2025

Environmental Mapping of **Industries in the Lahore Division**

Mapping Industrial Dynamics to Shape Lahore's ***Green Future***

The Urban Unit
Urban Sector Planning & Management Services Unit (Pvt.) Ltd.

EPA
اداره تحفظ ماحول-حکومت پنجاب

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Mapping Industrial Dynamics to Shape Lahore's ***Green Future*** 2025

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Abbreviations

CIWCE	Center for the improvement of working conditions and environment
ECS	Emission Control System
EPA	Environment Protection Agency
EPD	Environment Protection Department
EPD	Environment Protection Department
GIS	Geographic Information System
GOP	Government of Pakistan
ISIC	International Standard Industrial Classification of All Economic Activities
KIZ	Kasur Industrial Zone
NEQS	National Environmental Quality Standards
NGO	Non-Governmental organization
PCSIR	Pakistan Council of Scientific and industrial research
PEPA	Punjab Environmental Protection Act
QA	Quality Assurance
QC	Quality Control
QIE	Quaid I Azam Industrial Estate
SIE	Sundar Industrial Estate
UNSD	United Nations Statistical Division
WWTP	Waste Water Treatment Plant

Executive Summary

Industrial mapping is essential for understanding the spatial distribution of industries, assessing their environmental impacts, and guiding policymakers in implementing effective pollution control measures. Lahore Division, as one of the major industrial hubs of Pakistan, requires a systematic evaluation to track emissions, fuel consumption patterns, and compliance with environmental regulations. By conducting this comprehensive industrial mapping survey, a robust baseline has been established to support sustainable industrial development while addressing environmental concerns.

Understanding trends in the condition of environmental compartments such as air and water is a critical step in developing informed and effective environmental protection strategies. Industries, as significant contributors to environmental degradation, are at the heart of this challenge.

The **Punjab Environmental Protection Act (PEPA) 1997 (amended up to 2017) under Section 6 emphasizes the importance of conducting surveys, surveillance, monitoring, and research to prevent and control pollution within the industrial sector.** However, a lack of detailed and actionable data on industrial hotspots and their environmental impact has limited the effectiveness of these measures.

This report aims to address this gap by providing a comprehensive environmental mapping of industries within the Lahore Division. The mapping highlights the spatial distribution of industries, and the resulting environmental stressors. By doing so, it serves as a critical tool for policymakers, regulators, and industries themselves to prioritize interventions, enforce regulations, and transition toward sustainable practices.

The whole mapping exercise in Lahore Division focused on a comprehensive assessment of air and water pollution sources within key industrial estates, including Sunder Industrial Estate, Quaid-i-Azam Industrial Estate, Kasur Industrial Zone, Chunian Industrial Estate, and scattered industries throughout the division. The study covered a diverse range of industries, from large-scale operations to small cottage industries. Preliminary surveys included meetings with industrial stakeholders to identify pollution sources, and walkthrough surveys were conducted to gather data on air emissions, boilers, furnaces, fuel consumption, and water usage. A detailed analysis of these factors according to the findings of the surveys is available later in the report. After initial visits, revalidation surveys were also done in October and December (two phases) during which selected industries were visited again to see their ECS and the final findings are detailed in the report.

As Lahore Division (comprising Lahore, Sheikhupura, Kasur, and Nankana Sahib) hosts a diverse range of industries, including large-scale manufacturing units and smaller cottage industries. Given its economic significance and high industrial density, a structured approach was necessary to evaluate the sector's environmental footprint. This study was undertaken to gather reliable data that can inform policymakers, regulatory bodies, and industry stakeholders about the state of industrial operations and their impact on air and water quality. The survey aimed to provide transparent insights and encourage industries to adopt sustainable practices by assessing critical factors such as boiler and furnace conditions, fuel types, and emission control measures.

A structured methodology was employed, beginning with preliminary industrial surveys involving walkthrough inspections and stakeholder meetings. Extensive discussions were held with the Environmental Protection Agency (EPA) to refine the survey modalities, ensuring that key environmental parameters were effectively captured. To enhance efficiency, an Android-based application and dashboard were developed for real-time data collection and analysis. Surveyors were trained to ensure accuracy in data collection, and stringent quality control mechanisms were implemented, including multi-tier validation, app data screening, and revalidation surveys. A post-survey workshop facilitated experience sharing and methodological refinements, helping address gaps and inconsistencies in the data collection process.

Industrial Mapping at a Glance

7,475 industrial units across Lahore Division

5006 units in Lahore district

1531 units in Sheikhupura district

772 units in Kasur district

166 units in Nankana district

A vast majority (**92%**) of industries were functional, while **8**% were found to be non-functional. Boilers were identified in **570 industries**, with a total of **632 boilers** recorded. Wet bottom boilers were the most common, with biomass being the primary fuel source. Alarmingly, **39%** of boilers were in poor condition, with an additional 3% classified as failing. Similarly, furnaces were recorded in **338 industries**, totaling **374 units**. Heating furnaces were the most prevalent, with biomass and RLNG as the leading fuel sources. The condition of furnaces also raised concerns, with 38% in poor condition and 9% in failing condition.

The findings indicate a significant reliance on biomass, necessitating a deeper evaluation of its environmental impact. A substantial proportion of boilers and furnaces were found to be in poor or failing condition, highlighting inefficiencies and potential non-compliance with emission standards. The data underscores the need for targeted interventions, such as the promotion of cleaner fuels, modernization of industrial equipment, and stringent enforcement of environmental regulations. Furthermore, the study revealed gaps in compliance, emphasizing the need for enhanced transparency and improved industrial monitoring mechanisms.

One of the critical aspects evaluated in this study was the installation of Emission Control Systems (ECS) across industrial units in Lahore Division. A total of **622** ECS units were recorded, with wet scrubbers (249) and cyclone separators (180) being the most common types. The condition of these systems varied significantly, with 16% rated as excellent, 42% as good, 38% as poor, and 4% as failing.

Initially, only 43% of industries with boilers and furnaces had installed ECS. However, following strict regulatory enforcement and an awareness campaign on the direction by the Senior Minister under the CM Punjab Smog Mitigation Plan, the adoption of ECS increased significantly, reaching **96%** as of today. This remarkable progress highlights the effectiveness of consistent enforcement and due diligence. It serves as a strong example of how regulatory measures, when implemented persistently, can drive industry-wide change. However, while the installation of ECS has improved, *the next step is to assess their efficacy in reducing emissions*. A comprehensive study must be undertaken to evaluate the actual environmental impact of these systems, ensuring they operate effectively and meet desired air quality standards.

Green infrastructure remains limited within industrial zones. The survey found that only **2,299 industries (31%) have trees on their premises**, with a total tree count of **141,500** across all surveyed units. Expanding tree cover within industrial estates can help mitigate air pollution, heat stress, and carbon emissions, improving both environmental and workplace conditions.

Industrial wastewater management and water consumption in the Lahore Division present significant environmental concerns. About **57%** of industries dispose of wastewater into underground reservoirs, risking groundwater contamination, while **11%** discharge into water channels, affecting rivers and canals. Additionally, **7%** use open drains, and others discharge onto open or agricultural land, leading to soil and water pollution.

Only **32%** of industries have septic systems, **30%** use sedimentation tanks, and fewer adopt advanced treatments—**20%** have biological treatment units, **12%** use activated sludge, and 7% employ membrane bioreactors. Meanwhile, 41 wastewater treatment plants (WWTPs) are non-operational, and 17 are partially operational, raising concerns about untreated industrial discharge.

Water consumption patterns vary across industries, with **6,516** industries consuming less than **2,000 liters** per month, indicating minimal water use. However, **421** industries use between **2,001–10,000** liters, and **101** industries consume over **10,000 liters** per month, marking them as heavy water users, likely in textiles, pulp and paper, and beverage sectors. These findings highlight the urgent need for stricter wastewater management, enhanced treatment infrastructure, and improved water efficiency measures to mitigate industrial pollution and ensure sustainable water use in Lahore.

The results indicated that **38%** of industries have exhaust systems for power generators, which contribute significantly to air pollution. A staggering **99%** of these generators operate on diesel, leading to high emissions, particularly in densely industrialized areas. Only **0.53%** use petrol, and a mere **0.24%** operate on gas, highlighting the lack of cleaner fuel alternatives. Promoting natural gas or renewable energy-powered generators can play a crucial role in reducing industrial emissions.

Industrial dust pollution was observed in **27%** of industries, with furniture manufacturing, marble cutting, and grain processing among the most affected sectors. The high prevalence of airborne dust in these industries presents serious occupational health risks and contributes to ambient particulate pollution, necessitating improved dust control mechanisms, such as localized ventilation and air filtration systems.

For Lahore and Punjab, it is **recommended** that periodic performance evaluations of installed ECS be mandated, with strict penalties for non-functional or underperforming systems. Additionally, incentives should be provided to industries that demonstrate compliance and invest in cleaner technologies. A centralized monitoring system should be established to track emissions in real-time, integrating sensor-based data for continuous assessment. Moreover, dedicated funding should be allocated for the upgradation of outdated industrial equipment, encouraging a transition towards energy-efficient and environmentally friendly operations. Furthermore, an industry specific emission inventory should be developed to comprehensively assess pollutants as well as greenhouse gas (GHG) emissions and identify high-emission industries requiring targeted interventions. This will support Lahore and Punjab in setting up an emission trading system, where industries exceeding their allocated emission limits can buy or sell emission credits, incentivizing lower emissions and ensuring environmental sustainability.

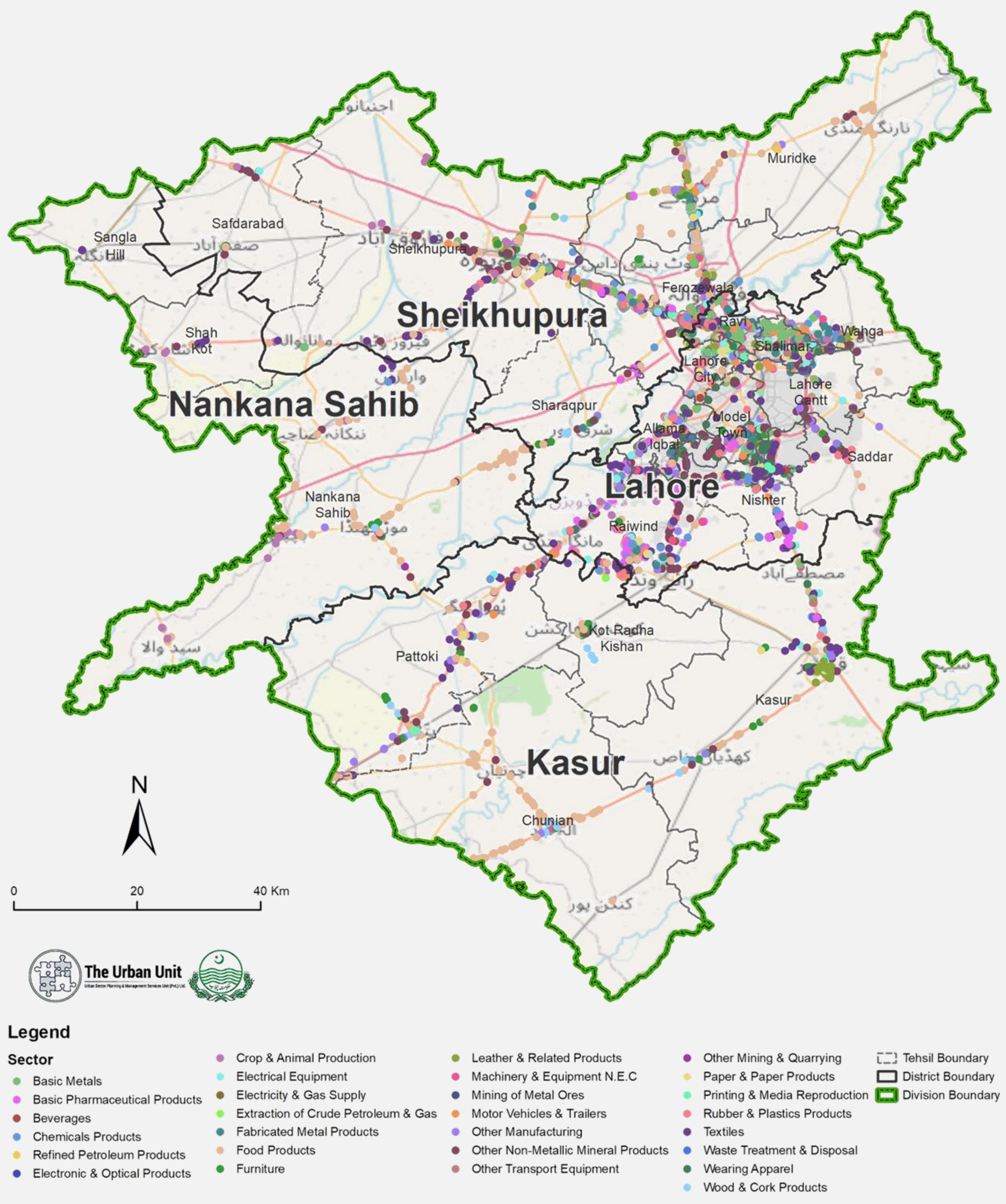
To address industrial wastewater management and water consumption challenges in Lahore, strict enforcement of wastewater treatment regulations is crucial, ensuring all industries install and maintain effective Effluent Treatment Plants (ETPs). The revival of non-operational WWTPs and mandatory monitoring of industrial discharge should be prioritized. Incentives, such as subsidies for wastewater treatment technology and penalties for non-compliance, can encourage industries to adopt biological treatment units, activated sludge, and membrane bioreactors. Furthermore, a centralized industrial wastewater treatment facility should be established for small and medium enterprises (SMEs) unable to afford individual systems. To curb excessive water consumption, water recycling and reuse strategies must be promoted, especially in high-usage sectors like textiles and beverage manufacturing. Public-private partnerships (PPPs) can facilitate investment in modern water-efficient technologies. Additionally, industries must ensure the use of Personal Protective Equipment (PPEs) for workers to safeguard occupational health and safety.

Lastly, a robust environmental monitoring framework must be implemented, integrating real-time digital tracking of industrial effluents and water use, ensuring transparency and accountability in Lahore's industrial sector.

These measures will ensure that the momentum gained through regulatory enforcement translates into long-term industrial sustainability, rather than being a one-time achievement. This industrial mapping survey serves as a critical resource for stakeholders to drive policy reforms, strengthen regulatory oversight, and facilitate the transition toward a more sustainable and environmentally responsible industrial sector in Lahore Division. By leveraging the insights gained from this study, authorities can take proactive measures to mitigate industrial pollution, support industries in adopting greener technologies, and establish market-based solutions such as emission trading, ensuring a balanced approach to economic growth and environmental stewardship.

Industrial Map of Lahore Division

Lahore Division hosts 7,475 industrial units, with the majority (5,006 units) concentrated in Lahore district, making it the region's primary industrial hub. Sheikhupura follows with 1,531 units, while Kasur (772 units) and Nankana Sahib (166 units) have relatively smaller industrial footprints. These Industries are largely confined to key corridors along major highways and urban peripheries, particularly in Lahore and Sheikhupura, where textile, chemical, pharmaceutical, and manufacturing units dominate. This concentration underscores the need for targeted environmental regulations, wastewater management, and emission control measures to mitigate industrial pollution and ensure sustainable growth.



Introduction

Industrial activity plays a pivotal role in the economic landscape of Punjab, contributing significantly to employment and growth. However, with this expansion comes the pressing challenge of environmental management. To develop a strategic and data-driven approach for industrial regulation, this survey provides a comprehensive mapping of industries across Lahore Division, covering both large-scale manufacturing units and small cottage industries. The study encompasses key industrial estates, including Sunder Industrial Estate (SIE), Quaid-e-Azam Industrial Estate (QIE), Kasur Industrial Zone (KIZ), and Chunian Industrial Estate, along with scattered industries throughout Lahore Division.

The geographical scope of this survey spans across multiple tehsils, including Raiwind, Allama Iqbal, Nishter, Model Town, Lahore Cantt, Saddar, Wahga, and Shalimar in Lahore; Ferozewala, Muridke, and Sharaq Pur in Sheikhupura; Chunian, Pattoki, and Kot Radha Kishan in Kasur; and Shahkot and Sangla Hill in Nankana Sahib. A diverse range of industrial units, from large industries engaged in high-scale production and exports to small-scale and cottage industries (5 to 10 Marla with a single manufacturing machine), were assessed.

1.1 Objectives:

The primary objective of this study is to conduct a comprehensive environmental mapping of industries across Lahore Division to assess their spatial distribution, and types / categories of industries to establish a data-driven foundation for regulatory enforcement, sustainable industrial practices, and policy interventions.

Specific objectives include:

- Identify and document the distribution of industrial units across key industrial estates and scattered industries within Lahore Division.
- Map the boilers and furnaces, and examine the installation and effectiveness of Emission Control Systems (ECS) in industries to track regulatory compliance and identify areas for improvement.
- Provide reliable data and insights to policymakers, regulators, and stakeholders on asset mapping of industrial pollution control systems and to guide industries in adopting cleaner technologies and sustainable practices
- Support the Punjab Environment Protection Agency in data-driven decision-making, enforcement actions, and policy formulation.
- Promote transparency in industrial environmental management.

1.2 Methodology

The following methodology was adopted to conduct an industrial mapping survey;

1.2.1 Preliminary Industrial Surveys

Walkthrough surveys were done in industries. Industrial visits were carried out prior to designing the industrial mapping “survey form” which aimed to record the type of pollution sources with the emission control systems, the types of boilers and furnaces present, along with fuel consumption details. The survey also focused on water consumption sources (such as tube wells, and bores) treatment levels, types, and final disposal stations. The survey form is provided at Annex – A.

Figure 1: Industrial Survey

1.3 Meetings with Environmental Protection Agency

Multiple meetings were held with the senior officials from the EPA to discuss the survey modalities and plan. These discussions focused on addressing challenges related to survey execution, app design, and defining the expected outcomes. Additionally, the necessary support and collaboration required for the successful implementation of the survey were outlined.

1.4 Development of an Android Application and Dashboard

Various meetings were held within the Urban Unit with IT experts, GIS and environment/industries team to discuss the app features/design, installation, functioning and information gathered in the database and data downloading in excel format for further analysis. Issues identified during these meetings were promptly addressed and fixed in subsequent versions, ensuring the development of an effective Android app and Dashboard.

