800	500	200	–
Zn	570	1500	–	3000	2000	–

Note:

United States: The USEPA set standards for metals in soil as per its SSL or soil screening levels (USEPA, 2002).[1]

Canada:2 Soil standards.

United Kingdom: CLEA 2009 (Contaminated Land Exposure Assessment) is an updated technical document issued by the Environment Agency, UK.[3]

EU: EC Directive 86/278/EEC as per the Code of Practice (Use in Agriculture) Regulations 1989 on protection of the environment.[4]

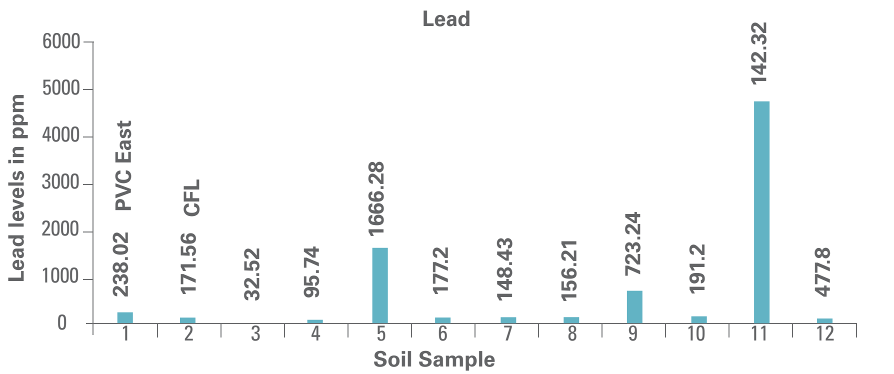
Taiwan: As per the Soil and Groundwater Remediation Act (2000) and Soil Pollution Monitoring Standard (2011).

In the Loni study, sample no. 3 was considered as the control sample and the data of other samples were compared with sample no. 3. This sample no. 3 was located at SW side and was 460 metres away from the centre point.

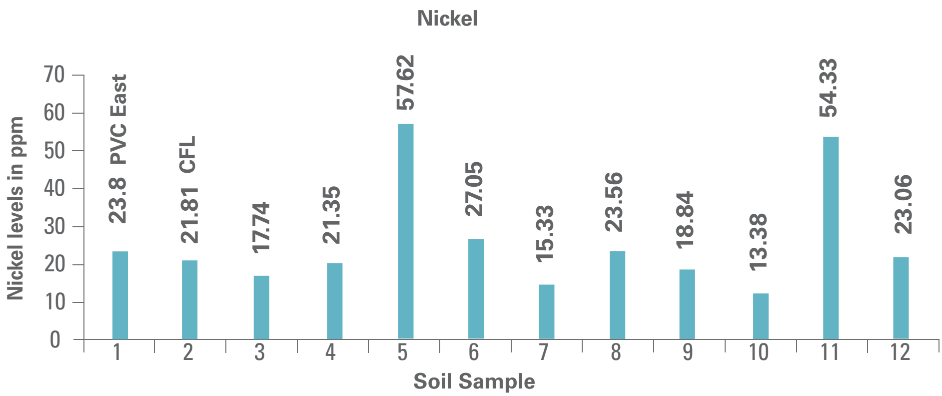
4.2.1.1 Lead, Cadmium and Nickel

The lead levels varied from 95.74 to 4,778 ppm; 100 per cent of the soil samples were found with very high lead levels as compared to the control sample (35.52 ppm). The highest lead level was almost 147 times higher than the control sample (Graph 14).

GRAPH 14
Lead levels in soil samples at Loni area



GRAPH 15
Nickel levels in soil samples at Loni area



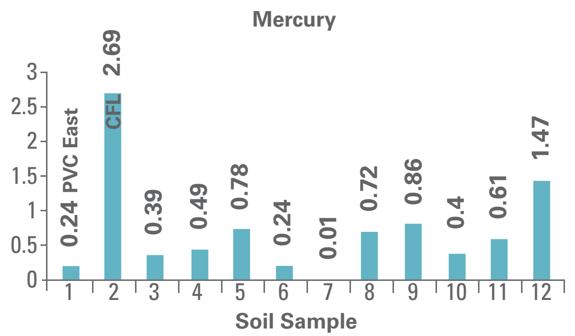
This clearly indicates a change in characteristics of the soil and can be directly linked to the ongoing industrial activity and presence of lead as an input material.

The cadmium levels varied from <0.1 to 5.4 ppm; 27 per cent of soil samples, that is, three samples (sample nos. 5, 9 and 11) were found with high cadmium levels. All other samples including the control sample were below the detectable limit (<0.1 ppm).

The nickel levels varied from 13.38 to 57.62 ppm. All samples (~82 per cent) recorded high values as compared to the control sample (18.65 ppm) except sample nos. 7 and 10. The highest nickel level was almost 6 times higher than the control sample (Graph 15). This indicates that the character of the soil in this area has undergone a change and there is a much higher presence of nickel in the soil.

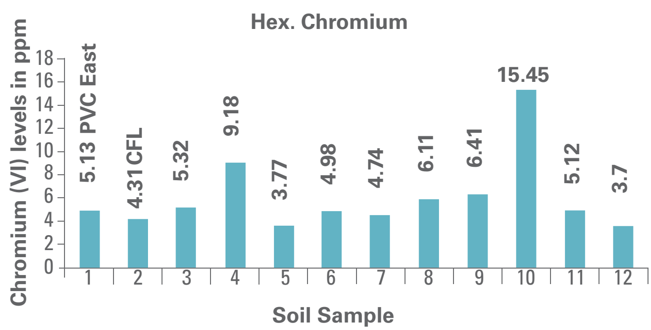
4.2.1.2 Mercury and Hexavalent Chromium

Mercury levels varied from 0.01 to 2.69 ppm. Around 73 per cent soil samples were found with high mercury levels as compared to the control sample (0.39 ppm). Three samples (sample nos. 1, 6 and 7) were found low as compared to the control sample. The highest mercury level was almost 7 times higher than the control sample (Graph 16). This variation in mercury concentration in soil is indicative of a certain degree of abnormality in the soil characteristics.



GRAPH 16
Mercury levels in soil samples at Loni area

The hexavalent chromium levels varied from 3.7 to 15.45 ppm. Around 36 per cent soil samples were found with high levels of hexavalent chromium as compared to the control sample (5.32 ppm). Six soil samples (sample nos. 1, 2, 5, 6, 7 and 12) were found with levels less than the control sample. The highest hexavalent chromium level was almost 3 times higher than control sample (Graph 17).