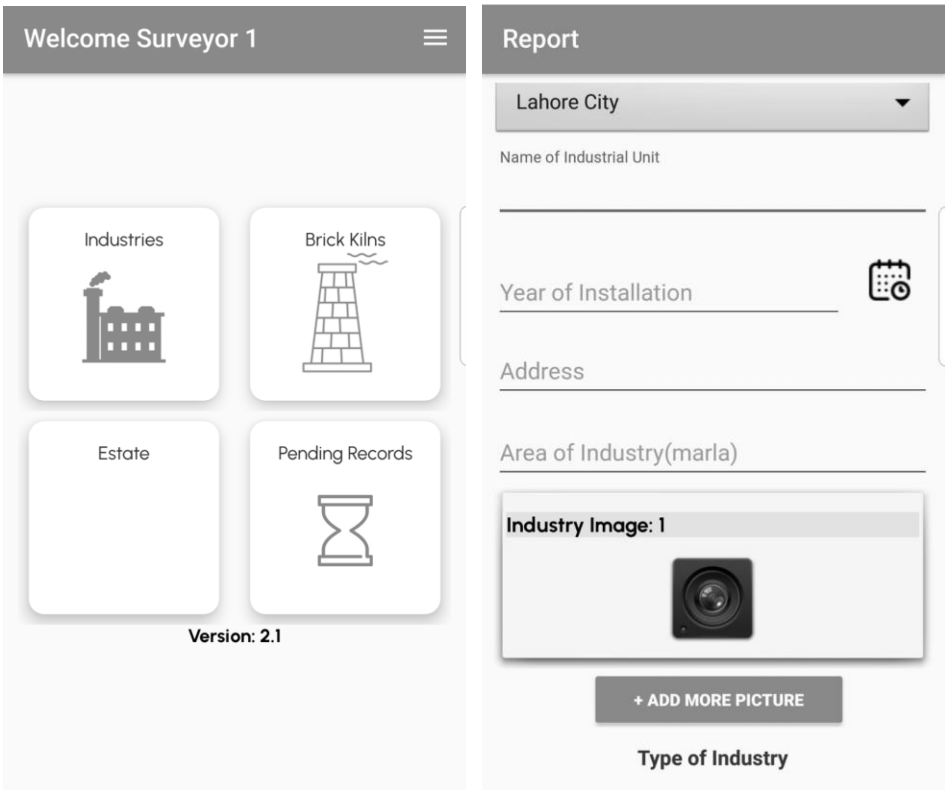


Figure 2: Android Application for Environmental Mapping of Industries

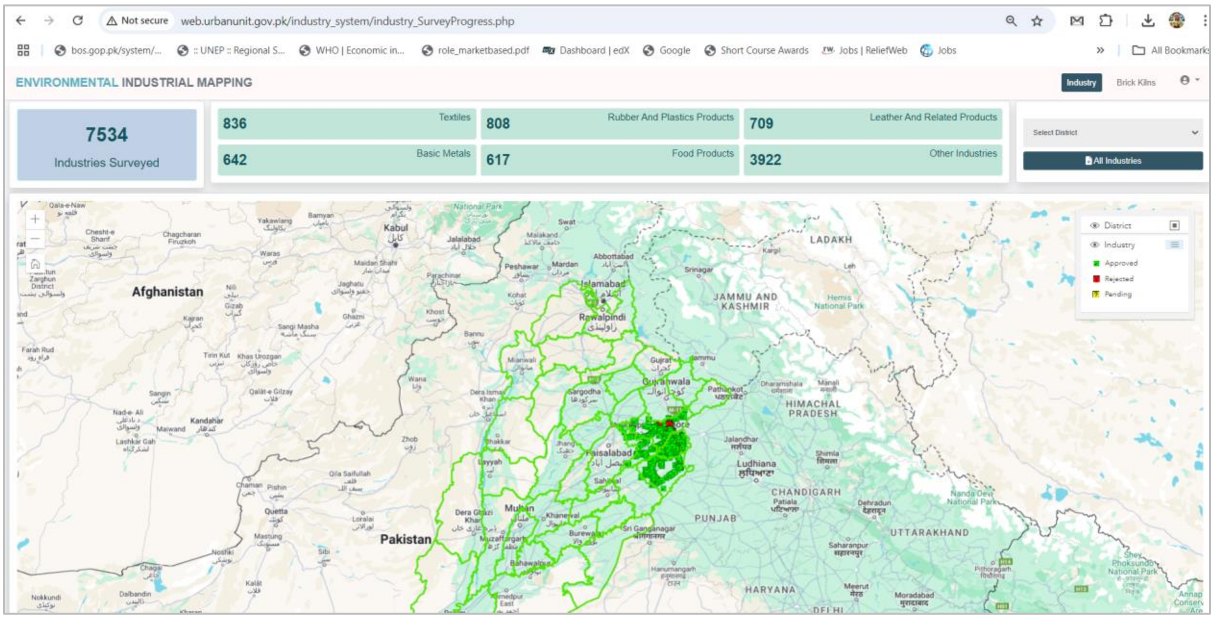


Figure 3: Dashboard for Environmental Mapping of Industries

1.5 Training of Surveyors

Pre-survey training played a critical role in refining the survey process, improving data accuracy, and empowering surveyors with the skills to conduct more effective environmental assessments. For that purpose, a team of qualified surveyors sharing academic backgrounds with sciences and engineers were hired for the environment mapping survey. Experienced supervisor surveys of the Urban Unit provided comprehensive training regarding data collection via android application in which types of boilers and furnaces were explained with pictures with special emphasis on the information recorded in SI units. Survey techniques, observation recording, and how to install and use Mapping App. User names and passwords were assigned to each surveyor

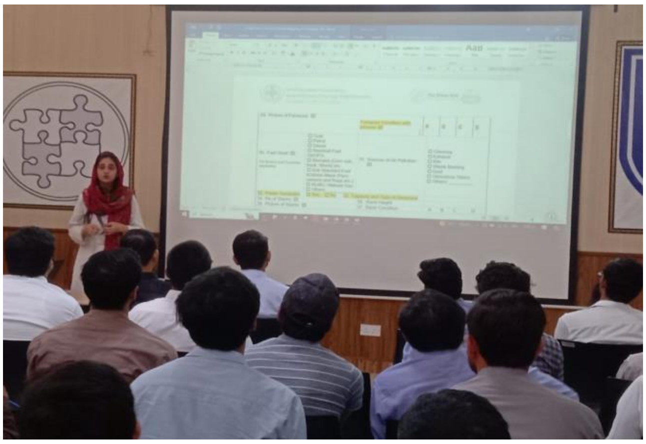


Figure 4: Training of Surveyors

1.6 Feedback, knowledge sharing, and corrective measures

After conducting the two-week industrial survey, experience-sharing workshop was organized by the Urban Unit's GIS and Environment teams at Aljazari Academy, Township, Lahore. The main aim of this workshop was to allow the surveyors to share their field experiences and observations. This allowed for valuable insights into any gaps or inconsistencies in the data collection process, helping to refine the survey methodology and improve the overall data quality.

1.7 Quality control and Quality assurance at different stages

1.7.1 Surveyor and supervisor teams

Each supervisor was assigned up to eight surveyors for better supervision. This arrangement supported in effective monitoring the performance of surveyors throughout the survey exercise.

1.7.2 Screening of App data

After Screening by the GIS supervisor, approved forms were sent to the environment supervisors for information screening. Approved forms were reviewed at a third level by the QC manager to give a final review before execution. (See **Figure 2-4**).

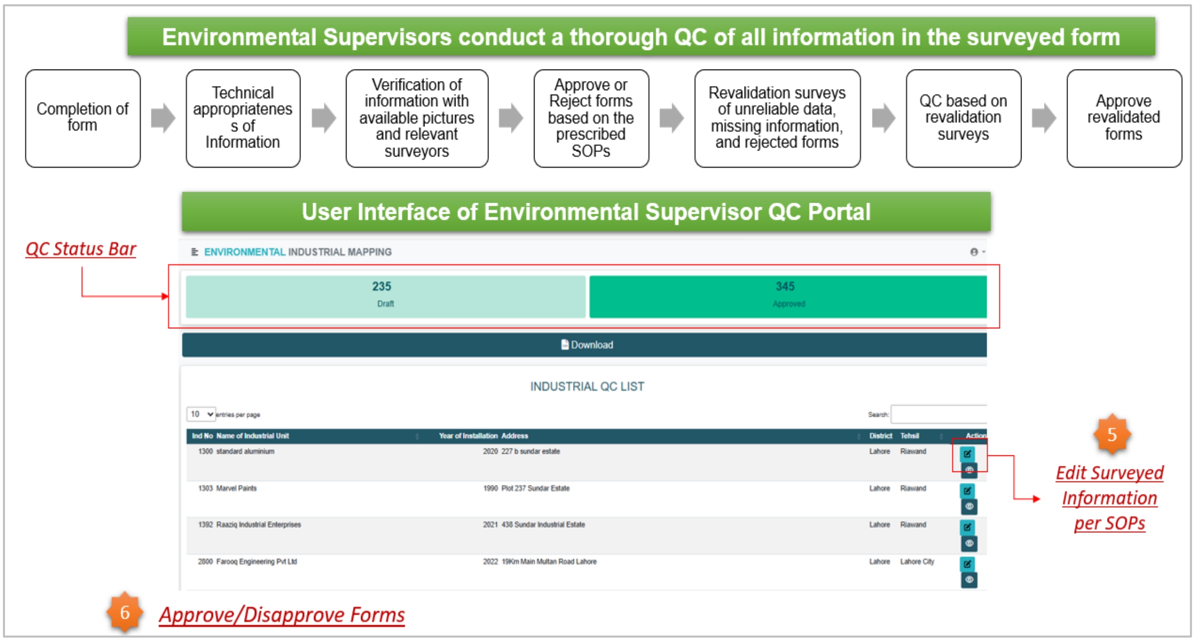


Figure 5: Systematic diagram showing Quality Control procedure for electronic survey conduct via app

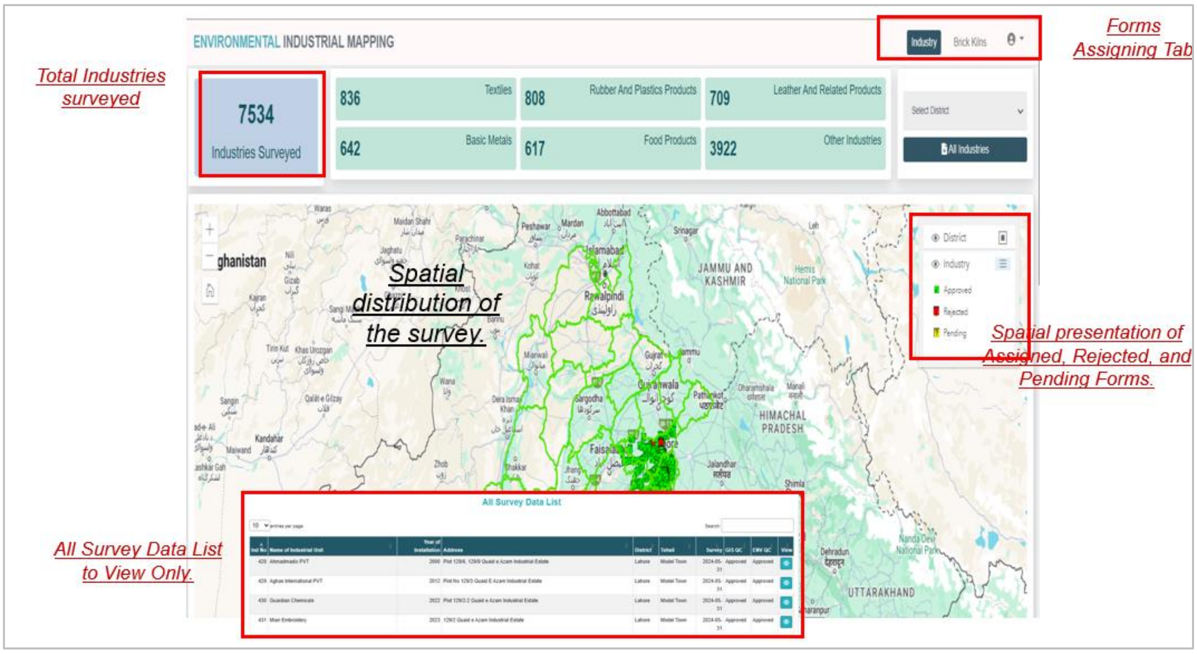


Figure 6: Environment QC manager portal showing survey status on manager dashboard

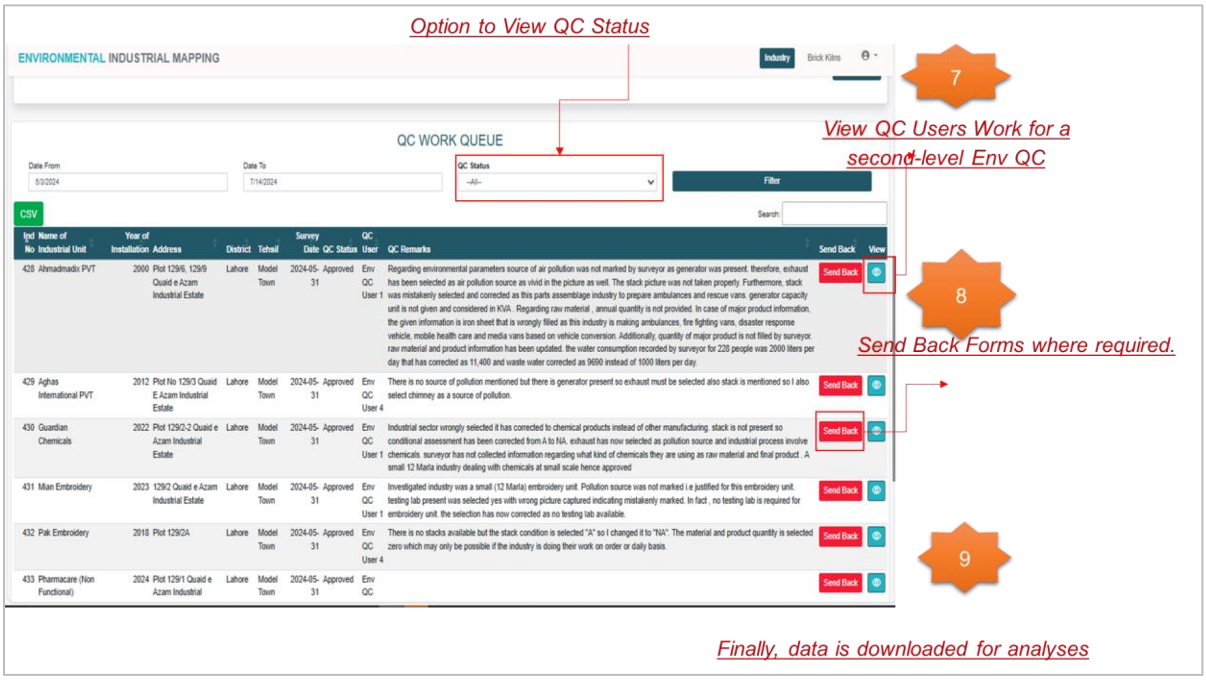


Figure 7: Three Step-wise Quality Control of Survey Forms on Dashboard

1.8 Revalidation Surveys

Revalidation surveys were conducted to verify the information provided by the surveyors. The aim was to cross-check the recorded information and ensures its accuracy.

Figure 8: Revalidation Surveys

Industrial Profile of Lahore Division

This chapter provides a baseline data of existing industries in Lahore Division;

2.1 Industries Classification

Based on the 2024 Environmental Industrial Mapping Survey, industries in Lahore Division were categorized as either functional or nonfunctional, and as seasonal or annual, depending on their operating hours. The classification also included an assessment of manufacturing processes, focusing on the type of production involved.

2.1.1 Classification based on Function /Operating Hours

The survey results provide a snapshot of industry functionality and operational patterns based on data from the Industrial Environment Survey 2024.

Industry Functionality: 92% of industries were operational/functional during the survey period while 8% of industries were non-functional at the time of the survey.

Operational Frequency: 15% of industries (1,178 units) operate on a seasonal basis, meaning their functionality is dependent on specific times of the year, such as agricultural cycles, demand-driven production, or energy availability. The remaining 85% of industries operate year-round, reflecting continuous or large-scale industrial activities. The prevalence of seasonal operations highlights the influence of market trends, resource availability, and sector-specific production cycles (**Fig. 9 and 10**).