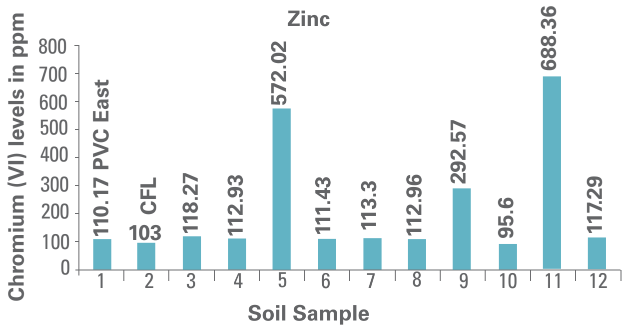


GRAPH 17
Hexavalent chromium levels in soil samples at Loni area

4.2.1.3 Zinc

The observed zinc levels varied from 95.6 to 688.36 ppm. Around 27 per cent soil samples were found with high zinc levels as compared to the control sample (118.27 ppm). Eight soil samples (sample nos. 1, 2, 4, 6, 7, 8, 10 and 12) were found with zinc levels less than the control sample. The highest zinc level was almost 6 times higher than the control sample (Graph 18).

GRAPH 18
Zinc levels in soil samples at Loni area



The test results of soil samples from Loni have high levels of a few heavy metals in select samples as compared to the controlled sample 3. It is important to observe that there is no uniform pattern in the concentration of different heavy metals. This is also indicative that there is deposition of metals in the soil due to the releases from ongoing activities in the adjoining areas.

The results indicate a change in soil quality in areas around the recycling units. The soil contamination is on account of leaching of heavy metals through discharge and also burning of waste in open land.

4.2.1.4 PBB and PBDE

PBBs and PBDEs are found in areas where computer components are disposed of in excess. Even at low concentration, these can cause irreparable damage to the nervous and reproductive systems. None of the soil samples at Loni and Mandoli have detected PBB and PBDE.

From the above, it can be inferred that soil at both the sites is significantly contaminated with heavy metals due to the e-waste recycling activities in these areas. Generally, the Mandoli soil has a higher concentration of these heavy metals as compared to the Loni area.

The results obtained from soil samples suggest that the soil characteristics have changed; also, the soil sample from the SE side has higher heavy metals content and it is important to note that the natural land gradient has a slope in the SE direction. The difference or change in the characteristic of soil appears to be on account of direct discharge of effluents into the soil and also related recycling activities being carried out in open land.

4.2.2 Mandoli Soil Quality

The characteristics of soil samples collected from the Loni area is presented in Table 10.

TABLE 10 Detailed analysis of Mandoli soil samples (18/10/2012)

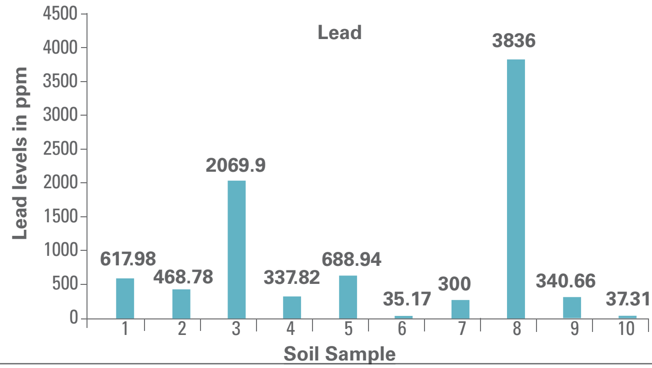
Sample description	Lead	Cadmium	Nickel	Mercury	Hex. chromium	Zinc	PBB	PBDE
	Ppm							
Soil sample 1	617.98	2.47	111.23	3.7	5.03	2,224.74	0	0
Soil sample 2	468.78	2.74	43.33	1.29	14.63	6,258.72	0	0
Soil sample 3	2,062.9	1.99	29.68	4.48	140.95	3,217.76	0	0
Soil sample 4	337.82	22.76	56.42	1.03	3.86	1,831.41	0	0
Soil sample 5	688.94	2.46	35.67	7.38	1.02	1,648.54	0	0
Soil sample 6	35.17	2.22	26	<1.0	5.42	1,510.87	0	0
Soil sample 7	300	2.98	74.58	8.71	14.93	2,237.58	0	0
Soil sample 8	3,836	1.24	13.47	4.99	3.06	1,148.04	0	0
Soil sample 9	340.66	2.24	112.47	<1.0	4.05	1,699.57	0	0
Soil sample 10	37.31	<1.0	18.65	<1.0	24.15	1,119.45	0	0

In the Mandoli area, sample no. 10 was considered as a control sample in the study; it was located at the NE side and was 700 metres away from the centre point. All the analysed samples were compared with sample no. 10 and found with very high levels of heavy metals.

4.2.2.1 Lead and Cadmium

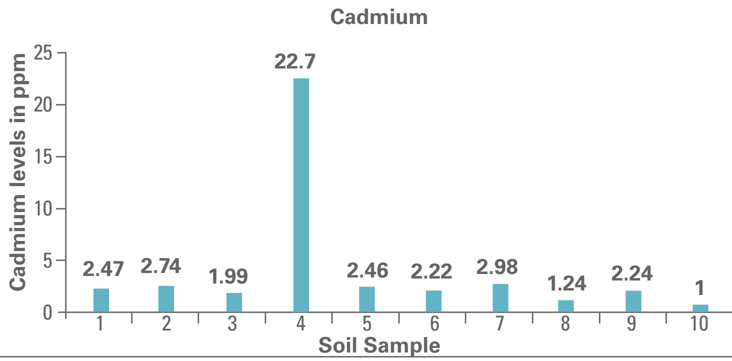
The lead levels varied from 35.17 to 3,836 ppm. All the samples (~89 per cent), except sample 6, presented much higher values as compared to the control sample (37.31 ppm). The highest lead level was almost 102 times higher than the control sample. The results of lead testing suggest that there is lead deposition in the soil in areas around the recycling units (Graph 19).

GRAPH 19
Lead levels in soil samples at Mandoli area



The cadmium levels varied from 1.24 to 22.76 ppm. All the samples showed the presence of cadmium, while the control sample was found below the detectable level (<1.0 ppm) (Graph 20).