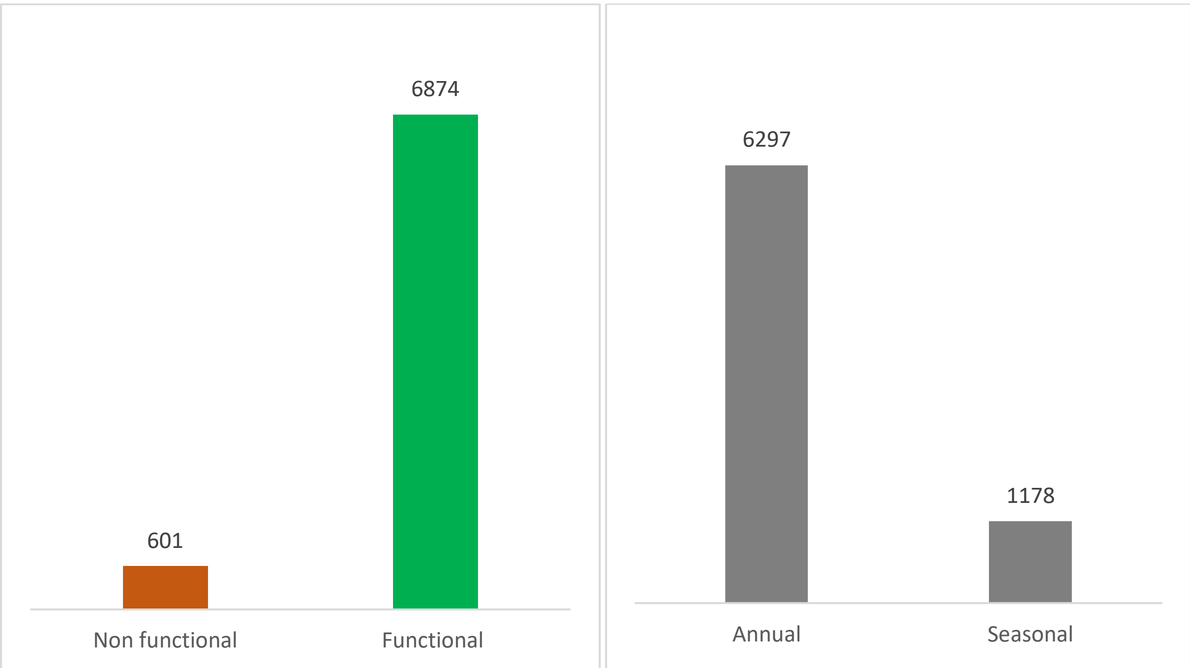


Figure 9: Industrial classification based on function /operating hours

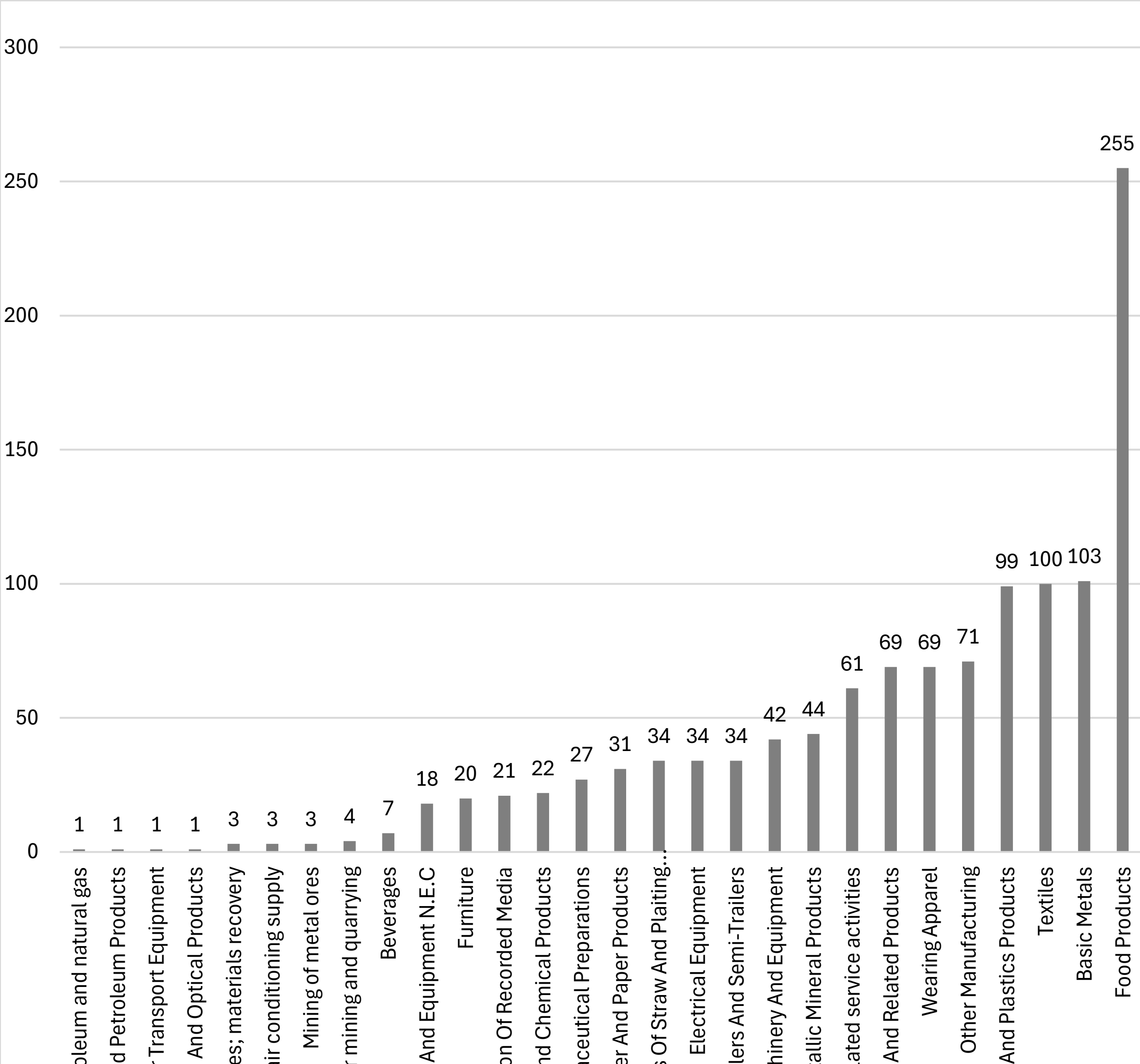


Figure 10: Seasonally Operation industries in the Lahore Division

2.1.2 Industrial classification based on product manufacturing

The United Nations Statistical Division (UNSD) classifies manufacturing industries based on the type of product made. The International Standard Industrial Classification of All Economic Activities (ISIC) is a classification system used by many countries to report statistics on economic activity (ISIC, Rev. 4 - Code C). this classification provides a structured approach and allows for precise classification of economic activities, facilitating effective analysis, policymaking, and international comparisons in Sectors, Groups and Classes.

a. Industrial sectors

Results of the Environmental industrial mapping survey provide insightful constituents of the various **industrial sectors** based on the number of units reported, with textiles signifying the largest and fabricated metal products representing the smallest of the mentioned industries.

Based on product manufacturing, 28 sectors of industries were reported in which textile units (829) form the biggest sector > rubber and plastic (806) > leather and related products (706) > basic metals (634)> food products (609)> other non-metallic mineral product (577)> wearing apparel (477)> other manufacturing (410) > paper and paper products (336) and fabricated metal products (282) as indicated in **Figure 11**. Each of these sectors contributes to the economy of Pakistan with distinct processes and product types, and they may have varied demands for energy, raw materials, and infrastructure, particularly in areas like industrial boiler usage.

b. Industrial groups

In terms of groups, plastic products (n= 676) form a larger group of industries in our data followed by non-metallic mineral products (563)> basic iron and steel (549) >Footwear (483)> other textile (471)> other manufacturing (359)> spinning weaving and finishing of textile (357). **Figure 12** provides the classification of industries in groups based on the manufacturing process in the Lahore Division.

c. Industrial Classes

In terms of classes, the results indicated as shown in Error! Reference source not found..

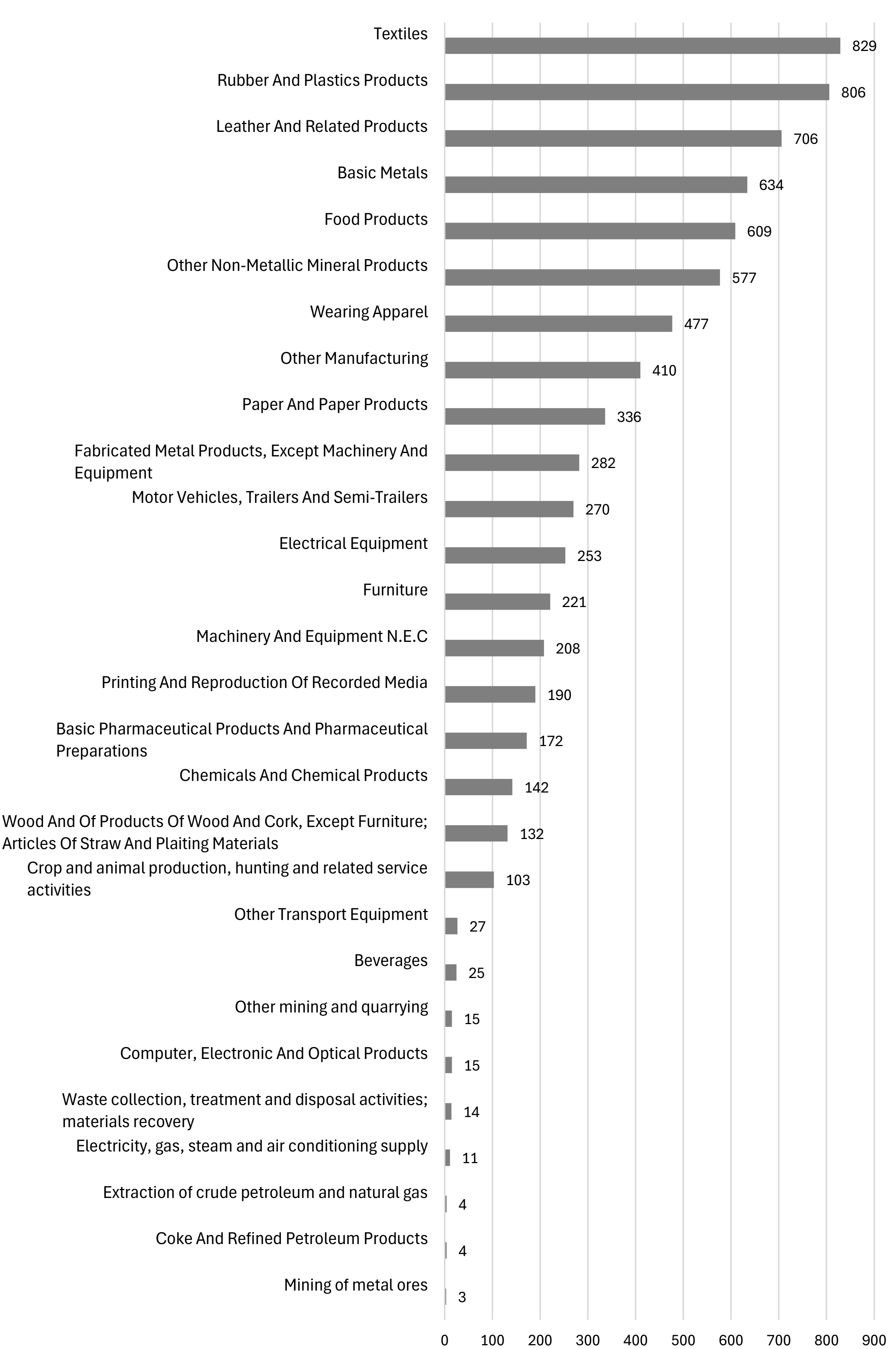


Figure 11: Sector-wise Classification of Industries

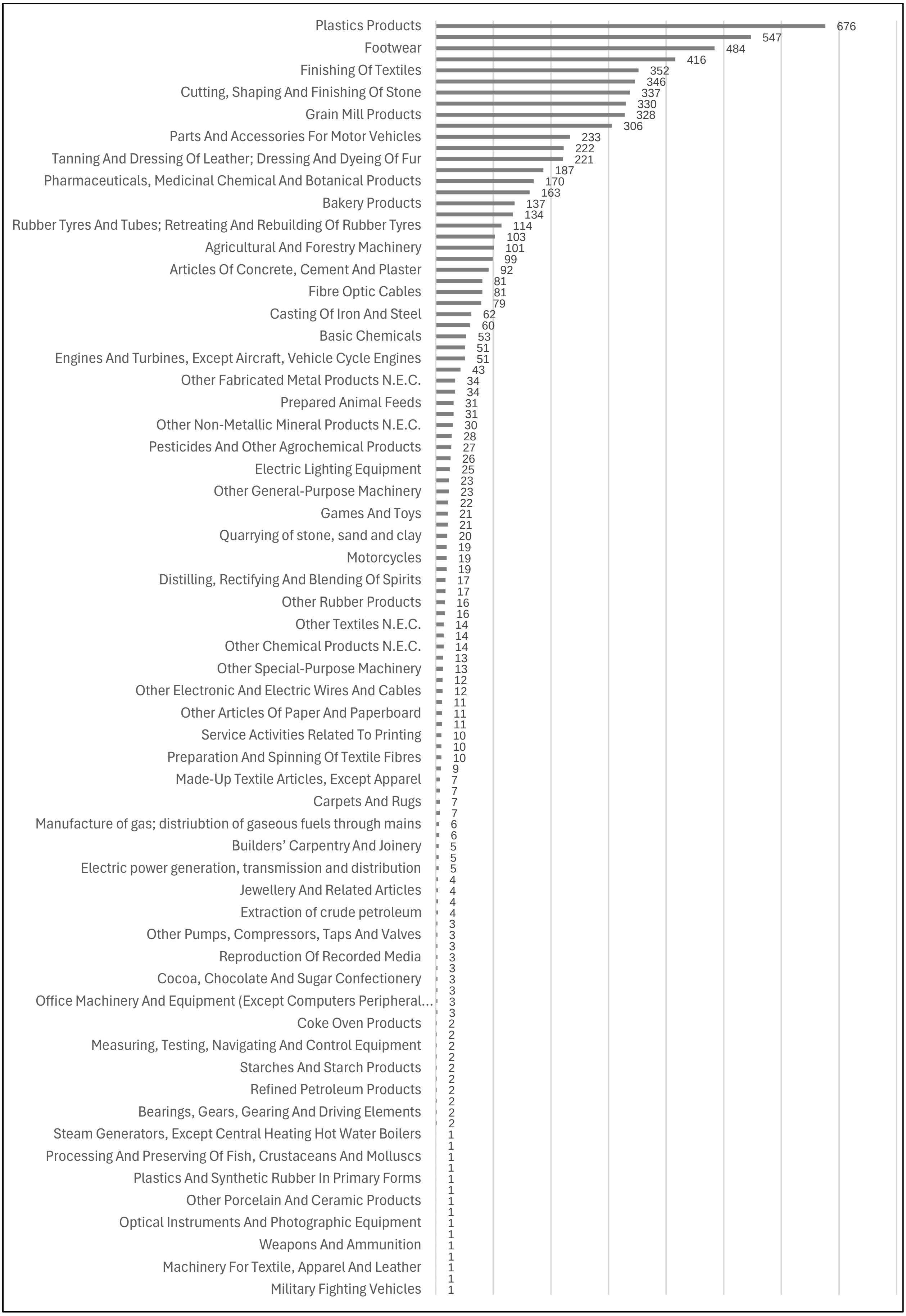


Figure 12: Classification of industries in groups based on the manufacturing process in the Lahore Division

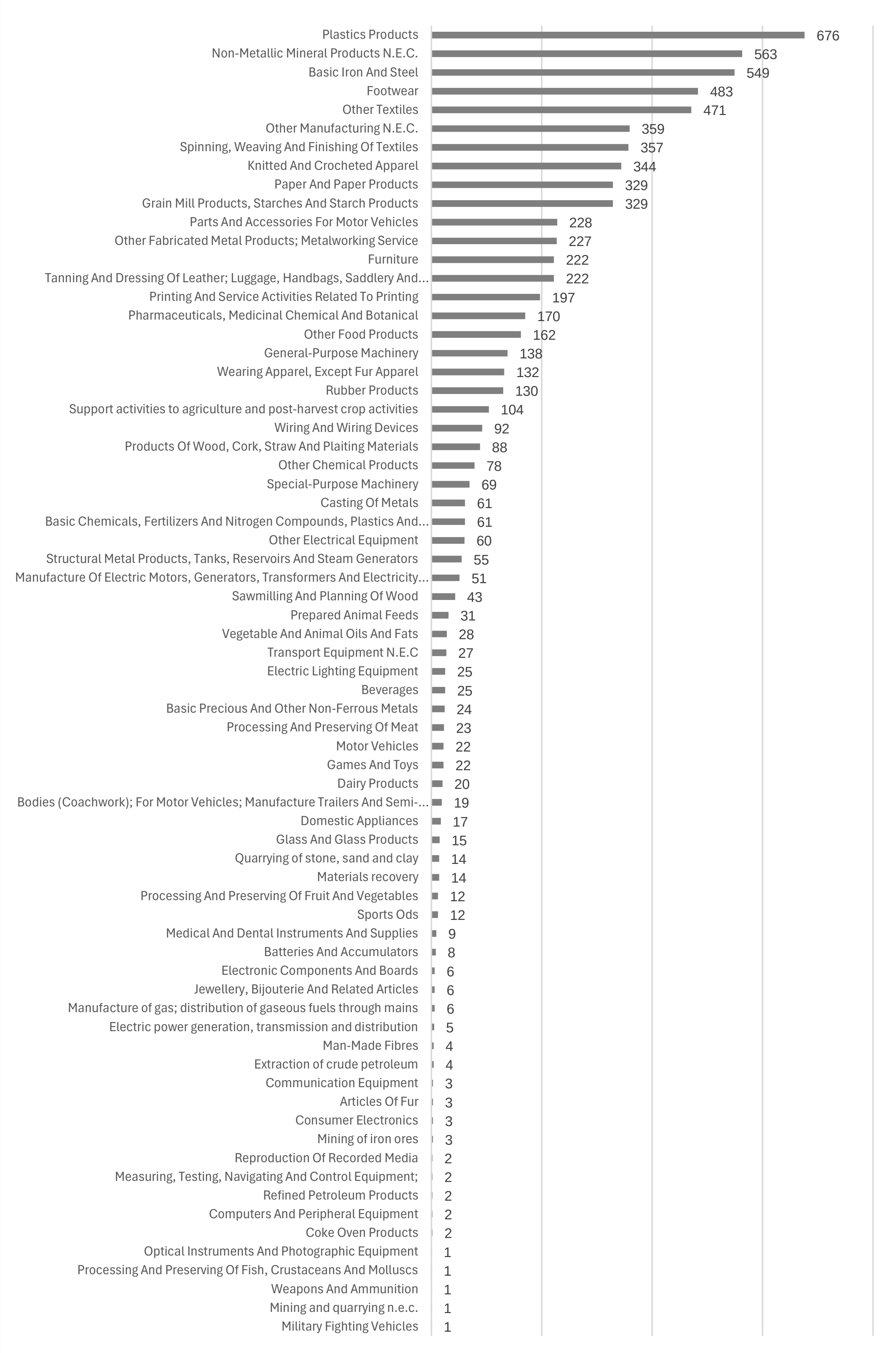


Figure 13: Industrial Classes of Lahore Division

2.1.3 Industrial Classification Based on SMART Rules 2001

The National Environmental Quality Standards (Self-Monitoring and Reporting by Industry) Rule, 2001[1] established under Section 31 of Pakistan's Environmental Protection Act, 1997 (SRO 528(I)/2001), mandate industries nationwide to monitor and report their environmental performance. These rules require industries to track emissions, effluents, and waste, ensuring compliance with environmental standards while promoting transparency and accountability. Moreover, the industries need to install monitoring equipment, maintain records, and regularly submit reports to environmental authorities, providing a framework for managing and mitigating their environmental impact.

These rules classify industries based on their emission levels and pollution load, with corresponding reporting requirements for their environmental impact in Schedule I (Liquid Effluents) and Schedule II (Gaseous Emissions). These schedules further bifurcate the industries into categories "A," "B," or "C". This classification determines the frequency and type of environmental monitoring reports they must submit:

- **Category A**: Industries with higher pollution levels must submit monthly reports for liquid effluents and gaseous emissions. During start-ups or disruptions, hourly monitoring of certain parameters is required, and records of these conditions must be maintained.
- **Category B**: Industries with moderate pollution levels must submit quarterly reports for liquid effluents and gaseous emissions.
- **Category C**: Industries with lower pollution levels must submit biannual reports for liquid effluents.

As initially during survey we classified industrial sectors on Pakistan Standard Industrial Classification (PSIC) details of which has been discussed earlier but when we tried to link PSIC codes with the classification defined in SMART rules, 2001 for emission and effluents from the industrial units, rose concerns regarding the operations of the specific sector according to the ground reality of the sectors, groups and classes of the industrial units. Therefore, it was required to check 7475 industries either they fall on which category according to the nature of operations.

Considering these categories, the environmental mapping survey of industries in the Lahore Division is elaborated below;

Table 1: Industrial Classification Based on SMART Rules 2001

Schedules	Total No. of Industries
Schedule I - Classification of Industrial Units for Liquid Effluents	1785
Schedule II - Classification of Industrial Units for Gaseous Emissions	1037

a. Schedule 1, Category A

Out of the total 7,475 industries in the Lahore division, the analysis categorizes industries under Schedule 1, Classification of Industrial Units for Liquid Effluents, Category A (1065) specifying their sectorial distribution as follows:

- **Tanning Industries:** 221 Most of the tanning units were found in Kasur.
- **Steel Industries:** 134 industries, Casting and Rerolling Mills & Steel units with furnaces
- **Pulp and Paper Industries:** 32 industries, pulp and paper mills
- **Metal Finishing:** 228 industries.
- **Printing:** 190 industries.
- **Rubber Products:** 27 industries.
- **Pigment and Dyes:** 4 industries.

[1] *https://epd.punjab.gov.pk/system/files/NEQS_SMART_Rules_2001_0.pdf*

- **Textile Processing:** 155 industries.
- **Paint and Varnishes:** 44 industries.
- **Pesticides Formulation:** 27 industries.
- **Synthetic Fiber:** 2 industries.
- **Combine Effluent Treatment:** 1 unit

This distribution emphasizes tanning, steel, metal finishing, printing and textile processing as the most prevalent industries within Category A, with smaller representations from sectors such as synthetic fibre, pesticides and rubber processing (**Figure**).

The largest sector under this category is tanning, with Kasur being a key region for tanning units. While some larger tanneries have their own wastewater treatment plants (WWTPs), many smaller units lack such facilities. Tanneries with WWTPs often include Chrome Recovery Units, which recover Chromium III for reuse in the tanning process. However, if Chromium III is not properly recovered, it can oxidize over time and convert into Chromium VI, a known carcinogen. The absence of WWTPs in many tanneries poses a significant environmental concern, particularly due to the risk of groundwater contamination from untreated effluents. Addressing this gap through the installation of WWTPs is critical for mitigating environmental risks in the region.

The steel sector industries should also be evaluated under Category A, as several units producing significant wastewater are associated with smelting operations. However, there are no smelting units in Lahore. Classifying the steel sector under Category A, as per the SMART Rules 2001, may not be appropriate in this context. A more objective classification based on the specific processes involved is applied, as this would prevent unnecessary environmental monitoring burdens. The environmental concerns typically linked to smelting units do not apply in this region, and the classification should reflect the absence of such operations.

Typical Regional Steel Mill

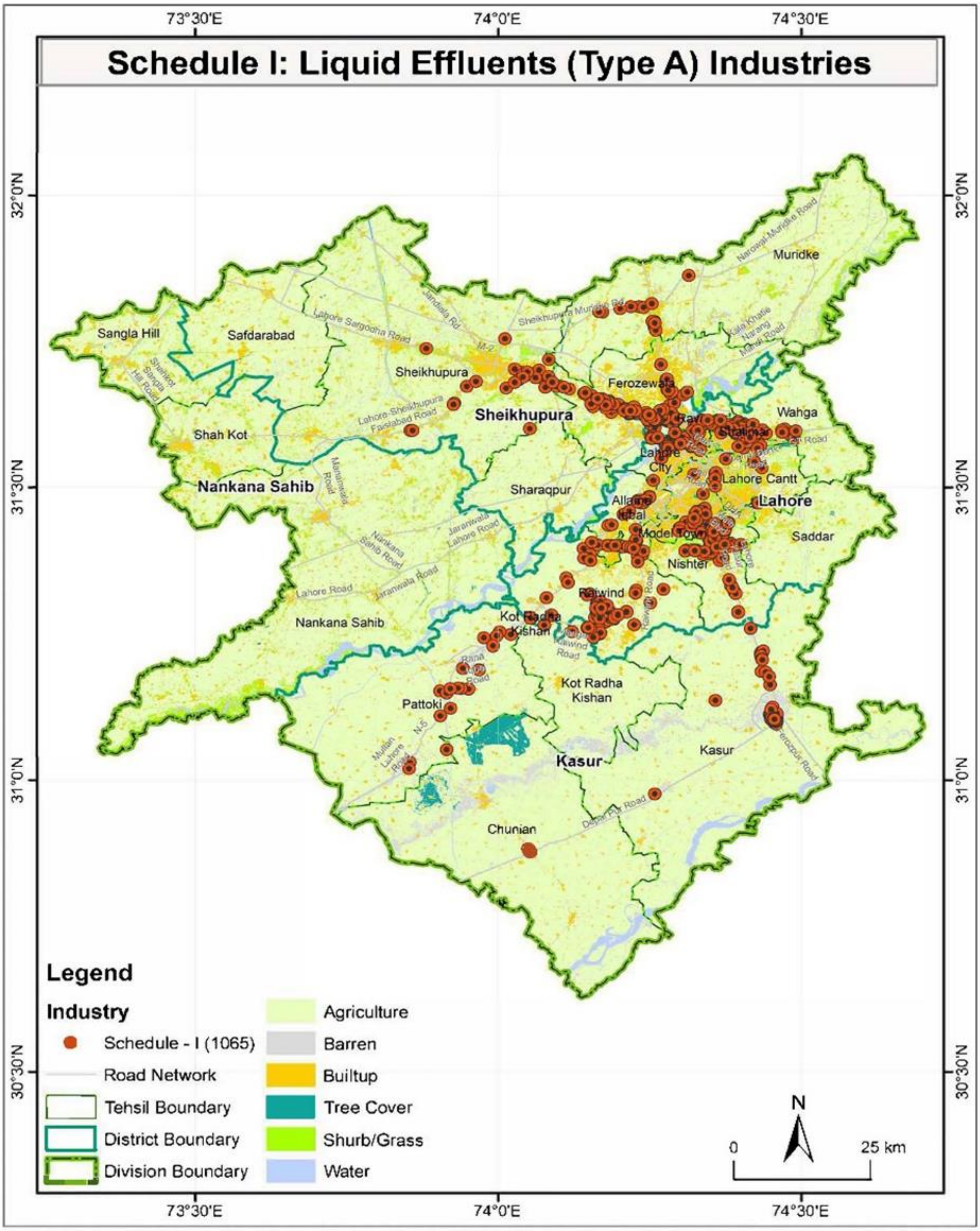


Figure 2.7. Map showing spatial Distribution of Schedule I Type A industries in Lahore division

b. Schedule 1, Category B Industries

The number of industries in the Lahore division that lie under Schedule 1, Classification of Industrial Units for Liquid Effluents, Category B (107) shows the following distribution across various sectors:

- **Plastic Materials and Products:** 46 industries. Plastic process industries and plastic recycling units
- **Detergents:** 7 industries.
- **Dairy Industry:** 19 industries.
- **Glass Manufacturing:** 12 industries.
- **Fruits and Vegetables Processing:** 11 industries.
- **Vegetable Oil and Ghee Mills:** 7 industries
- **Woolen Mills**: 4 industries
- **Glue Manufacturing:** 1 industry.

This distribution highlights woollen mills and plastic materials and products as the dominant sectors within Category B, while glue manufacturing and vegetable oil and ghee mills represent the smallest sectors in this category as given in Map (see **Figure 14**).

Main dominant sector comes under category B is the Plastic Products sector. But the concern is many of the units that come under the Plastic Products section are moulding machine units, where there is no waste water generation so they should not be included under the Liquid Effluent Industries list.

c. Schedule I, Category C Industries

The analysis of industries under Schedule 1, Category C (613) in the Lahore division identifies the following sector distribution:

- Marble Crushing: 441 industries.
- Pharmaceutical Formulation Industry: 172 industries.

These figures, out of the total 7,475 industries, indicate that marble crushing leads within Category C, followed by pharmaceutical formulation as seen in Map (see **Figure 15**).

In this category, the Lahore Division hosts several major pharmaceutical companies, some of which have installed wastewater treatment plants (WWTPs). However, it is essential to evaluate the effectiveness of these WWTPs and ensure adherence to Standard Operating Procedures (SOPs) aligned with Best Available Techniques (BAT), tailored to the specific requirements of their formulations.

Additionally, Lahore is home to numerous small marble-cutting units that utilize water in their operations. While many of these units recycle water to conserve resources, their effluent often contains fine marble particles. If not properly managed and disposed of, this can pose a significant environmental concern. Implementing effective measures for effluent treatment and disposal is crucial to minimize environmental impacts.

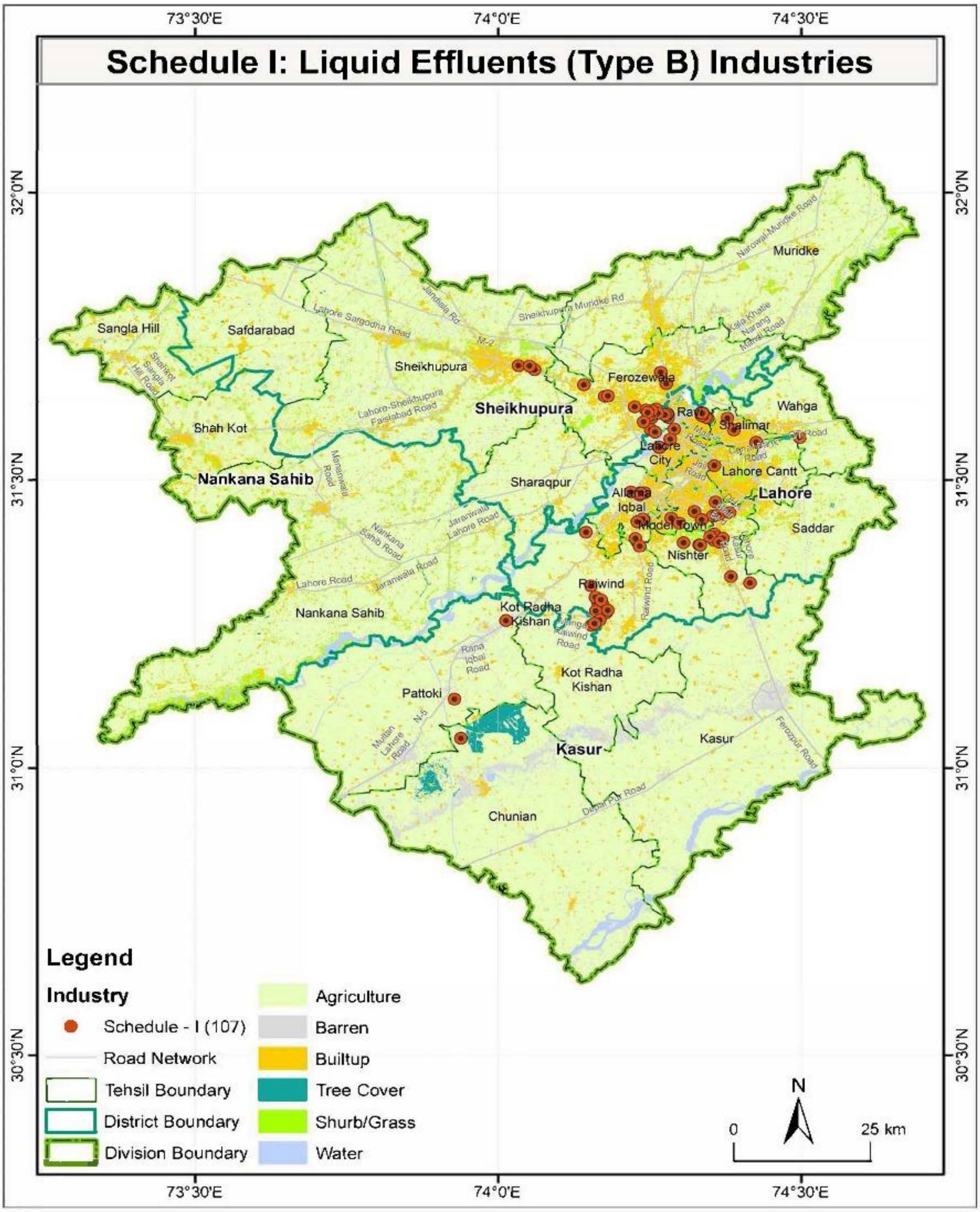


Figure 14: Spatial distribution of Schedule I type B Industries of Lahore Division

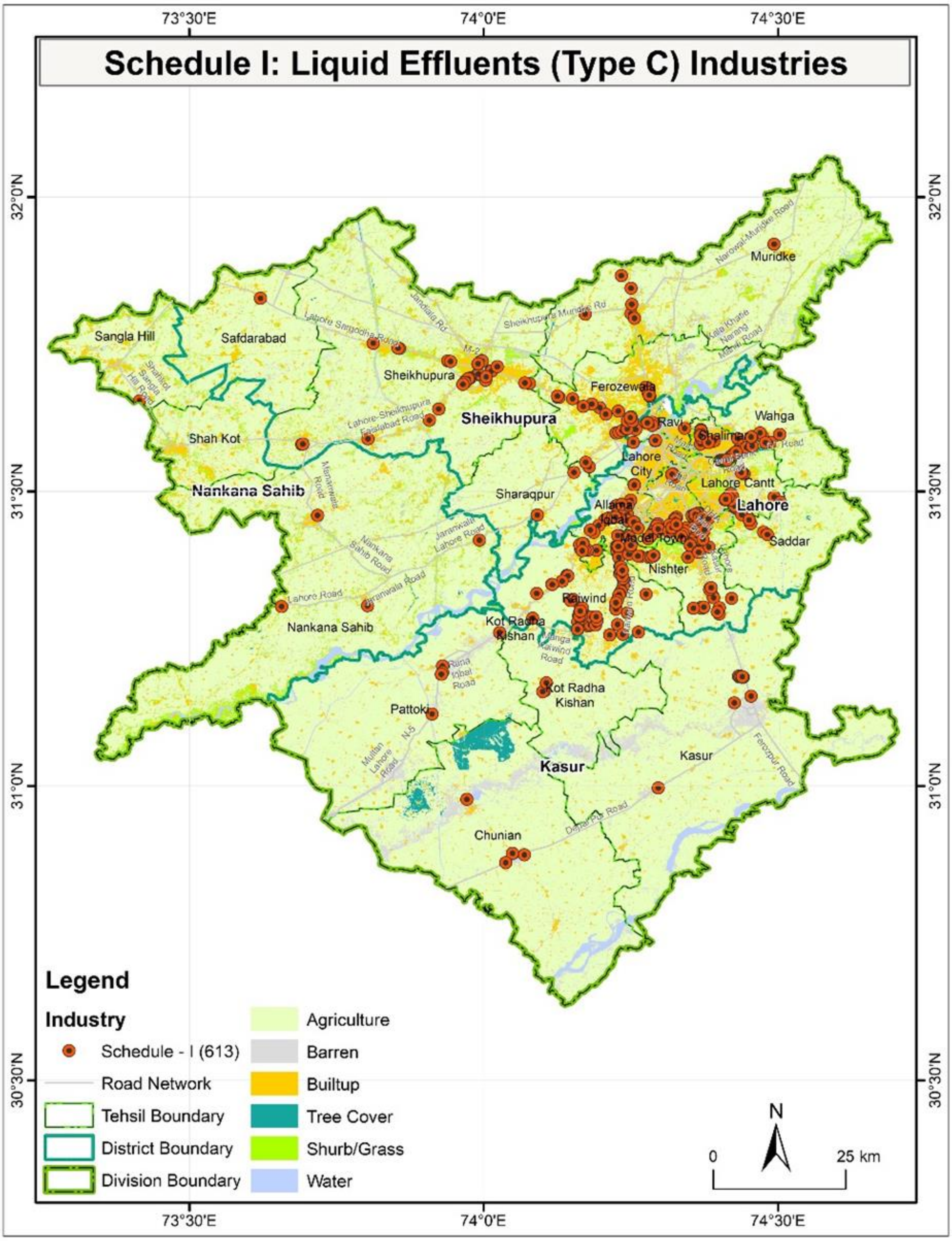


Figure 15: Spatial Distribution of Schedule I type C Industries deals with Liquid Effluent in Lahore division

d. Schedule II, Category A industries

The breakdown of Schedule II, Category A (252) industries in the Lahore division includes the following sectors:

- **Iron and Steel:** 134 industries, the largest group in this category.
- **Pulp and Paper:** 32 industries.
- **Boilers (Coal & Oil Fired):** 70 industries.
- **Glass Industry:** 15 industries.
- **Nitrogenous Fertilizer:** 1 industry

This categorization indicates that iron and steel industries dominate within Schedule II, Category B, while the glass industry has the smallest representation among these sectors as shown in Map (see **Figure 16**).

The dominant sector in the Lahore Division is Iron & Steel Mills, comprising numerous re-rolling mills that include both key players and a significant number of smaller units. These mills employ various types of furnaces, such as cupola, blast, or crucible furnaces, depending on their capacity and operational needs.

Larger mills typically install bag filters to capture small metal particles from dust emissions. The collected waste is often sold to scrappers, providing an additional source of income for the mills. However, the installation of bag filters requires substantial capital investment, which is often unaffordable for smaller mills. Consequently, many of these smaller mills operate without such filters, contributing to environmental concerns.

To mitigate costs, some small and medium enterprises (SMEs) in this sector have developed locally manufactured bag filters. While these alternatives help reduce initial expenses, their effectiveness remains a significant concern and requires proper assessment to ensure adequate environmental protection.

e. Schedule II, Category B

The Schedule II, Category B industries (785) in the Lahore division include the following sectors:

- **Textile:** 401 industries, the largest sector in this category.
- **Metal Finishing & Electroplating:** 230 industries
- **Boiler (Gas Fired)**: 123 industries
- **Dairy Industry:** 19 industries.
- **Fruits and Vegetables Processing:** 12 industries.

This distribution shows that electroplating and textile industries lead within Schedule II, Category B, as depicted in Map (see **Figure 17**).

The textile sector emerges not only as the dominant industry in this category but also as a key economic driver for the region and the second-largest contributor to greenhouse gas (GHG) emissions among industrial sectors in Pakistan. GHG emissions in this sector are primarily associated with operational activities. While some prominent players operate across multiple stages of textile production, many units focus on specific operations.

The distribution of GHG emissions across various textile operations highlights significant variations. Spinning accounts for 0.84 kg CO2e (1%), weaving contributes 18.8 kg CO2e (22%), processing generates 27.8 kg CO2e (32%), garmenting produces 17.19 kg CO2e (20%), and denim washing accounts for 21.68 kg CO2e (25%). This distribution indicates that spinning operations are relatively low-impact in terms of GHG emissions, whereas processing and denim washing are the most significant contributors.

These insights emphasize the need to prioritize emission-reduction strategies in high-impact operations, such as processing and denim washing, while continuing to support the relatively lower-emission spinning units.