GRAPH 20
Cadmium levels in soil samples at Mandoli area

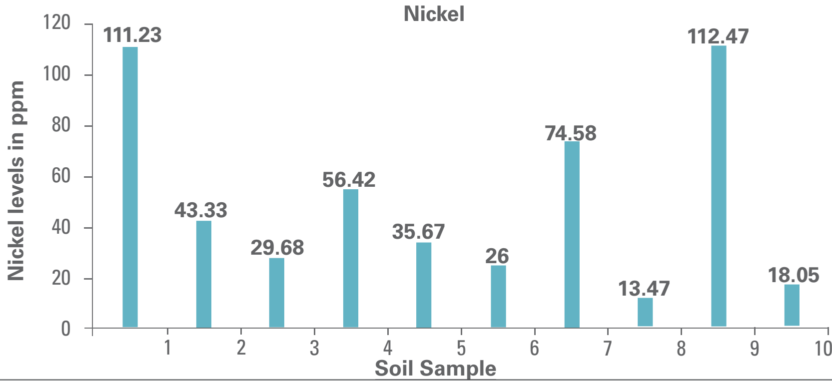


Higher values of cadmium in the soil samples are indicative of this heavy metal getting deposited in the soil in areas closer to the vicinity of the recycling units, suggesting a change in the soil quality and confirming contamination of the soil.

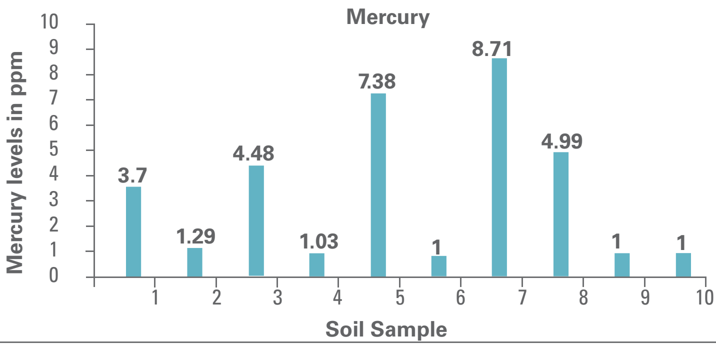
4.2.2.2 Nickel and Mercury

Nickel levels varied from 13.47 to 112.47 ppm. All the samples (~89 per cent) except sample no. 8 presented higher values as compared to control sample (18.65 ppm). The highest nickel level was almost 6 times higher than the control sample. This indicates that the character of soil in this area has undergone a change and there is a much higher presence of heavy metals in the soil (Graph 21).

The mercury levels varied from <1.0 to 8.71 ppm; 78 per cent samples were found to have high mercury levels. The other three samples as well as the control sample have shown mercury levels below the detectable limit. A higher value of mercury in



GRAPH 21
Nickel levels in soil samples at Mandoli area

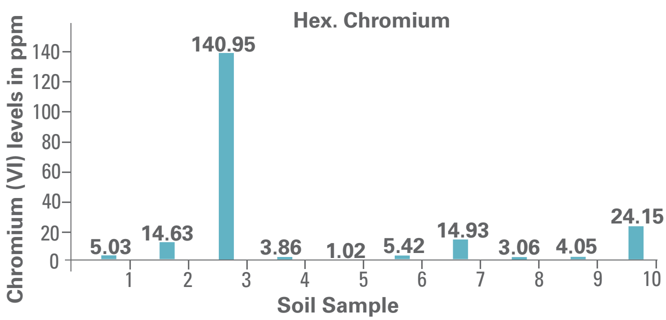


GRAPH 22
Mercury levels in soil samples at Mandoli area

the tested samples confirms the presence of mercury in the soil in excess quantity and suggests changes in the soil character around the recycling units (Graph 22).

4.2.2.3 Hexavalent Chromium and Zinc

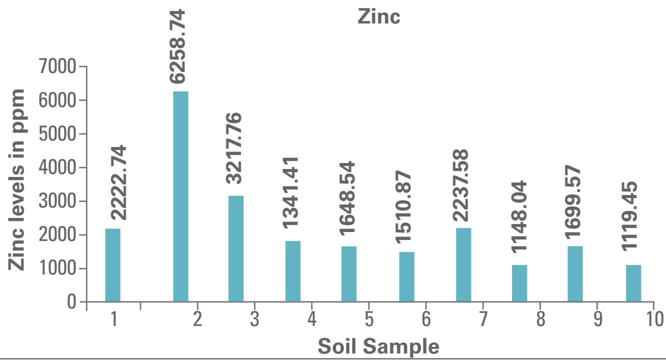
The hexavalent chromium levels varied from 1.02 to 140.95 ppm. Only one sample (sample 3) observed high levels, that is, 140.95 ppm, which was 6 times higher as compared to the control sample (24.15 ppm). The other eight samples were found with low levels of hexavalent chromium (Graph 23).



GRAPH 23
Hexavalent chromium levels in soil samples at Mandoli area

The zinc levels in all samples varied from 1,148.04 to 6,258.72 ppm; 100 per cent of the sample were found with very high zinc levels as compared to the control sample (1,119.45 ppm). The highest zinc level was almost 6 times higher than the control sample. This result also confirms change in the soil parameters in areas around the recycling sites (Graph 24).

GRAPH 24
Zinc levels in soil samples at Mandoli area



There being no standard for soil in India, the results obtained for all parameters have been compared to sample 10, which is located in a village at a distance of 750 metres, which has been considered as the control sample.

The test results of soil samples from Mandoli indicate the presence of high levels of heavy metals as compared to the control sample. Lead levels are higher even if we compare these with the US standard for lead levels in soil. The levels of other heavy metals are also higher as compared to the control sample. This suggests that the soil in and around the recycling areas are being adversely impacted due to the ongoing activities and there is a direct relationship between the metals found in the tests and the input materials used in recycling and other related activities.

The levels of mercury were also in excess as compared to the control sample, though if we compare these with the mercury standards from the US or Canada, it is within those limits.

The results obtained from soil samples suggest that the soil characteristics have changed and this may be directly on account of the recycling practices and resultant discharge of heavy metals into the medium of soil.