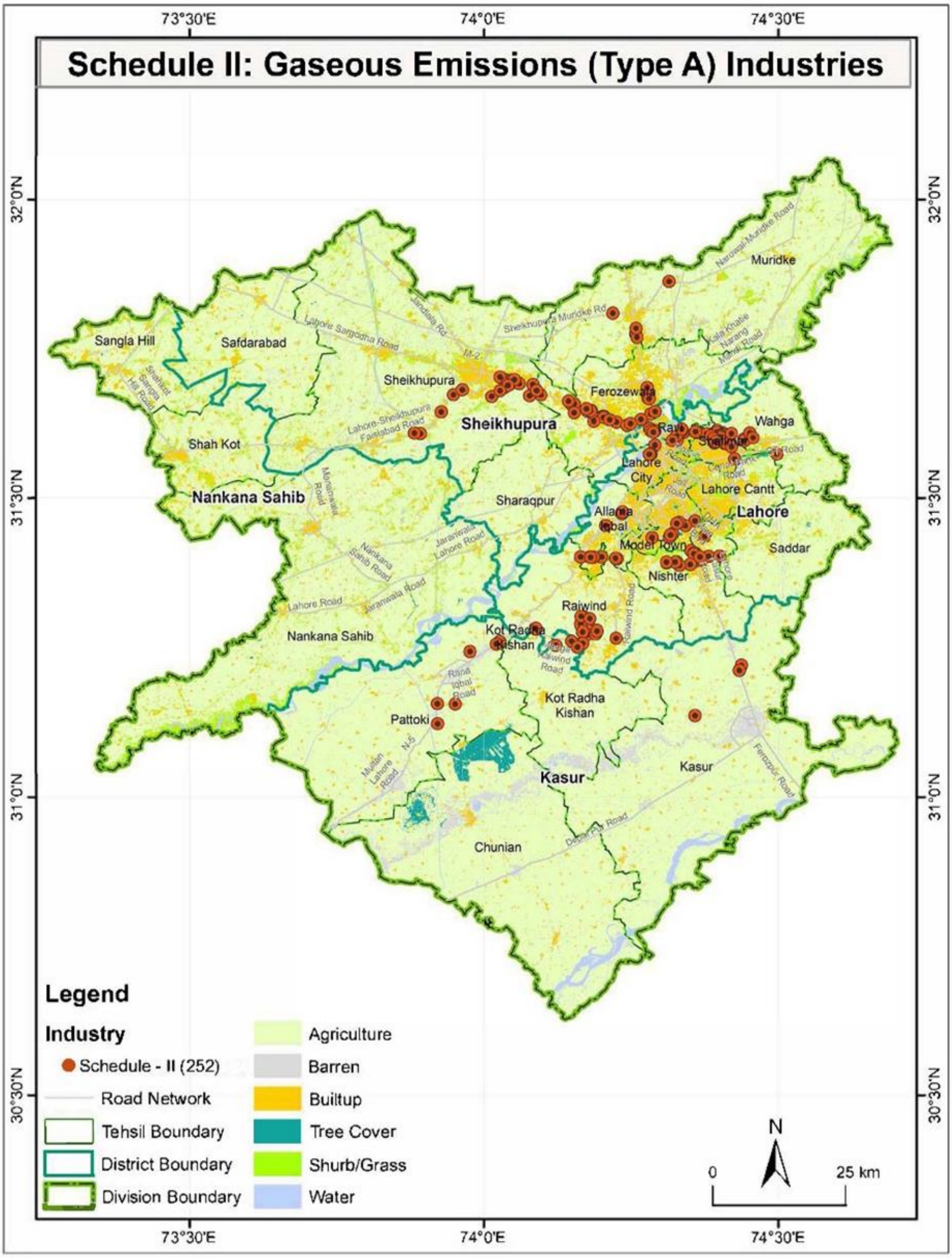


Figure 16: Spatial Distribution of Schedule II type A industries of Lahore Division

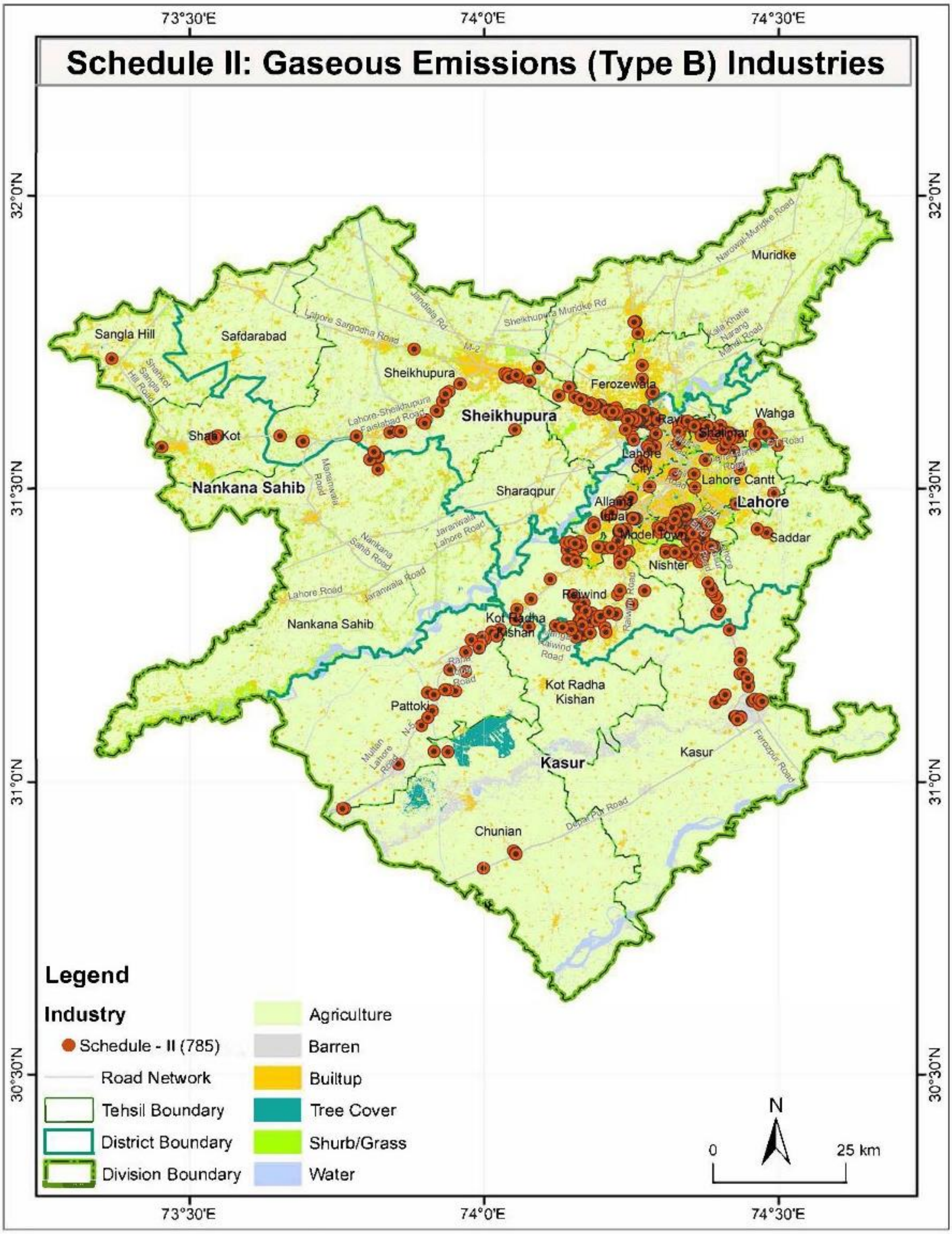


Figure 17: Spatial distribution of Schedule II (Gaseous Emissions) Type B Industries of Lahore Division

2.2 Work force scenario in industrial sectors of Lahore division

The workforce scenario in the industrial sectors of Lahore Division underscores a critical need to address the significant gender disparity for fostering inclusive economic growth and enhancing industry competitiveness. Current data reveals that 89% of the workforce consists of men, while only 11% are women (see **Figure 18**). This imbalance highlights the underutilization of female potential in industries that could benefit from a more diverse and skilled workforce.

Several factors contribute to this disparity. Many industrial sectors, such as textiles, basic metals, leather, and non-metallic minerals, require physically demanding tasks that traditionally attract more male workers. Conversely, women are more often employed in less physically intense sectors, like wearing apparel, food products, and other light manufacturing. However, even in these sectors, gender barriers persist due to limited access to technical training, inadequate workplace safety, and a lack of gender-sensitive facilities such as separate restrooms, day care centres, and safe transportation options. Societal norms and stereotypes further restrict women from entering or thriving in industrial roles, while insufficient policies on maternity benefits, flexible work hours, and anti-harassment measures exacerbate the gap.

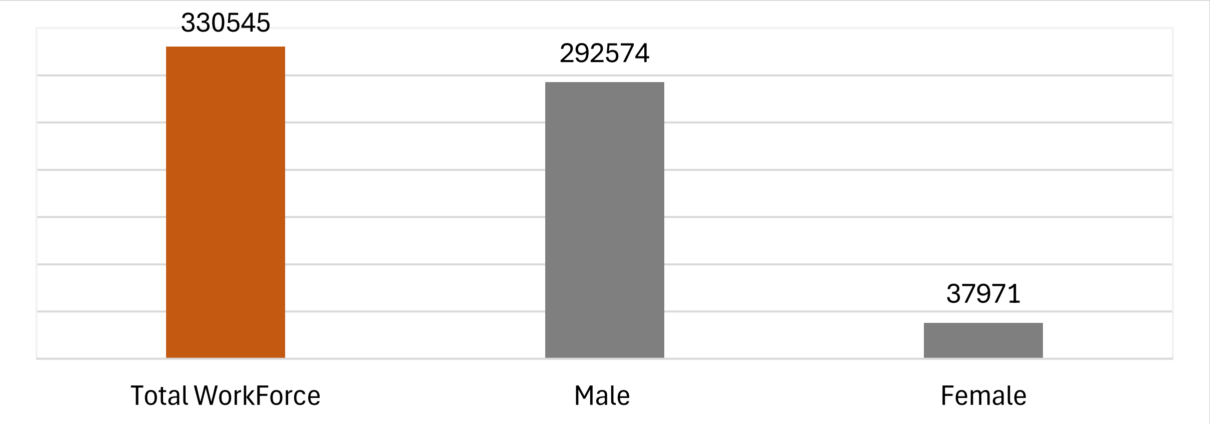


Figure 18: Number and percentage of Human Resource in the Industrial Sector of Lahore Division

2.3 Availability of Services (Gas, Water) in Industrial Sector

Survey analysis showed key infrastructural and export features of industries in the Lahore division. Results revealed that 16% of industries have a Gas connection, while 51% of industries have a water connection. This indicates that, while water connections are relatively more common, a substantial proportion of industries still operate without access to essential gas infrastructure, underscoring a critical gap in utility provisions.

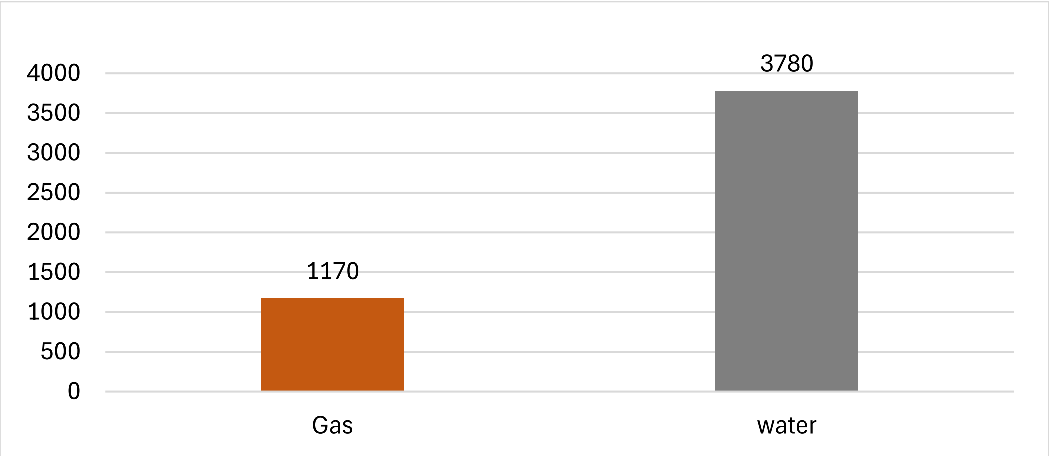


Figure 19: Basic Utilities Provision in Industries of Lahore Division

2.4 Export Industries

Export-oriented industries play a vital role in contributing to the economic growth of the Lahore Division by producing goods for international markets. Based on the survey, it was observed that **7% of industries** in the Lahore Division are **primarily export-driven**. The environmental performance and operational efficiency of these industries are critical not only for their market reputation but also for ensuring compliance with national and international environmental standards.

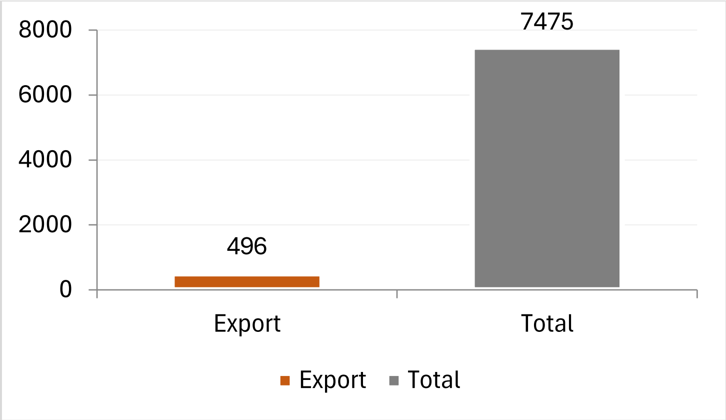


Figure 20: Export status in Industries of Lahore Division

2.5 Trees Plantation

The plantation of trees within industrial units plays a crucial role in offsetting emissions into the environment. Trees were found in 2299 industrial units; however, many industries with smaller land areas lacked any tree cover. To address this issue, tree plantation can be made mandatory under the Punjab Plantation and Maintenance of Trees Act, 1974. According to Section 3 of the Act, it is stipulated that "three trees per acre shall be planted and maintained by the occupier in a manner as prescribed."

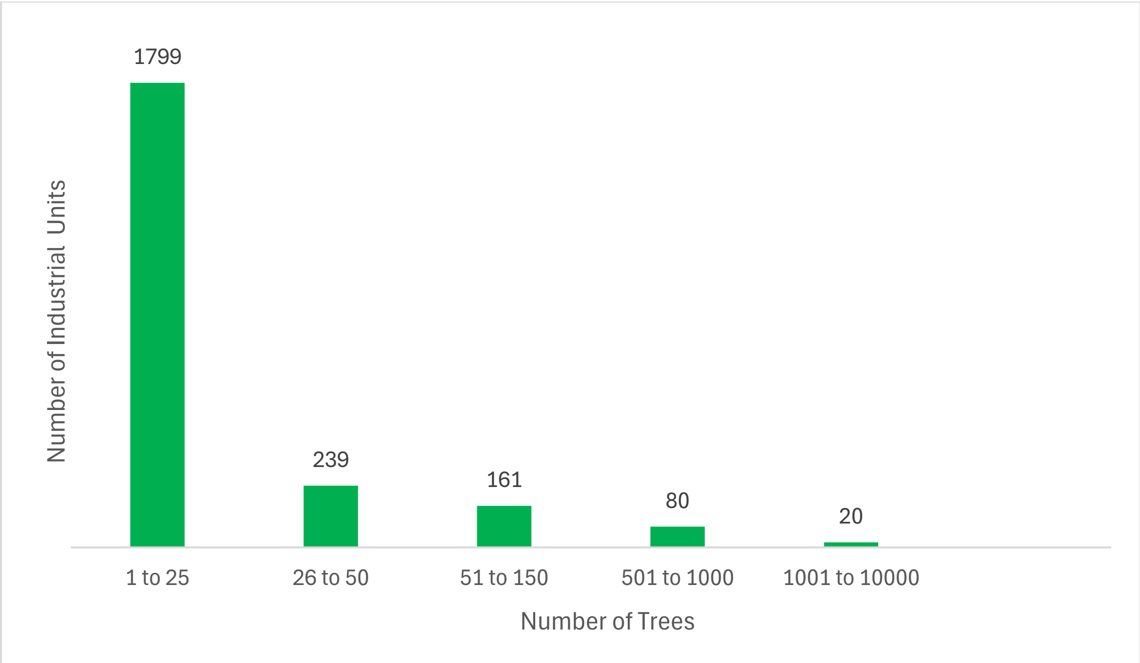


Figure 21: Number of trees present in industrial sector of Lahore division

Conditional Assessment of Industrial Buildings

The physical condition of industrial buildings plays a crucial role in ensuring operational efficiency, worker safety, and regulatory compliance. This assessment categorizes buildings based on their structural integrity, highlighting the extent of deterioration and functionality. The classification system used in this study provides a clear understanding of the current state of industrial infrastructure, identifying areas that require maintenance or immediate intervention. The rating criteria is provided below:

Rating	Asset Condition	Description
A	**Excellent**	No noticeable defects. Some aging or wear may be visible
B	**Good**	Only minor deterioration or defects are evident
C	**Fair**	Some deterioration or defects are evident, but function is not significantly affected
D	**Poor**	Serious deterioration in at least some portion of the structure. Function is inadequate
F	**Failing**	No longer functional. General failure or complete failure of a major structural component

The survey results reveal the infrastructure and condition of buildings in the industries surveyed:

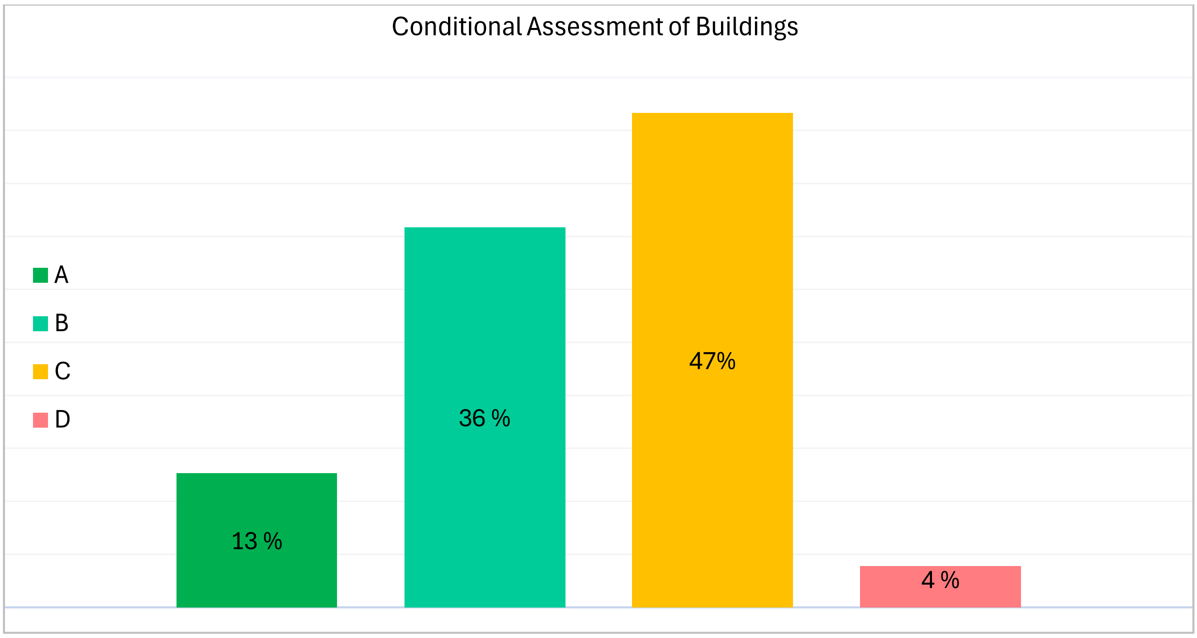


Figure 22: Conditional Assessment of Buildings

3.1 Building Designation:

- 2% (n=131) of industries have separate buildings for raw material storage.
- 2% (n=157) have separate buildings for product storage.

- 14% of industries have separate office space.

3.2 Building Condition Assessment:

- Condition D: 4% of buildings are in poor condition, requiring significant repairs or improvements in the near future.
- Condition C: 47% of buildings fall into this category, indicating moderate issues and some maintenance needs.
- Condition B: 36% of buildings are in this category, showing fewer issues than C but still not optimal.
- Condition A: 13% of buildings are in the best condition, with minimal issues.