5

Conclusion

E-waste is globally associated with environmental contamination and serious health issues due to its chemical constituents. In India, large volumes of such waste is handled in the informal sector and recycled without any environmental safeguards. However, there is a paucity of data and evidence to correlate the activities of this sector and its impacts on the mediums of water and soil. This study has attempted to establish a relationship between the activities and its impacts. The final findings of the study suggest the following:

1. The areas of Loni and Mandoli, both on the outskirts of Delhi, support extensive e-waste recycling.
2. Both sites discharge their effluents into open lands in the absence of drains.
3. They also dispose of their solid waste in open lands, while most residual matter is disposed by open burning.
4. The effluents discharged at Mandoli are acidic, with very low pH values and high levels of heavy metals. The levels of heavy metals and other physical parameters are much beyond the accepted limits for effluents as provided by Indian standards.
5. These effluents, heavy in pollutants, are being directly discharged into soil, thus impacting the soil.
6. The water quality at Loni is better as compared to Mandoli. There is a wide variation in the levels of zinc and nickel, though within the standards for drinking water, suggesting change in water quality at various locations. High mercury levels in one of the samples are a reason for concern. This result throws up serious questions on the use of this water for drinking purposes and the need for further intensive studies.

7. Soil results at both sites confirm changes in soil parameters as compared to the respective control samples and also if compared to standards from other countries. The levels of heavy metals in soil are much higher in the Mandoli area as compared to Loni. Some of the metals found in the soil are the input materials or residues discharged into soil .There is clear evidence of changes in soil characteristics at both recycling sites and this directly relates to the activities and input materials of the waste recycling sector.

The report clearly indicates changes in soil quality in the recycling areas and this change is attributable to the recycling activities being conducted in these areas. The water quality at both sites also demonstrates some impacts of pollution but this requires further investigation. The study could not assess health impacts on the population engaged in recycling activities or living in the neighbourhood, but this needs to be investigated.

Scopes for Further Study

6

One can find enormous scope for research and further studies in this field. There is a need to come up with solutions for the various issues regarding e-waste management and address the problems emerging at present with alternative technological solutions.

Further studies in medical science can be pursued in this field as there is a huge number of human health risks associated with this problem. So, one can pursue research and studies on various health problems and diseases caused, as well as on their prevention and cure.

Contaminants can prove to be an area of vast research, as there are infinite numbers of contaminates present, which are the root cause of this problem, and which have not been adequately studied or have been completely neglected. So efforts are required to invent techniques for the removal of contaminates or at least suppress their effects.

Not much thought has been given to the field of recycling as well. If some logical efforts are made in this area, it can prove to be very successful in the management of e-waste, with considerably less capital and resources, and with the help of new techniques. As it saves the cost of raw material and prevents the e-waste to become contaminated and pollute the environment.

Field studies of various geographical locations and the condition of their air, water, and soil samples can also be an area for some fruitful research. Such studies will be helpful in understanding the severity of the problem of that particular location, so that accordingly steps can be taken to improve conditions.

References

1. http://www.un.org/esa/dsd/resources/res_pdfs/publications/trends/trends_Chemicals_mining_transport_waste/ch4_waste_management.pdf
2. Lok Sabha Unstarred Question no. 650, dt. 28.07.2010
3. Sandeep Joshi, ‘Growing E-waste Is Causing Concern’, ***The Hindu***, 28 February 2009.
4. http://rajyasabha.nic.in/rsnew/publication_electronic/E-Waste_in_india.pdf
5. J. Puckett and T. Smith, ‘Exporting Harm: The High-Tech Trashing of Asia’, The Basel Action Network, Seattle 7 Silicon Valley Toxics Coalition, 2002.
6. U. Soderstrom, ‘Boliden bAlte Handys und PCs sind wertvolle KupferminenQ’, 2004, http://www.neuematerialien.de/alle_fachbereiche/nachrichten/
7. ETC/RWM is part of the European Environment Information and Observation Network (EIONET), 2003, http://waste.eionet.eu.int/waste/6
8. http://pac.iupac.org/publications/pac/pdf/2002/pdf/7405x0793.pdf
9. http://soil-environment.blogspot.in/2009/07/heavy-metals-and-their-health-effects.html
10. http://soils.usda.gov/sqi/management/files/sq_utn_3.pdf
11. Wenjie Fan and Hongjiang Zhang, ‘The Comparison of Heavy Metals in Soils from the North and South Regions of the Tianshan Mountains’, ***Journal of Food, Agriculture & Environment***, 11 (2): 915–17, 2013.
12. http://www.waterboards.ca.gov/rwqcb2/water_issues/programs/stormwater/MRP/2013_AR/BASMAA/BASMAA_2012-13_MRP_AR_POC.pdf
13. http://www.epa.gov/superfund/students/wastsite/grndwatr.htm
14. https://fortress.wa.gov/ecy/clarc/FocusSheets/Tee%20Simplified.pdf
15. http://sgw.epa.gov.tw/resag/Update_Data/Information8839253Nov30_01Regulatory%20Standards%20of%20Heavy%20Metal%20Pollutants%20in%20Soil_20111116.pdf
16. Contaminated Land Assessment Model - Soil Guideline Values: The Way Forward (Defra,2006a)
17. http://webtoprint.yara.com/kunder/yaradev/ymark/ymark/ymark/j2012/m08/t29/0016224_2.pdf

18. http://www.lenntech.com/periodic/elements/zn.htm

19. https://www.engg.ksu.edu/CHSR/outreach/resources/docs/15HumanHealthEffectsofHeavyMetals.pdf

20. http://hppcb.gov.in/eiasorang/spec.pdf

21. Omitted by Rule 2(i)(iii) of the Environment (Protection) Third Amendment Rules, 1993, vide G.S.R. 801(E) dated 31.12.1993.

22. Inserted by rule 2(k) (ix), ibid.

... in India

large volumes of e-waste is handled in the informal sector and recycled without any environmental safeguards

Annexures

I

Annexure

Heavy Metals and Their Health Effects[13,14]

Heavy metals	Health effects	Regulatory limits
Lead: As a result of human activities, such as fossil fuel burning, mining and manufacturing, lead and lead compounds can be found in all parts of our environment. This includes air, soil and water. Lead is used in many different ways. It is used to produce batteries, ammunition, metal products like solder and pipes, and X-ray shielding devices. Lead is a highly toxic metal and, as a result of related health concerns (see below), its use in several products like gasoline, paints and pipe solder has been drastically reduced in recent years. Today, the most common sources of lead exposure in the United States are lead-based paint and possibly water pipes in older homes, contaminated soil, household dust, drinking water, lead crystal, lead in certain cosmetics and toys, and lead-glazed pottery.	• EPA has determined that lead is a probable human carcinogen. • Lead can affect every organ and system in the body. • Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system; weakness in fingers, wrists or ankles; small increases in blood pressure; and anaemia. • Exposure to high lead levels can severely damage the brain and kidneys and ultimately cause death. • In pregnant women, high levels of exposure to lead may cause miscarriage. • High-level exposure in men can damage the organs responsible for sperm production.	• EPA – 15 parts per billion (ppb) in drinking water, 0.15 micrograms per cubic metre in air. • Indian Standard – 0.05 ppm

13 http://www.lenntech.com/periodic/elements/zn.htm

14 https://www.engg.ksu.edu/CHSR/outreach/resources/docs/15HumanHealthEffectsofHeavyMetals.pdf

Heavy metals	Health effects	Regulatory limits
Cadmium: Cadmium is a very toxic metal. All soils and rocks, including coal and mineral fertilisers, contain some cadmium. Cadmium has many uses, including batteries, pigments, metal coatings and plastics. It is used extensively in electroplating.	• Cadmium and cadmium compounds are known human carcinogens. Smokers get exposed to significantly higher cadmium levels than non-smokers. • Severe damage to the lungs may occur through breathing high levels of cadmium. • Ingesting very high levels severely irritates the stomach, leading to vomiting and diarrhoea. • Long-term exposure to lower levels leads to a build-up in the kidneys and possible kidney diseases, lung damage and fragile bones.	• EPA – 5 parts per billion (ppb) or 0.005 parts per million (ppm) of cadmium in drinking water. • Food and Drug Administration (FDA) – Concentration in bottled drinking water should not exceed 0.005 ppm (5 ppb). • OSHA – An average of 5 micrograms per cubic metre of workplace air for an 8-hour workday, 40-hour work week. • Indian standards – 0.01 ppm
Nickel: Nickel is a silvery-white, hard, malleable and ductile metal. It is of the iron group and it takes on a high polish. It is a fairly good conductor of heat and electricity. In its familiar compounds, nickel is bivalent, although it assumes other valences. It also forms a number of complex compounds. Most nickel compounds are blue or green. Nickel dissolves slowly in dilute acids but, like iron, becomes passive when treated with nitric acid. Finely divided nickel absorbs hydrogen.	• Humans may be exposed to nickel by breathing air, drinking water, eating food or smoking cigarettes. Skin contact with nickel-contaminated soil or water may also result in nickel exposure. In small quantities, nickel is essential, but when the uptake is too high it can be a danger to human health. • An uptake of too large quantities of nickel has the following consequences: • Higher chances of development of lung cancer, nose cancer, larynx cancer and prostate cancer • Sickness and dizziness after exposure to nickel gas	Indian standards* – 3 ppm *– general standard for discharge of environmental pollutanats for inland surface waters
	• Lung embolism • Respiratory failure • Birth defects • Asthma and chronic bronchitis • Heart disorders	

Heavy metals	Health effects	Regulatory limits
Mercury: Mercury combines with other elements to form organic and inorganic mercury compounds. Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings, switches, light bulbs and batteries. Coal-burning power plants are the largest human-caused source of mercury emissions to the air in the United States. Mercury in soil and water is converted by microorganisms to methyl mercury, a bioaccumulation toxin.	• The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens. • The nervous system is very sensitive to all forms of mercury. • Exposure to high levels can permanently damage the brain, kidneys and developing foetuses. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing and memory problems. • Short-term exposure to high levels of metallic mercury vapours may cause lung damage, nausea, vomiting, diarrhoea, increases in blood pressure or heart rate, skin rashes and eye irritation.	• EPA – 2 parts per billion parts (ppb) in drinking water. • FDA – 1 part of methyl mercury in a million parts of seafood. • OSHA – 0.1 milligram of organic mercury per cubic metre of workplace air and 0.05 milligrams per cubic metre of metallic mercury vapour for 8-hour shifts and 40-hour work weeks. • Indian standards – 0.001 ppm
Chromium: Chromium is found in rocks, animals, plants and soil, and can be liquid, solid or gas. Chromium compounds bind to soil and are not likely to migrate to ground water, but they are very persistent in sediments in water. Chromium is used in metal alloys such as stainless steel; protective coatings on metal (electroplating); magnetic tapes; and pigments for paints, cement, paper, rubber, composition floor covering and other materials. Its soluble forms are used in wood preservatives.	• Chromium (VI) compounds are toxins and known human carcinogens, whereas chromium (III) is an essential nutrient. • Breathing high levels can cause irritation to the lining of the nose; nose ulcers; runny nose; and breathing problems, such as asthma, cough, shortness of breath or wheezing. Skin contact can cause skin ulcers. Allergic reactions consisting of severe redness and swelling of the skin have been noted. • Long-term exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation.	• EPA – 0.1 ppm (parts per million) in drinking water. • FDA – Should not exceed 1 milligram per litre (1 ppm) in bottled water. OSHA – An average between 0.0005 and 1.0 milligram per cubic metre of workplace air for an 8-hour workday, 40-hour work week, depending on the compound. • Indian standards – 0.05 ppm

Heavy metals	Health effects	Regulatory limits
Zinc: As for other heavy metals, zinc is also needed by the human body in traces.	• When people absorb too little zinc they can experience a loss of appetite, decreased sense of taste and smell, slow wound healing and skin sores. • Zinc shortages can even cause birth defects. Although humans can handle proportionally large concentrations of zinc, too much zinc can still cause imminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia.	Indian standards – 5 ppm
	• Very high levels of zinc can damage the pancreas, disturb protein metabolism and cause arteriosclerosis. • Extensive exposure to zinc chloride can cause respiratory disorders. • In the workplace environment, zinc contagion can lead to a flu-like condition known as metal fever. This condition will pass after two days and is caused by over sensitivity. Zinc can also be a danger to unborn and newborn children, who are exposed to it through blood or milk of their mothers.	

II

Annexure

Details of Activities and Processes and Workers in Loni and Mandoli Area

1. Loni Area

1.1 Activities and Processes at Loni Area

The Loni area consists of around 40 operational units which carry out waste recycling in a rudimentary manner. The methodology, tools and techniques used here are basic such as heating by blow torch or stove, breaking with hammer, chemical stripping, melting or open burning, without any concern for the environment. These units operate in semi-constructed buildings which act both as working places as well as accommodations for the people engaged in recycling activities.