These findings, visualized in Error! Reference source not found., show a majority of buildings needing some level of m aintenance (Conditions B and C), with a smaller portion in excellent condition (A) and a minimal percentage in poor condition (D). There seems to be a limited focus on storage infrastructure, as indicated by the low percentage of industries with separate storage facilities. The industrial building conditions lies under D need a special attention as it can be a hazard for the Workers in case of collapse.

3.3 Lab testing Facility

Lab testing facilities were available in 811 industries out of 7475 total investigated industries as shown in **Figure 23**. The availability of lab testing facilities for internal quality assurance in industries is crucial for maintaining product standards, ensuring compliance with regulations, and enhancing competitiveness, especially in manufacturing and export-driven sectors. In current industrial data, 11% of industries have lab testing facilities, which suggests that a significant majority of industries (nearly 89%) lack internal capabilities for quality assurance. Results revealed that, without internal testing, industries face challenges in maintaining product consistency and innovation to meet changing market demands. overall industrial output, export, and competitiveness can be improved by enhancing access to internal quality assurance laboratories.

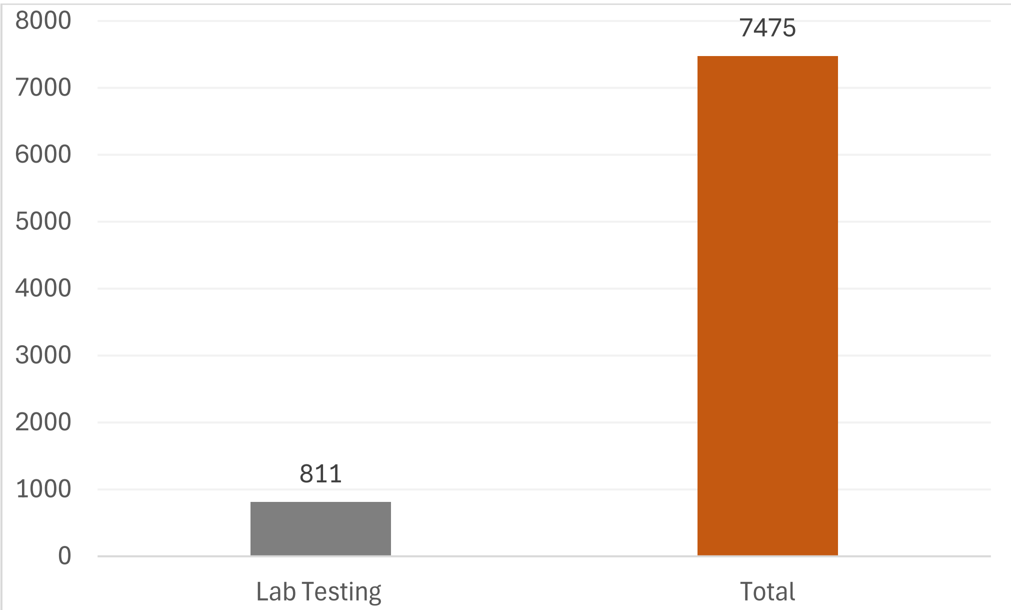


Figure 23: Lab testing facilities present in industrial sector of Lahore division

Air Pollution Sources and Control Measures

This section provides an in-depth assessment of potential air pollution sources associated with industrial activities in the Lahore Division. Key contributors such as exhaust systems from power generators, dust pollution, and emissions from chimneys are analysed to establish a baseline. The presence and operational status of boilers and furnaces (Annex II and III), along with their emission control systems, are examined to evaluate compliance with environmental standards. Furthermore, the chapter outlines the relevant laws and regulations governing industrial emissions.

3.4 Sector-wise Pollution Industries

The sectorial results of industries highlight the varying levels of pollution associated with different industries based on their prevalence. The analysis reveals that the *textile sector*, with 829 units, is the largest contributor to pollution, particularly air pollution from dyeing, printing, and finishing processes, water pollution from chemical-laden effluents, and solid waste generation from sludge and textile waste.

- The *rubber and plastic industry* follow closely with 806 units, contributing significantly to air pollution from VOCs and hydrocarbons during manufacturing, water pollution from effluents containing plasticizers, and solid waste from non-biodegradable off-cuts and rejected products.
- The *leather sector* (706 units) predominantly contributes to water pollution with tannery effluents rich in chromium and sulphides, air pollution from odors and VOCs, and solid waste in the form of chrome-laden sludge.
- Similarly, *basic metal industries* (634 units) are major sources of air pollution, emitting CO, SO_2, and metal particulates, alongside water pollution from contaminated effluents and soil contamination from heavy metal-laden waste.
- *Food processing units* (609 units) are associated with air pollution from particulate matter and odors, water pollution from organic effluents, and solid waste in the form of shells and husks.
- *Non-metallic mineral product industries* (577 units) contribute significantly to air pollution from dust emissions, water pollution from effluent containing suspended solids, and solid waste from non-recyclable residues.
- The *wearing apparel sector* (477 units) generates minor air pollution from steaming and finishing operations, minimal water pollution, and solid waste from textile off-cuts.
- The *other manufacturing sector* (410 units) varies in pollution contributions depending on the specific processes, often emitting VOCs and generating industry-specific effluents and waste.
- *Paper and paper products* (336 units) emit VOCs, particulates, and odors while producing water pollution from lignin-rich effluents and solid waste from paper trimmings and sludge.
- Finally, the *fabricated metal products sector* (282 units) contributes to air pollution from welding and finishing fumes, water pollution from metal-laden effluents, and solid waste in the form of scrap metal.

It is important to state here that this sectoral analysis of industries and the type of pollutants is based on a generic assessment of pollution associated with various types of industries. **However, the exact contribution of air and water pollution from each sector can only be precisely defined through comprehensive surveys and the establishment of a continuous monitoring regime at the source.** Implementing regular air and water quality monitoring across the province will allow for a more accurate assessment of sector-specific pollution and inform targeted mitigation strategies. Moreover, the sectoral analysis demonstrates that there is a need for targeted interventions in these sectors.

4.1 Potential Air Pollution Sources

The surveys conducted in the Lahore Division revealed significant insights into the pollution sources across 7,475 industries. The details are as follows;

4.1.1 Exhaust Systems from Power Generators

The results indicated that 38% of the industries have exhaust systems of Power Generators (Annex – V).

a. Power Generator Capacity:

The different power generators of varying capacity were in use by industries ranging from (0 to 50), (50 to 100), (100 to 200), (200 to 500), (500 to 1000) and more than 1000 comprised of 32%, 21%,15%, 20%. 7% and 5% respectively as shown in Error! Reference source not found. The survey of power generators used in industries within varying c apacity ranges shows the following distribution:

- **0 to 50 units:** 32% of generators fall within this capacity range, indicating a preference for smaller generators.
- **50 to 100 units:** 21% of generators are in this capacity range.
- **100 to 200 units:** 15% of generators have this capacity.
- **200 to 500 units:** 20% of generators are in this mid-range capacity.
- **500 to 1000 units:** 7% of generators have this larger capacity.
- **More than 1000 units:** 5% of generators are in the highest capacity range.

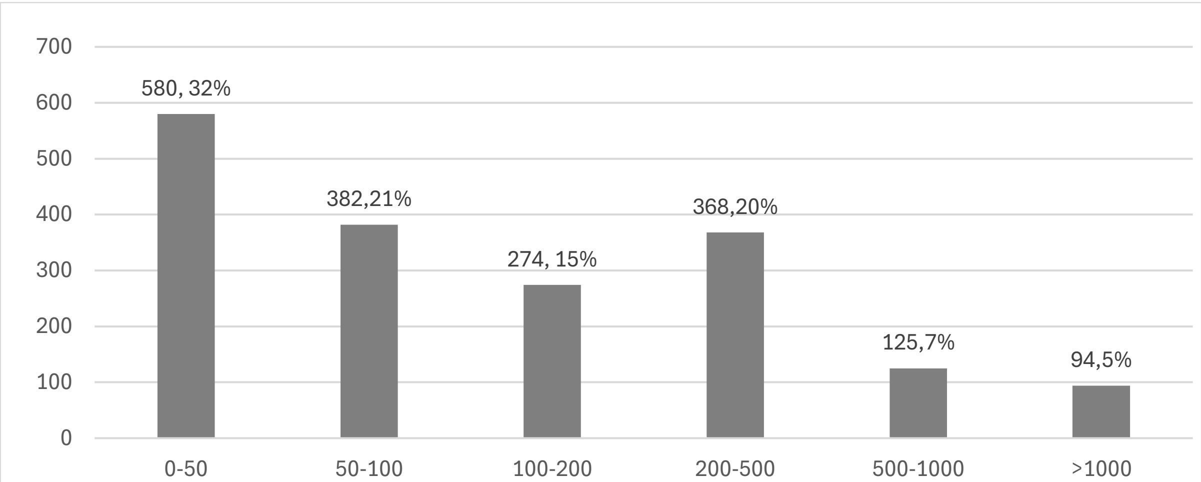


Figure 24: Varying capacity of power generators placed in industries of Lahore Division

These percentage reveal a trend where smaller capacity generators (0–50 units) are most common, while high-capacity generators (over 1000 units) are less frequently used in the industries surveyed.

b. Diesel Usage:

A staggering **99% of these generators operate on diesel**, making them a significant contributor to industrial emissions. The widespread reliance on diesel-powered generators results in substantial air pollution, particularly in areas where industries operate in close proximity. Poorly maintained units exacerbate the issue, emitting higher levels of particulate matter, nitrogen oxides, and sulfur dioxide, all of which contribute to deteriorating air quality. Additionally, inefficient combustion in aging generators leads to increased carbon monoxide (CO) emissions, posing health risks to workers and nearby communities. The heavy dependence on diesel also underscores concerns related to fuel costs, energy efficiency, and the urgent need for cleaner alternatives such as gas-powered or hybrid systems.

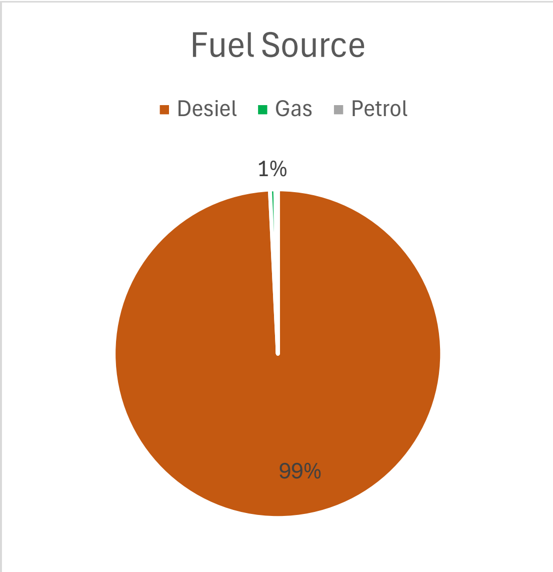


Figure 25: Fuel sources of power generators in industries of Lahore division

Alternative Fuel Sources for Power Generators:

- **0.53%** of power generators use petrol.
- **0.24%** of power generators operate on gas.

These findings highlight a strong dependence on diesel, with minimal adoption of petrol or gas for power generation in the industrial sector.

Punjab Clean Air Action Plan - Policy Measure 21 aims at reducing generator emissions through formulating emission standards, mandating the installation of catalytic converters on new generators, and implementing sound mufflers on all generators to mitigate noise pollution.

4.1.2 Dust Pollution

Dust issue was observed in **27%** of industries, with its prevalence notably higher in sectors such as furniture manufacturing, marble cutting, and grain processing. These industries inherently release fine particulate matter during processes like cutting, shaping, grinding, and polishing. The furniture sector, for instance, generates sawdust and wood particles, while marble processing releases stone dust, and grain processing mills produce husk and other particulate residues.

An important observation during revalidation surveys of rice mills highlighted that dust was present even in non-operational mills. This indicates that dust accumulation is not solely tied to active production but also results from inadequate cleaning or ventilation systems. Such findings underscore the persistent nature of dust pollution in these industries, which can adversely affect both indoor air quality and the health of workers, particularly in poorly ventilated facilities.

4.1.3 Chimneys

Chimneys were present in 19% of industries, serving as outlets for gases and smoke from energy systems like boilers and furnaces. The condition of these emission vents (stacks) was also assessed, highlighting the need for monitoring and maintenance to ensure compliance with emission standards.

These results highlight the pressing need for industrial practices and regulatory actions to combat pollution and enhance the quality of the air in the Lahore division.

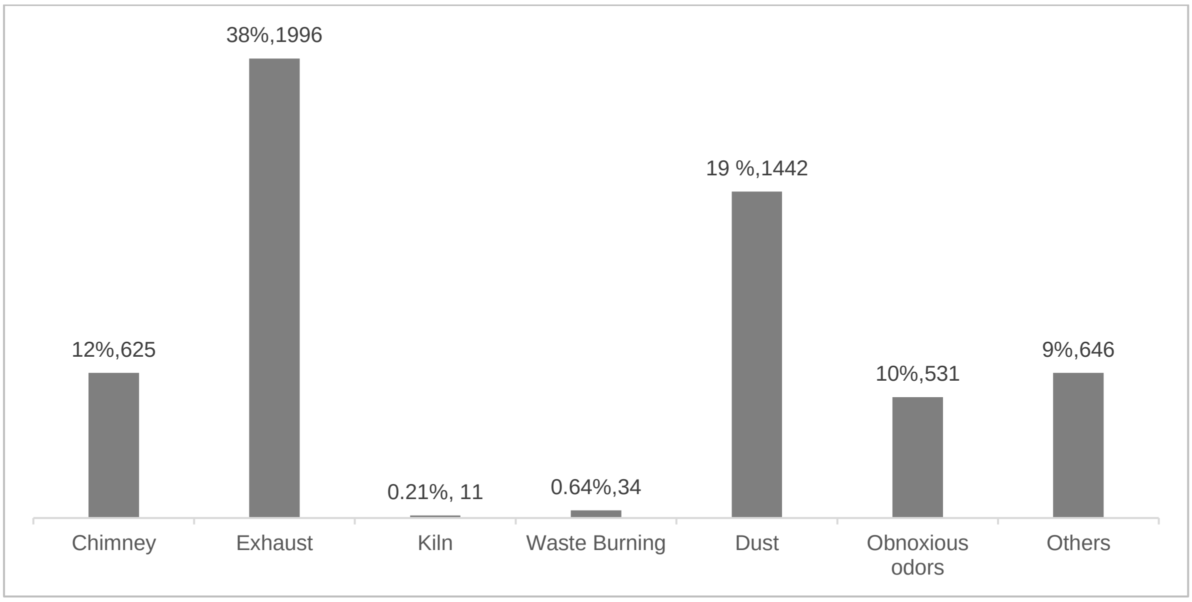


Figure 26: Potential Air Pollution Sources

These statistics underscore exhaust emissions as the predominant pollution source, with dust and chimney emissions also contributing significantly, while kiln emissions remain a minor factor in the pollution profile.

The assessment of industrial stacks provides insights into their structural and operational condition. A total of 1,429 (19% of the total) are recorded. The conditional assessment indicates that most of the stacks were in good condition: 50% of stacks are in excellent condition (A), while 32% are rated good (B). However, 16% fall into the fair category (C), and a small fraction (D) is in poor condition, indicating serious deterioration and need immediate attention.

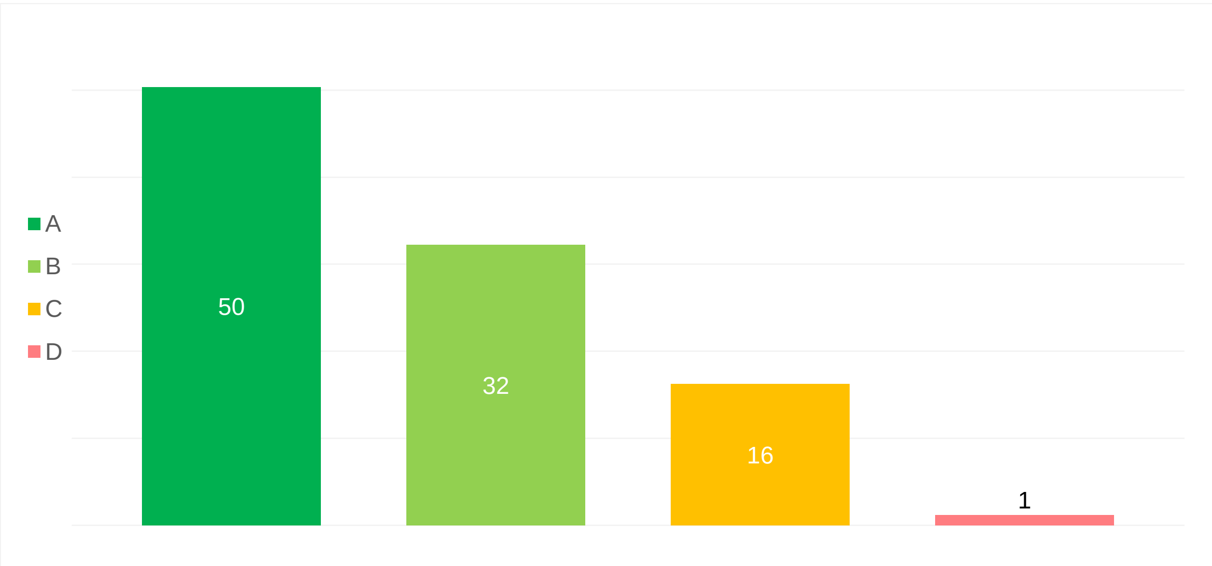


Figure 27: Number of stacks and their conditional assessment

4.2 Emission Control System (ECS) on Boilers and Furnaces

Boilers and furnaces, operating across various industries, release a mix of harmful pollutants, including particulate matter (PM), nitrogen oxides (NO_x), and sulfur oxides (SO_x). These emissions from boilers and furnaces influence by some key factors. These factors are

- Boiler/Furnace Design
- Combustion Controls
- Fuel type and its parameters
- Maintenance and optimization
- Use of ECS

Type of ECS which have to be utilized depends upon emissions coming out of the combustion chamber. Mostly the components of the effluent gas are Carbon Dioxide (CO_2), Carbon Monoxide (CO), Oxides of Nitrogen and Sulphur and Particulate Matters (PM) and the type of ECS to be used depends upon the fact that which component exceeds the allowable limits according to standards. For nitrogen oxides Selective Catalytic Reduction (SCR) or Selective Non-Catalytic Reduction (SNCR) can be utilized and for sulphur oxides Flue Gas Desulphurization (FGD) is available as ECS. For PM control the simplest option is Cyclone but to increase its effectiveness wet scrubber system can be added. But for PM control to achieve maximum efficiency the options are Electrostatic Precipitator (ESP) and Bag Filters (Annex – IV).