Recycling the waste circuit boards of CFLs to extract lead, aluminium and iron is the primary activity taking place in the area. One can witness some copper extraction carried out by dismantling transformers (copper is extracted in very small amounts because of limited availability of waste transformers, as most of the waste transformers end up with other recycling units). These activities are essentially rudimentary as there is hardly any focus on using efficient and environmentally friendly methods. The method used to extract copper, lead and aluminium is based on the rule of thumb, and people rely on their conventional wisdom and experience to extract whatever is possible. There is very little attempt to innovate or make changes in the process of extraction. Moreover, there is no inclination or motivation to improve working conditions perhaps due to low profit margins and also lack of awareness on health impacts.

The area is more or less homogeneous as far as the recycling activities are concerned—most of the units indulge in recycling circuit boards of CFLs. There are at most two to three units who recycle circuit boards of telephones and televisions. However, there is no set pattern of a particular unit working on a particular type of waste; people take up recycling activities based on availability of waste in the market. Metals are extracted and sold to dealers from different trades. The desoldering and manual dismantling is done in the workers' homes. Open burning at large is carried out in the open field areas outside the homes. The workers heat the circuit board with the help of blow torches using LPG cylinders. The boards are then slapped against the ground to shed the mounted components such as chips, condensers, resistors and solders.

The solders are melted in a vessel on the gas stove and sold. The chips and diodes are sold for gold recovery to the acid chemical strippers at Meerut and Muradabad. The components are also separated manually by hammers, wire clippers, etc. The components found to be resaleable are sold in the market. The rest of the boards along with their components (like capacitors and transformers) are burned in heaps in open fields to recover metals like copper, iron, brass and aluminium. The area is scattered with the ashes and the charred circuit board residues. The workers use no protective devices.

Almost all workers engaged in these activities are illiterate, which further exacerbates their lack of awareness and understanding of the gravity of the situation. The activity with blow torches is carried out in a small, congested and poorly ventilated area. With the workplace and residence being common, the workers effectively live, cook and eat in the same place. This exposes them to the lead fumes from the solders in PWBs, highly toxic dioxins and furans released from PCBs in older capacitors and transformers, and brominated flame retardants (BFRs) in PCBs, plastic casings, cables and polyvinyl chloride (PVC) cable insulation when burned to retrieve copper from the wires.[15]

1.2 Workers in the Loni area

Most of the units operational in the Loni area employ family members of the household where the unit is functioning. On an average 2–4 persons are employed in each unit. In total, there are around 150 workers employed at any given point of time. Most of workers belong to the minority community and have migrated from rural areas of the state of Bihar and few are from the state of Uttar Pradesh. Most of them live in residence-cum-factories of the area. The earnings from each unit depend on the individual's ability to purchase raw material as economies of scale come into

15 Toxic Links, 'Time Is Running Out'.

play. While some smaller units could barely manage Rs 10,000 to 12,000 a month, larger ones with more raw materials at hand could even earn up to Rs 100,000 per month. The nature of wok is mostly hazardous, thus it obviously poses a considerable threat to the health and well-being of the workers. Unfortunately, since these units are operating in the backyards of these houses, all members of the family including children are directly exposed to these hazardous elements. The working hours of these people depend on the availability of waste. These people work during the whole year, there being no clear-cut seasonal pattern. Everything depends on the profit margins and the availability of waste. Most people working here are self-employed, living at the very place where these activities are conducted. While often the entire family is involved in the recycling job, in some instances, the men are employed outside and the women are engaged in the recycling.

2. Mandoli Area

2.1 Activities and Processes

The Gaddha colony cluster consists of around 80 operational units and most are engaged in waste recycling activities. These units run in temporary, semi-constructed buildings, with only four walls and a door and without any kind of roofing. E-waste recycling or processing of PCBs is the most common activity in this area.

There are no provisions for electricity and water since the area is largely illegal. Therefore, all the work is done in daylight in the open. Water is sourced from the subsoil and is pumped by a tube well, which is shared between two or three units. It is difficult to ascertain the total quantum of water being pumped out daily for the industrial process but physical verification suggests that many pumps are operating in this area.

The following is a brief discussion regarding the type of units operational in the area:

1. **Mild steel casting:** There are 2 mild steel casting units operational in the area. The process involves heating the raw steel at 800 degree Celsius, after which silver is added to it, which acts as the catalyst; then the steel is heated again, this time up to 1,400 degree Celsius. Molten iron is then poured into moulds of desired shapes. These units have essential linkages with the automobile industry as they basically prepare automobile parts.
2. **Metallic waste reprocessing:** These units thrive on the metallic industrial waste from furnaces, also known as *keet*, which is brought here free of cost from the

adjoining industrial area of Mandoli. Keet has a very low content of metals in it, which is extracted adopting some of the most rudimentary processes. The process involves crushing of keet, followed by precipitation of metals while waste is settled at the bottom. There is a meagre output of around 4–5 per cent of metals, generally copper and iron. There in only one such unit operational in the area.

3. **Footwear segregation and sorting:** These units are involved in sorting old, discarded, out-of-use, worn-out shoes and slippers. They can be easily identified in the area by the presence of massive heaps of shoes alongside these units. Their basic work is to segregate shoes according to their utility as furnace fuel, these shoes are brought here from Delhi and outside and after segregation they are sold to industries in Mandoli and adjoining industrial areas. These industries use them as an alternative to wood and coal in furnaces as they are comparatively cheaper and also burn better. While wood costs around Rs 7/kg, shoes cost only Rs 5/kg, which is the basic driver for its demand. However, using shoe and slippers for burning has serious implications for the environment.
4. **Glass:** These units first segregate coloured and colourless glass. While colourless glass is sold directly in the market, coloured ones are first treated with acid to remove the colour and then sold in the market. There are 2 glass units operational in the area.
5. **Denim washing:** There were three such units, which have been closed a few years back because of the huge amount of water consumed by these units. They were also a major source of ground water contamination in the area.
6. **Television dismantling:** There is only one such unit operational in the area, where various parts of televisions are segregated. Plastic casing, metallic parts and picture tubes are separated and further sold separately.
7. **Copper extraction:** These units constitute a large chunk of the area. There are 60–65 such units operational in the area. They extract copper from mother boards of electronic equipments such as computers, televisions and cell phones.

Mother boards are brought here from other computer dismantling units in Delhi and outside where the integrated circuits (ICs) are removed from the circuit boards and sold separately.

Most of the units use acid wash as the primary copper extraction method, while some burn the mother boards directly.

In the acid bath method, mother boards are dipped in a solution containing 100 litres of water with 15 litres of aqua-regia in it and left for 24 hours. After this the solution is drained out with the help of a drainage pipe attached to the container and copper is separated from the plastic. Copper thus extracted is dried in the open and then sold in the market, with the yield being around 80 per cent. The plastic base of the board is sometimes used to make washers.

The method involved in this process is extremely harmful from the environmental point of view and also poses occupational hazards to the workers employed in the units.

Apart from these major categories of units, the area also has some residential buildings, a few tea-stalls, some petty general stores, a few property dealing shops, a water tank and some sand blasting units.

2.2 Workers at Mandoli Area

Most of the units operational in Gaddha colony employ 2–4 workers, barring a few like the keet unit, which employs as much as 6 workers. In total, there are around 300 workers employed at any given point of time.

Most of the workers have migrated from rural areas of Bihar and a few from other parts of Uttar Pradesh. These workers reside in nearby colonies like Amit Vihar in rented accommodations, while some workers even live in the factory premises for economic reasons.

Almost all the workers are adults as factory owners avoid recruiting minors and mothers who bring children to work as the nature of work is hazardous and involves dangerous chemicals and acids.

One can see a considerable difference in the amount of money which female workers fetch as against their male counterparts. While a male worker may attract Rs 5,000 to 7,000 per month depending on the nature of his skill and experience, a female worker gets only Rs 3,000 to 3,500 per month. The difference can perhaps be attributable to the fact that male workers are involved in more labour-intensive and dangerous work, while female workers are restricted to peripheral jobs like sorting, scrubbing and cleaning of the material.

The nature of work is mostly hazardous, thus it poses a considerable threat to the health and well-being of workers. Although some factory owners do provide workers with gloves, masks and boots, the lack of any standards and set procedures means that workers continue to work with or without them.

In the Mandoli area, the predominant process of recycling is acid bath recovery of copper metal from PCBs. Most of the activity here is done in small, unorganized, unregistered industrial sheds, employing a small number of male and female contractual workers. The e-waste is bought from scrap dealers or through bulk industrial waste auction purchases. After the manual dismantling of mounted accessories like capacitors, diodes and ICs, mostly by female workers, the metal is recovered as depicted in the following flowchart.

III

Annexure

Standards for Water

Drinking Water Specification: IS: 10500, 1992 (Reaffirmed 1993)[16]

S. No	Parameter	IS: 10500 Requirement (Desirable limit)	Undesirable effect outside the desirable limit	IS: 10500Permissible limit in the absence of alternate source
Essential Characteristics				
1.	pH	6.5 – 8.5	Beyond this range the water will effect the mucous membrane and / or water supply system	No relaxation
2.	Colour (Hazen Units), Maximum	5	Above 5, consumer acceptance decreases	25
3.	Odour	Unobjectionable	--	--
4.	Taste	Agreeable	--	--
5.	Turbidity, NTU, Max	5	Above 5, consumer acceptance decreases	10
Following Results are expressed in mg/1 :				
6.	Total hardness as CaCO3, Max	300	Encrustation in water supply structure and adverse effects on domestic use	600
7.	Iron as Fe, Max	0.30	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria.	1.0

16 http://hppcb.gov.in/eiasorang/spec.pdf

8.	Chlorides as Cl, Max	250	Beyond this limit taste, corrosion and palatability are effected	1000
9.	Residual, Free Chlorine, Min	0.20	--	--
Desirable Characteristics				
10.	Dissolved solids, Max	500	Beyond this palatability decreases and may cause gastro intentional irritation	2000
11.	Calcium as Ca, Max	75	Encrustation in water supply structure and adverse effects on domestic use	200
12.	Magnesium as Mg, Max	30	--	100
13.	Copper as Cu, Max	0.05	Astringent taste, discoloration and corrosion of pipes, fitting and utensils will be caused beyond this	1.5
14.	Manganese as Mn, Max	0.1	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures	0.3
15.	Sulphate as SO4 Max	200	Beyond this causes gastro intentional irritation when magnesium or sodium are present	400
16.	Nitrates as NO3	45	Beyond this methanemoglobinemia takes place	100
17.	Fluoride, Max	1.0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1.5
18.	Phenolic compounds as C6H5OH, Max	0.001	Beyond this, it may cause objectionable taste and odour	0.002
19.	Mercury as Hg, Max	0.001	Beyond this, the water becomes toxic	No relaxation
20.	Cadmium as Cd, Max	0.01	Beyond this, the water becomes toxic	No relaxation
21.	Selenium as Se, Max	0.01	Beyond this, the water becomes toxic	No relaxation
22.	Arsenic as As, Max	0.05	Beyond this, the water becomes toxic	No relaxation
23.	Cyanide as CN, Max	0.05	Beyond this, the water becomes toxic	No relaxation
24.	Lead as Pb, Max	0.05	Beyond this, the water becomes toxic	No relaxation
25.	Zinc as Zn, Max	5	Beyond this limit it can cause astringent taste and an opalescence in water	15
26.	Anionic detergents as MBAS, Max	0.2	Beyond this limit it can cause a light froth in water	1.0

27.	Chromium as Cr^{6+}, Max	0.05	May be carcinogenic above this limit	No relaxation
28.	Ploynucleararomatic hydrocarbons as PAH, Max	--	May be carcinogenic	--
29.	Mineral Oil, Max	0.01	Beyond this limit undesirable taste and odour after chlorination take place	0.03
30.	Pesticides, Max	Absent	Toxic	0.001
31.	Radioactive materials a) α emitters Bq/1, Max b) β emitters Pci/1, Max	-- --	-- --	0.1 1
32.	Alkalinity, Max	200	Beyond this limit taste becomes unpleasant	600
33.	Aluminum as Al, Max	0.03	Cumulative effect is reported to cause dementia	0.2
34.	Boron, Max	1	--	5

IV

Annexure

General Standards for Discharge of Environmental Pollutants

Part A: Effluents

SN	Parameter	Standards			
		Inland surface water	Public sewers	Land of irrigation	Marine/Coastal areas
1.	Colour and odour	Of Annexure 4	–	See 6 of Annexure 5	See 6 of Annexure 5
2.	Suspended solids mg/1, max.	100	600	200	For processing wastewater, 100 For cooling water effluent, 10 per cent above total suspended mater of influent
3.	Particle size of suspended solids	Shall pass 850 micron IS sieve	–		Floatable solids, solids max. 3 mm Settleable solids max. 856 microns
4.	pH value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
5.	Temperature	Shall not exceed 5°C above the receiving water temperature	–	–	Shall not exceed 5°C above the receiving water temperature
6.	Oil and grease, mg/1 max.	10	20	10	20
7.	Total residual chlorine, mg/1 max	1.0	–	–	1.0