Observation during the survey finds that most boilers on NG and other liquid fuels have not utilized any of the ECS whereas boilers on solid fuels utilize cyclone and wet scrubbers. Large steel mills and metal re rolling mills have bag filters as their ECS and they also manage their solid waste as they sell that at good price to local scrappers which extract metal from waste. The management of solid waste seems to be missing at SMEs that use boilers which is a serious concern regarding the effectiveness of ECS towards PM entering into surrounding. Following shows the final assessment after the revalidation survey on ECS of the tested areas.

4.2.1 Survey Report on Boilers

The survey on boiler types used in industries reveals that wet bottom boilers are the most prevalent, making up 51% of the total. Dry bottom boilers follow at 19%. Gas turbine boilers account for 6%, while fluid bed boilers are used in 2% of the industries. Additionally, various other types of boilers, including chain grade, thermos oil, and stationary engines, make up the remaining share.

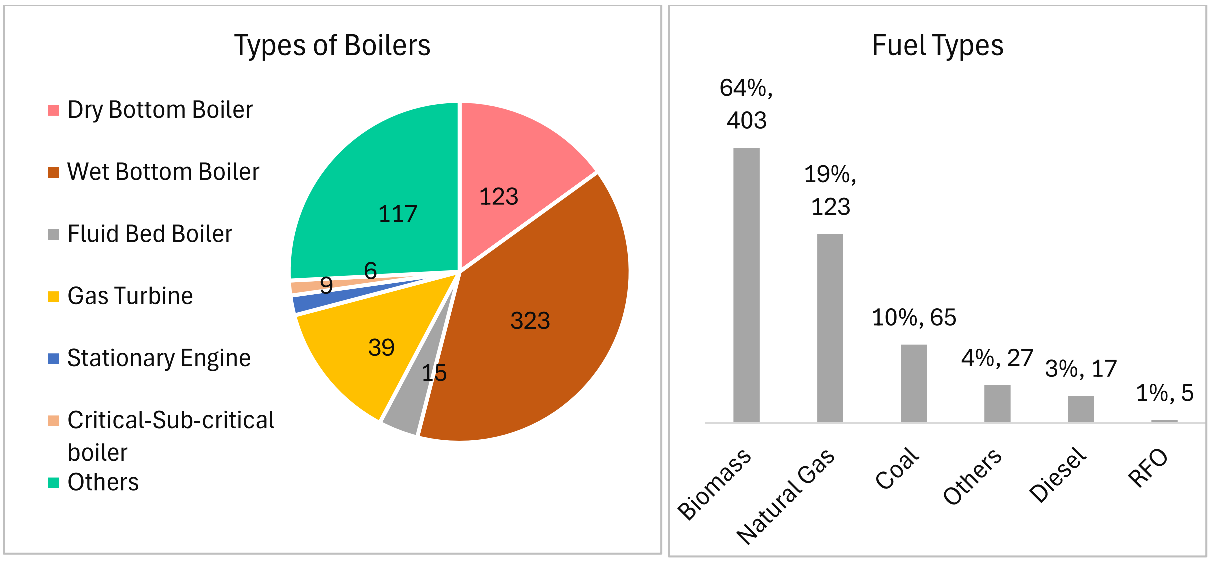


Figure 28: Types of boilers and fuel used in them in industries of Lahore Division

The effectiveness of a boiler depends on a range of factors, with fuel type and quality being among the most critical. In the region, many boilers use biomass as fuel, with only a few units utilizing hardwood. A significant number of boilers operate on high-moisture biomass, which can affect their efficiency. Most of these boilers are small, with capacities ranging from 1 to 3 tons. Small biomass-fueled boilers are typically of the dry bottom type, raising concerns about the proper management of bottom ash. However, some smaller units and most large-capacity boilers are wet bottom, which simplifies ash management.

Natural gas (NG) is the second most commonly used fuel, primarily in small boilers or for hot water generation in the textile and pharmaceutical sectors. Large-capacity boilers, on the other hand, commonly use coal or agricultural waste as their fuel source. However, it is imperative to highlight that regardless of their fuel type and emission control systems, all of the industries are legally bound to comply their emissions with the Punjab Environmental Quality Standards.

An additional concern arises with the use of bagasse as fuel. Bagasse management poses a fire hazard, particularly when small particles of bagasse become suspended in the air around the boiler section. Proper storage and handling of bagasse are crucial to minimizing this risk and ensuring safe boiler operations.

Figure 29: Low Quality Agri Fuel (Source of Black Emissions)

The effectiveness of boilers is significantly influenced by their design and maintenance, as well as the condition of the burners. These factors directly impact combustion efficiency, heat transfer efficiency, and, ultimately, the overall performance and environmental impact of the boilers.

During the revalidation survey, boilers were assessed with the assistance of a boiler engineer. The checks focused on the availability of a valid boiler fitness certificate and the presence of a qualified boiler engineer appropriate to the boiler's capacity. While some larger firms demonstrated compliance by maintaining readily accessible fitness certificates at the boiler section and employing on-site boiler engineers, instances of negligence in adhering to these requirements were also observed. This highlights the need for stricter compliance and regular inspections to ensure operational and environmental efficiency.

The effectiveness of both the burner and the boiler is closely interconnected. A properly functioning burner ensures optimal combustion, enhances heat transfer, reduces emissions, and improves overall boiler efficiency. Regular monitoring, maintenance, and tuning are crucial to sustaining this performance. Factors such as the air-to-fuel ratio, flame stability, and fuel quality play a significant role in optimizing burner and boiler operations. Addressing these factors leads to energy savings, reduced emissions, and prolonged equipment life. However, conducting a direct conditional assessment of the burner during boiler operation is challenging. To address this, it is recommended to maintain an emissions gas report at the boiler section. This report can indirectly indicate the burner's health by analyzing the combustion quality.

Figure 30: Boiler Engineer & Boiler Fitness Certificate

The exhaust gas temperature of boilers is another critical factor affecting their efficiency. High exhaust gas temperatures represent heat loss to the environment, which contributes to increased ambient air temperatures in the surroundings. While some units use economizers to recover heat, only a limited number of facilities are equipped with dedicated waste heat boilers. These boilers utilize excess process waste as an energy source, offering both economic and environmental benefits. By recycling waste heat back into the system, they reduce fossil fuel consumption and lower overall emissions.

An excellent example of efficient waste heat utilization is observed at Naveena Textile. The facility uses exhaust gas temperature as a heat source and then directs the lower-temperature exhaust to their wastewater treatment plant (WWTP). The exhaust aids in neutralizing basic wastewater, leveraging the acidic nature of CO2, which is a primary component of combustion exhaust gases. This innovative approach not only improves energy efficiency but also contributes to environmentally sustainable operations.

The condition of boiler has a crucial role in its contribution to harmful emissions and energy efficiency so the conditional assessment was also carried out through observation of the appearance, checking for rust, leakages and noise as given in figure.

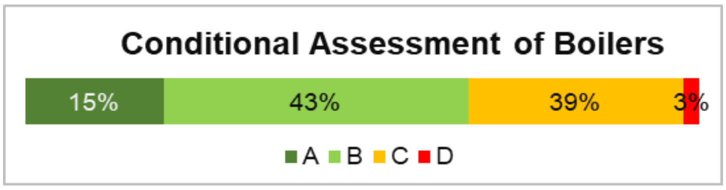


Figure 31: Condition assessment of Boilers of Lahore Division

A: Excellent or New Condition

B: Good Condition

C: Poorly Maintained and Worn-Out

D: Failing Condition (needs replacement or immediate maintenance)

4.3 Survey Report on Furnaces

Furnace data indicates a significant number of heating furnaces in Lahore Division, primarily associated with the metal sector. These mills utilize a variety of furnaces based on their specific requirements and operational capacities. Commonly used furnace types include cupola, crucible, and blast furnaces.

- **Cupola furnaces** are well-suited for medium- to large-scale metal recycling mills,
- while **blast furnaces** are primarily used for processing iron ore but can also handle large-scale steel recycling operations.
- **Crucible furnaces**, on the other hand, are typically employed in mills working with precious metals, alloys, or small-scale specialized recycling processes.

The data also reveals that only 7% of the furnaces in the Lahore Division are process furnaces, highlighting the limited presence of heavy process industries. Among these, the majority are glass manufacturing furnaces, where raw materials are heated at high temperatures to produce new glass products. This underscores the specialized nature of process furnaces in the region, with glass manufacturing being the dominant application.

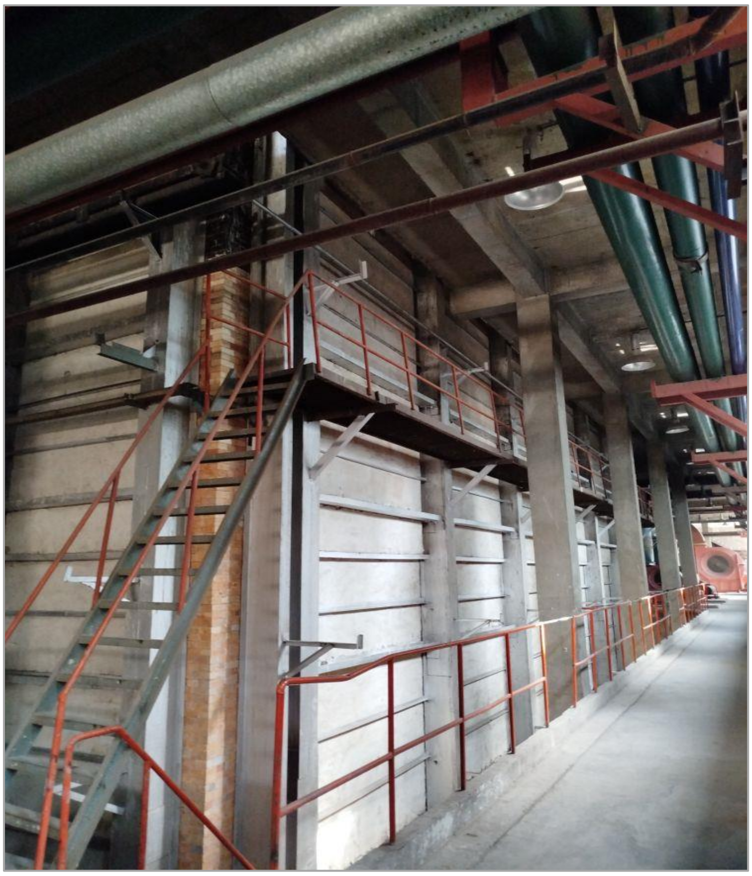


Figure 32: Glass Manufacturing Furnace

Combustion of fossil fuels in furnaces can release carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur dioxide (SO_2), particulate matter, and volatile organic compounds (VOCs)[2].

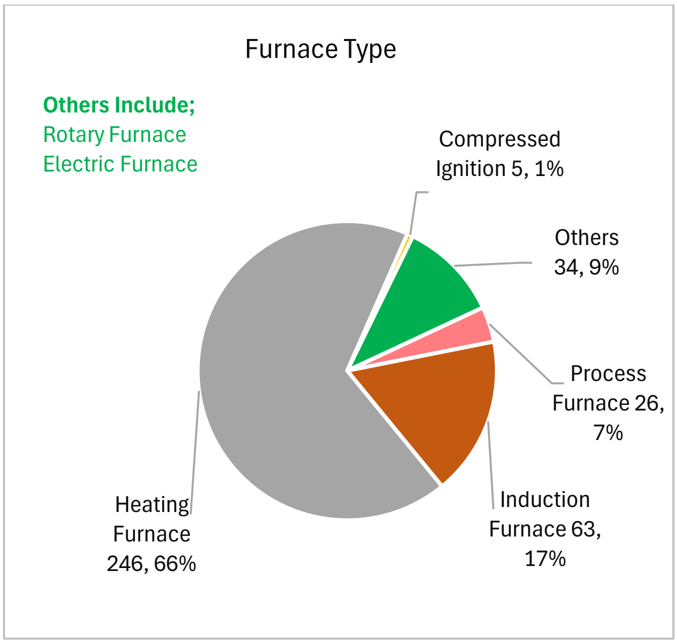
4.3.1 Energy Use:

The electricity used by electric furnaces often comes from fossil fuel power plants, contributing indirectly to air pollution.

In the industries of Lahore division, the distribution of furnaces and emission control systems varies significantly across sectors. The Basic Metals sector leads with 155 furnaces, of which 79 are equipped with emission control systems, indicating a proactive approach to environmental compliance. In contrast, the Machinery and Equipment sector has only 35 furnaces, with just 11 featuring emission controls, highlighting a potential area for improvement.

[2] *Bai, L., Xie, M., Zhang, Y., & Qiao, Q. (2017). Pollution prevention and control measures for the bottom blowing furnace of a lead-smelting process, based on a mathematical model and simulation. Journal of Cleaner Production, 159, 432-445.*

Similarly, the Fabricated Metal Products sector has 26 furnaces, with more than half (18) lacking emission control systems. This suggests that while the Basic Metals sector is more advanced in implementing emission controls, the other sectors may benefit from increased investment and attention to emissions management to enhance sustainability and regulatory compliance.



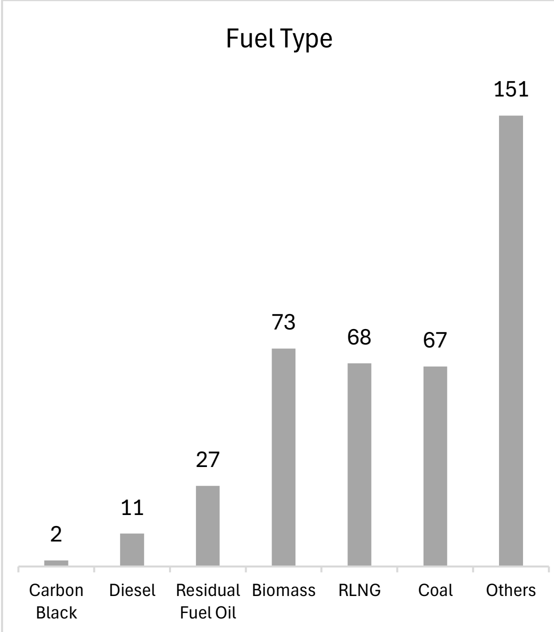


Figure 33: Furnace types and fuel used in industries of Lahore division

Similar to boilers, the conditional assessment of furnaces was also done on the basis of their appearance, working and rustiness. The furnaces present in the industries were of following conditions:

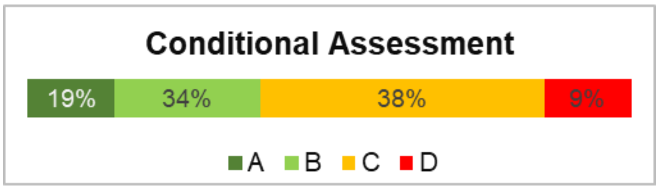


Figure 34: Condition assessment of Furnaces in operation in industries of Lahore division

A: Excellent or New Condition

B: Good Condition

C: Poorly Maintained and Worn-Out

D: Failing Condition (needs replacement or immediate maintenance)

4.4 Laws applicable on control of Emissions from Boiler and Furnaces

Smog Prevention and Control Rules 2023, Clause 4 Standard Operating Requirements for Industrial Units states that; Air Pollution Control System complying with PEQs.

4.4.1 Prohibition on the use of sub-standard fuels

Maintaining inventory of environmental management including compliance reports with PEQs, brief of system or device of air pollution control measures, the capacity of the mill, and approvals or NOC by the Agency and line departments, Installation of online access through CCTV camera for emissions control monitoring system in air pollution causing industrial units for live monitoring of industrial unit.

4.4.2 The Boilers and Pressure Vessels Ordinance, 2002

The Boilers and Pressure Vessels Ordinance, 2002 governs the design, installation, and operation of boilers to ensure their safety and efficiency. It requires boilers to be inspected and certified for compliance with operational and environmental standards, including emissions control.

Boilers with greater than 91 liters capacity can be inspected under this ordinance. Clause 5: Prohibition of the use of uncertified or unregistered boilers, Clause 20, 21, 22, 31: Penalties for Illegal use of boilers, breach of regulations, unregistered alterations, tempering with registration number, non-reporting of accidents, and any form of hampering with boiler structure. Clause 11: Revocation of registration certificates.

4.4.3 Punjab Environment Protection Act – PEPA 2012 (Amended up to 2017)

The Punjab Environment Protection Act describes the prohibition on discharges of emissions and effluents. **Section 11** prohibits the discharge or emission of pollutants beyond the limits prescribed under the Punjab Environmental Quality Standards (PEQS). Industries operating boilers and furnaces must comply with PEQS for gaseous emissions and ensure proper treatment or mitigation measures. The Act further enforces penalties and legal actions for non-compliance with emission standards.

Water Footprint Mapping

The water footprint mapping of the industrial sector in the Lahore Division provides a detailed breakdown of water sources, supply methods, and consumption patterns across industries:

5.1 Water consumption

The water consumption in the industrial sector of the Lahore division indicates that the boring (groundwater extraction) is the most common source, supplying 39% of the industries. Whereas, WASA (Water and Sanitation Agency) provides water to 28% of the industries. Pumps (which also extract groundwater) supply 24% of industries. Industrial estate supplies (from estates like SIE and QIE) contribute 4% to the overall water provision in industrial units located within these estates. A small percentage of industries (3%) in Lahore rely on alternative water sources such as tube wells and turbines for their water supply that is fit for use in industrial processes.

Industrial data analysis provides important visions into both the availability of clean drinking water for workers and the water-intensive nature of certain industries. Water filtration and RO plants are installed in 100 industries, representing only 1% of the total industries in the Lahore Division. These systems are specifically used to purify water for drinking, serving the owner, staff, and factory workers. The low adoption of water purification (filtration and reverse osmosis systems (only 1%) highlights a concern about access to clean and safe drinking water for workers. This is particularly important for ensuring the health and safety of the human resources involved in industrial operations.

High water consumption in specific industries like textiles, beverages, marble and pharmaceuticals points to the need for sustainable water management practices, particularly in regions where groundwater is a key source. Addressing water sustainability and expanding access to clean drinking water could be important areas for policy intervention and investment in the industrial sector of the Lahore Division.