SN	Parameter	Standards			
		Inland surface water	Public sewers	Land of irrigation	Marine/Coastal areas
8.	Ammonical Nitrogen (as N), mg/l, max.	50	50	–	50
9.	Total nitrogen (as N), mg/l, max.	100	–	–	100
10.	Free ammonia (as NH3), mg/l, max	5.0	–	–	5.0
11.	Biochemical oxygen demand (3 days at 27°C), mg/l, max	30	350	100	100
12.	Chemical oxygen demand, mg/l, max	250	–	–	250
13.	Arsenic (as As) mg/l, max	0.2	0.2	0.2	0.2
14.	Mercury (as Hg), mg/l, max	0.01	0.01	–	0.01
15.	Lead (as Pb), mg/l, max	0.1	0.1	–	2.0
16.	Cadmium (as Cd), mg/l, max	2.0	1.0	–	2.0
17.	Hexavalent chromium (as Cr+6), mg/l, max	0.1	2.0	–	1.0
18.	Total chromium (as Cr), mg/l, max	2.0	2.0	–	2.0
19.	Copper (as Cu), mg/l, max	3.0	3.0	–	30
20.	Zinc (as Zn), mg/l, max	5.0	15	–	15
21.	Selenium (as Se), mg/l, max	0.05	0.05	–	0.05
22.	Nickel (as Ni), mg/l, max	3.0	3.0	–	50
23.	Cyanide (as CN), mg/l, max	0.2	2.0	0.2	0.2
24.	Fluoride (as F), mg/l, max	2.0	15	–	15
25.	Dissolved phosphates (as P), mg/l, max	5.0	–	–	–

SN	Parameter	Standards			
		Inland surface water	Public sewers	Land of irrigation	Marine/Coastal areas
26.	Sulphide (as S), mg/l, max	2.0	–	–	5.0
27.	Phenolic compounds (as C6H5OH), mg/l, max	1.0	5.0	–	5.0
28.	Radioactive materials				
	α emitters micro cure mg/l, max	10–7	10-7	10–8	10–7
	β emitters micro cure mg/l, max	10–6	10–6	10–7	10–6
29.	Bio-assay test	90 % survival of fish after 96 hours in 100 % effluent	90 % survival of fish after 96 hours in 100 % effluent	90 % survival of fish after 96 hours in 100 % Effluent	90 % survival of fish after 96 hours in 100 % effluent
30.	Manganese (as Mn)	2 mg/l	2 mg/l	2 mg/l	2 mg/l
31.	Iron (as Fe)	3 mg/l	3 mg/l	3 mg/l	3 mg/l
32.	Vanadium (as V)	0.2 mg/l	0.2 mg/l	–	0.2 mg/l
33.	Nitrate Nitrogen	10 mg/l	–	–	20 mg/l

*Note: * These standards shall be applicable for industries, operations or processes other than those industries. Operations or processes for which standards have been specified in Schedule of the Environment Protection Rules 1989.*

Annexure V

(For the purposes of Parts – A, B and C)

The State Boards shall abide by the following guidelines in enforcing the standards specified under the schedule VI:

1. The waste waters and gases are to be treated with the best available technology (BAT) in order to achieve the prescribed standards.
2. The industries need to be encouraged for recycling and reuse, of waste materials as far as practicable in order to minimize the discharge of wastes into the environments.
3. The industries are to be encouraged for recovery of biogas, energy and reusable materials.
4. While permitting the discharge of effluent and emission into the environment, State Boards have to take into account the assimilative capacities of the receiving bodies, especially water bodies so that quality of the intended use of the receiving waters is not affected. Where such quality is likely to be effected discharges should not be allowed into water bodies.
5. The Central and State Boards shall put emphasis on the implementation of clean technologies by the industries in order to increase fuel efficiency and reduce the generation of environmental pollutants.
6. All efforts should be made to remove colour and unpleasant odour as far as practicable.
7. The standards mentioned in the Schedule shall also apply to all other effluents discharged such as industrial mining, and mineral processing activities and sewage.
8. The limit given for the total concentration of mercury in the final effluent of caustic soda industry is for the combined effluent from (a) Cell house, (b) Brine Plant, (c) Chlorine handling, (d) hydrogen handling and (e) hydro choleric acid plant.

9. 1[(a).... (f)]

10. All effluents discharge including from the industries such as cotton textile, composite woollen mills, synthetic rubber, small pulp & paper, natural rubber, petrochemicals, tanneries, point dyes, slaughter houses, food & fruit processing and diary industries into surface waters shall conform to be BOD limit specified above, namely 30 mg/l. For discharge an effluent having a BOD more than 30 mg./l, the standards shall conform to those given, above for other receiving bodies, namely, sewers, coastal waters, and land for irrigation.

11. [***.......][17]

12. In case of fertilizer industry the limits in respect of chromium and fluoride shall be complied with at the outlet of chromium and fluoride removal units respectively.

13. In case of pesticides:
    a. The limits should be complied with at the end of the treatment plant before dilution.
    b. Bio-assay test should be carried out with the available species of fish in the receiving water, the COD limits to be specified in the consent conditions should be correlated with the BOD limits.
    c. In case metabolites and isomers of the Pesticides in the given list are found in significant concentration, standards should be prescribed for these also in the same concentration as the individual pesticides.
    d. Industries are required to analyze pesticides in waste water by advanced analytical methods such as GLC/HPLC.

14. [18]The chemical oxygen demands (COD) concentration in a treated effluent, if observed to be persistently greater than 250 mg/l before disposal to any receiving body (public sewer, land for irrigation, inland surface water and marine coastal areas), such industrial units are required to identify chemicals causing the same. In case these are found to be toxic as defined in the Schedule I of the Hazardous Rules 1989 the State Board in such cases shall direct the industries to install tertiary treatment stipulating time limit.

15. Standards specified in Part A of Schedule – VI for discharge of effluent into the public sewer shall be applicable only if such sewer leads to a secondary treatment including biological treatment system, otherwise the discharge into sewers shall be treated as discharge into inland surface waters].

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17 Omitted by Rule 2(i)(iii) of the Environment (Protection) Third Amendment Rules, 1993, vide G.S.R. 801(E) dated31.12.1993

18 Inserted by rule 2(k) (ix), ibid.

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