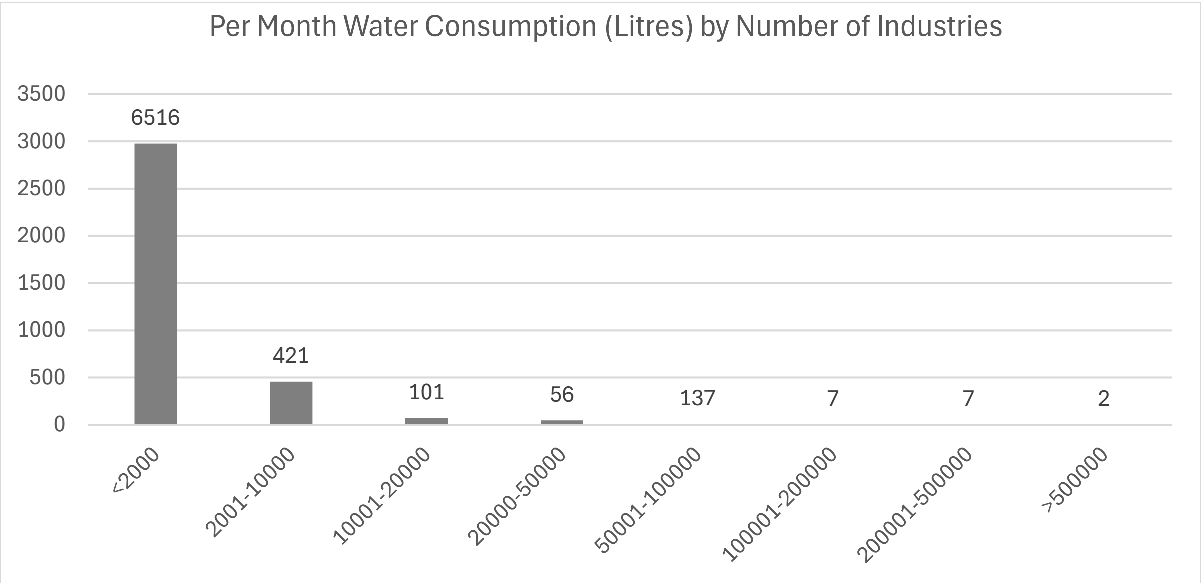


Figure 35: . Water consumption(L/month) breakdown in industries of Lahore division

The data on water consumption patterns among industries in the Lahore Division highlights the varying levels of water use across sectors, indicating the least and most water-intensive industries. Industries (n=6516) consume less than 2000 liters per month. This large group represents industries with minimal water usage, likely those that do not engage in water-intensive processes or have efficient water management practices. However, 421 industries have a monthly water consumption ranging from 2001 to 10,000 liters, indicating moderate water use, likely due to specific industrial processes that require water but not at excessive levels. Furthermore, 101 industries consume between 10,001 to 20,000 liters per month, marking them as significant water users. These are likely in sectors that rely heavily on water, such as textiles, pulp and paper, and beverage manufacturing.

On one hand, a high number of industries (6516) with low water consumption suggests that the majority of industries either do not require much water viz., plastic and rubber, embroidery, stitching apparel including spare parts of machines making units. On the other hand, the smaller proportion of industries consuming between 2,001 to 20,000 liters per month indicates that specific sectors are responsible for the bulk of water usage, reinforcing the idea that water-saving technologies or better water management practices could be focused on these industries. This pattern further emphasizes the concentration of water consumption in specific sectors such as textile, pulp and paper, beverages and marble.

Regarding wastewater disposal in Lahore division, 57% of industries were throwing their waste water in underground reservoirs followed by> water Channel 11% > open drain 7% > open land and agricultural land.

5.2 Wastewater Disposal Methods

The wastewater disposal practices in the industrial sector of Lahore Division provide insight into how industries are managing their wastewater, with varying impacts on the environment:

In the Lahore division, 57% of industries dispose of their wastewater into underground reservoirs. This practice could lead to serious environmental consequences, such as the contamination of groundwater, which can affect both local water supplies and ecosystems. Around 11% of industries discharge wastewater into water channels, which can pollute rivers, and canals, affecting both aquatic life and the quality of water available to other users downstream. Furthermore, 7% of industries use open drains for wastewater disposal, contributing to local pollution, clogging of drains, and poor sanitary conditions. Other industries dispose of their wastewater onto open land or agricultural land, which can result in the contamination of soil, affecting crop health, and, in some cases, the infiltration of pollutants into groundwater systems.

The Wastewater disposal into water channels and open drains could lead to the degradation of water quality in natural water bodies and pose health risks for nearby populations. Open land or agricultural land disposal can affect soil fertility and, if untreated, pose risks to crops, livestock, and, ultimately, human health through contaminated food chains. This pattern points to a significant need for improved wastewater management practices, including treatment facilities, stricter regulations on disposal methods, and initiatives to encourage more sustainable disposal solutions. Proper wastewater treatment and disposal would help mitigate the negative impact on groundwater, soil, and water channels, contributing to better environmental and public health outcomes.

5.3 Existing Situation of Waste Water Treatment

The wastewater treatment practices and regulatory framework in the industrial sector of Lahore Division highlight both existing situation in wastewater management and challenges in enforcement.

5.3.1 Types of Waste Water Treatment Plants (WWTPs)

The Lahore Division has a total of 225 wastewater treatment plants (WWTPs), with 188 industries equipped with WWTPs. The Lahore District has the highest number (145), followed by Sheikhupura (22) and Kasur (21) (Annex – VI).

Table 2: Status of WWTPs in Lahore

Category	Count
Total WWTPs in Lahore Division	225
Industries with WWTPs	188
WWTPs in Lahore District	145
WWTPs in Kasur	21
WWTPs in Sheikhupura	22

Moreover, Lahore has the highest percentage of WWTPs in excellent (26%) and good (51%) condition, while Kasur has the highest percentage in poor condition (37%). Sheikhupura has a balanced distribution, with 45% rated as excellent and good.

Table 3: WWTP Condition by District

District	Excellent Condition	Good Condition	Poor Condition	Failing
Lahore	26%	51%	20%	1%
Kasur	9.5%	57%	37%	0%
Sheikhupura	45%	45%	10%	0%

Results indicate, 32% of industries have installed septic systems as a form of wastewater treatment while 30% use sedimentation tanks, which allow for settling of solids from wastewater. Only 20% have biological treatment units to degrade organic matter while 12% utilize the activated sludge process, an advanced method involving aeration and microbial action. However, 7% use membrane bioreactors, a more sophisticated filtration technology. In fact, 6% implement coagulation or neutralization processes to treat wastewater. Certainly, 3% have trickling filters for treating water biologically and 2% employ advanced oxidation processes, a chemical method used to break down contaminants.

Septic systems (32%) and sedimentation tanks (30%) are the most common WWTP types, while biological treatment units account for 20%. Advanced oxidation processes are the least used, making up only 2%.

Table 4: WWTP Types in Lahore Division

Wastewater Treatment Plant Type	Percentage
Septic System	32%
Sedimentation Tanks	30%
Biological Treatment Units	20%
Activated Sludge Process	12%
Coagulation or Neutralization Process	6%
Membrane Bioreactors	7%
Trickling Filters	3%
Advanced Oxidation Processes	2%

Out of 225 WWTPs, 167 (74%) are fully operational, while 17 are partially operational. A significant number, 41 WWTPs, are non-operational, indicating maintenance and functionality issues.

Environmental industrial mapping results showed, 167 WWTPs are fully operational while 41 WWTPs are not operational, which means a significant portion of industries are likely discharging untreated or partially treated wastewater. In addition, 17 WWTPs are partially operational, indicating inefficiencies or breakdowns in the wastewater treatment process.

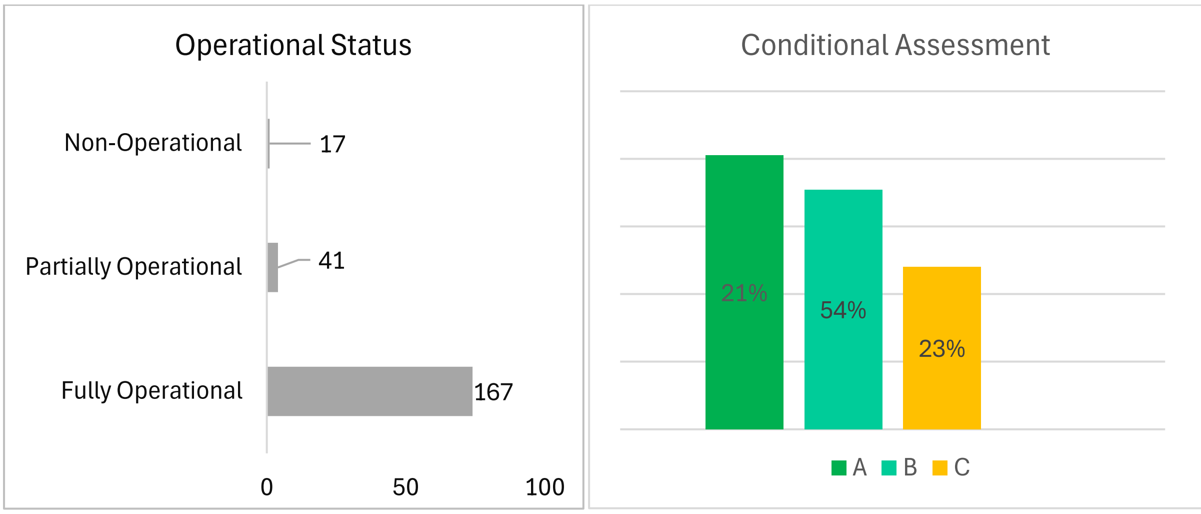


Figure 36: Indicating operation status and condition assessment in industries of Lahore division

Several legal provisions govern wastewater management and pollution control in Lahore Division, aimed at protecting water resources

- Section 14 of the Factories Act, 1934 mandates that every factory must make effective arrangements for the disposal of waste and effluents, ensuring they do not harm the environment.
- The Canal and Drainage Act, 1873, specifically Section 70, imposes fines and up to three months of imprisonment for corrupting or fouling canal waters, which can render them unfit for ordinary use.
- Section 73 of the Canal and Drainage Act also makes it an offense to will fully damage, obstruct, or interfere with canals or drainage systems.
- The Punjab Environmental Protection Act, Section 11, prohibits certain discharges and emissions into water bodies, reinforcing the need to control industrial wastewater pollution.

5.4 Key Implications

- Despite a variety of wastewater treatment systems in place, the fact that some WWTPs are not fully operational poses a challenge to effective water pollution control. This could lead to untreated effluents being discharged into water bodies, contributing to environmental degradation.
- The Factories Act, Canal and Drainage Act, and Punjab Environment Protection Act provide a strong legal basis for controlling water pollution, but enforcement remains a challenge. The operational status of WWTPs suggests that more rigorous compliance checks and enforcement mechanisms are needed to ensure industries adhere to these laws.
- While advanced treatment methods like membrane bioreactors and advanced oxidation processes are used by some industries, their adoption remains limited. Expanding the use of such technologies could improve the quality of wastewater discharged and reduce the environmental impact.
- While there has been progress in the installation of wastewater treatment facilities, the non-operational plants and the uneven adoption of advanced technologies indicate that more efforts are needed in ensuring compliance with regulations and promoting effective wastewater treatment practices.

Recommendations & Way Forward

The recommendations presented in this chapter aim to provide a comprehensive roadmap for addressing the environmental challenges faced by industries in the Lahore Division, with a specific focus on air and water pollution control.

Given the growing concerns about the impact of industrial emissions on air quality and public health, it is imperative to adopt a combination of regulatory measures, technological advancements, and market-based solutions to mitigate pollution. These recommendations are designed to guide policymakers, industry stakeholders, and environmental agencies in implementing effective strategies to enhance environmental sustainability, improve industrial compliance, and foster a cleaner, healthier environment for the communities surrounding industrial areas.

Through a collaborative approach, the industrial sector can play a key role in achieving air quality standards while promoting economic growth and competitiveness. The recommendations are as follows;

6.1 Enhanced Monitoring and Data Collection

- Establish a comprehensive air and water quality monitoring network within industrial zones to track emissions from industries in real-time and identify key sources of pollution.
- Enforce the installation of Continuous Emission Monitoring Systems (CEMS) in major industrial units and power plants, ensuring real-time pollutant tracking and direct data access to the EPA.
- Develop a Centralized Digital Monitoring & Compliance Portal allowing the EPA, Industries and other associated entities to monitor compliance in real time. Enable automated alerts for industries exceeding permissible pollution levels, triggering inspections and enforcement actions.
- Use CEMS data to fine-tune the operation of Emission Control Systems (ECS) and ensure their efficiency in reducing air pollution.
- Create a standardized computerized system for collecting and utilizing environmental compliance data at a local scale.

6.2 Enforcement and Regulatory Measures

- Strengthen the enforcement of existing rules and regulations, and compliance of Punjab Environmental Quality Standards (PEQs), through regular inspections and penalties for non-compliance.
- Enforce mandatory environmental impact assessments (EIAs) and regular audits for new and existing industries.
- Restrict hazardous and high-pollution industries to designated industrial zones away from residential areas, water bodies, and agricultural land.
- Identify industries discharging untreated wastewater and high emissions within urban areas and develop a phased relocation strategy to move them to designated industrial zones.

- Offer financial incentives, technical support, and subsidies for industries that adopt cleaner production techniques, wastewater recycling, and emission reduction technologies.
- Establish Eco-Industrial Parks (EIPs) with centralized wastewater treatment plants, emission control systems, and energy-efficient infrastructure.
- Implement mandatory green buffers (tree belts and green corridors) around industrial zones to reduce air and noise pollution.
- Encourage rooftop solar installations and rainwater harvesting systems in industrial estates to promote sustainability.
- Prohibit the use of waste plastics, rubber, cloth, and used tires as industrial fuel sources. Enforce a strict ban on illegal tyre pyrolysis plants.
- Implement smart grids and metering systems for water and energy consumption tracking, ensuring efficient resource utilization.
- Tailor industry-specific environmental standards based on local geographical and ecological conditions rather than using uniform regulations.

6.3 Environmental Audits

- Require annual or bi-annual environmental audits for industries, focusing on pollution control, resource efficiency, and regulatory compliance.
- Categorize industries based on risk level (e.g., high, medium, low) and set audit frequency accordingly.
- Establish accredited third-party auditors to conduct unbiased environmental audits.
- Allow industries to self-audit under regulatory supervision, with random verification by EPA and EMC.
- Link Audits to Incentives & Penalties e.g. Industries meeting environmental standards could receive tax benefits, subsidies, or certifications like "Green Industry Label". Non-compliant industries should face progressive penalties, fines, or mandatory corrective actions.
- Conduct regular energy audits in industries to identify opportunities for improving energy efficiency and reducing carbon footprints.

6.4 Adoption of Modern Environmental Technologies and Treatment Systems

- Convert all traditional Bull-Trench Brick Kilns to modern, energy-efficient alternatives to reduce emissions and improve air quality.
- Devise a strategy for industrial sector to adopt modern treatment techniques and technologies, such as electronic emissions control devices and effluent treatment plants. Encourage industries to transition to low-sulphur fuels and alternative energy sources such as solar power, biomass, and natural gas to reduce emissions.
- Establish combined effluent treatment plants for clusters of industries that cannot afford individual plants due to financial, physical, or technological limitations.
- Promote and incentivize cleaner production practices and industrial symbiosis in industrial estates.
- Encourage industries to implement green building practices and the use of renewable energy sources such as solar, wind, or biogas to reduce the carbon footprint and air pollution from industrial activities.

- Promote the use of clean fuels (e.g., natural gas, biofuels) and discourage the use of high-sulphur coal or other polluting fuels in industrial boilers, furnaces, and power generators.
- Publicize environmental performance reports and implement a rating system to incentivize compliance, including rewards or tax rebates for high-performing industries.

6.5 Develop and Implement Best Available Techniques (BAT) Guidelines

Currently, the concept of Best Available Technology (BAT) is not incorporated into the Punjab Environmental Protection Act (PEPA), highlighting a critical gap in the regulatory framework for controlling industrial emissions and promoting cleaner production practices throughout the industrial operations. It definitely includes the examination of fuel being utilized in industrial practices and then expert opinion regarding specific ECS especially for boilers on NG as a fuel as it represents a large number of units with no post PM emission controller has been utilized. The following recommendations outline a proposed way forward for Punjab EPA;

- In the first phase, the Punjab EPA is recommended to establish a structured BAT system for major polluting industries.
    - Develop sector-specific BAT guidelines for industries, particularly focusing on high-emission sectors such as textiles, steel, cement, etc. These guidelines will provide industries with a clear roadmap on how to upgrade their operations to meet international environmental standards.
    - The process may include identifying feasible control technologies, eliminating infeasible options, ranking the most effective technologies based on emission reduction potential, economic feasibility, and environmental impact, and selecting the most appropriate BAT for each pollutant and process.
    - The Punjab EPA could prepare a detailed list and guidelines on basis of sectorial environmental risk registries for each pollutant, including data such as Emission reductions (% pollutant removed), Expected emission rate (tons/year, pounds/hour), Energy impacts, Environmental impacts (including impacts on other media like water or solid waste, and effects on toxic or hazardous air contaminants).
    - Decision would be required on the integration of BAT Conclusions into PEQS. For example, how BAT conclusions will relate to PEQS, as the current PEQS do not address BAT, new provisions must be developed to incorporate these requirements effectively.
- In the second phase, an incentive-based system for BAT adoption is essential to be developed. For instance, propose incentives (e.g., tax breaks, subsidies) for industries to voluntarily adopt BAT to control emissions, reduce energy consumption, and minimize their environmental footprint. These incentives could be tied to compliance with environmental quality standards and the successful implementation of pollution control measures.
- In the third phase, Punjab EPA needs to establish a monitoring and evaluation system to track the implementation of BAT across industries, ensuring that these technologies are effectively reducing emissions. Industries found not complying with BAT guidelines should be subject to penalties or forced to make improvements.
- In the last phase, the Punjab EPA can roll out the plan and encourage industries to adopt BAT for reducing emissions, which are the most effective and advanced technologies available to minimize pollution. This includes implementing energy-efficient equipment, air pollution control technologies, and cleaner production techniques. Capacity building and awareness sessions would be a key for successful implementation of BAT.

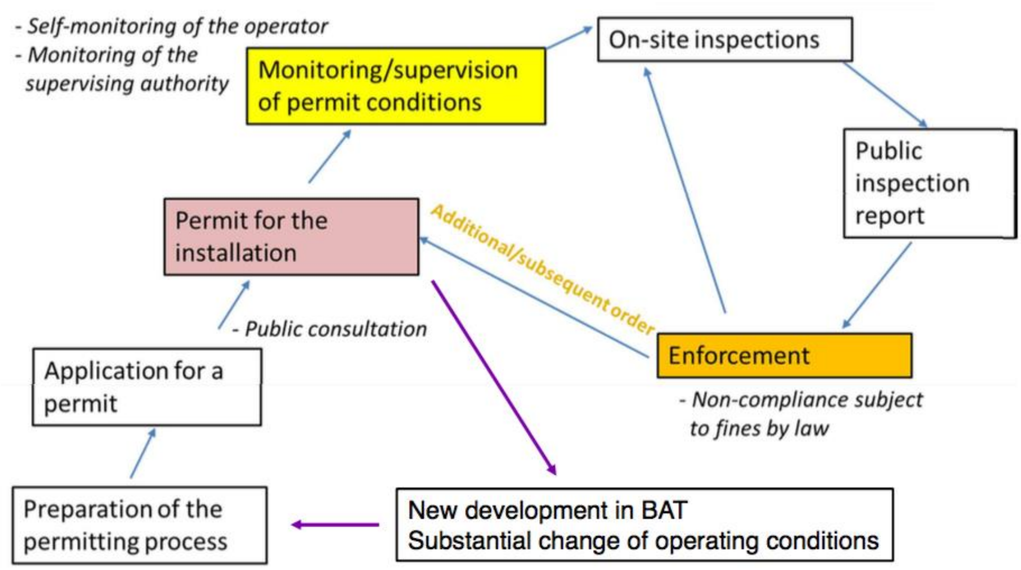


Figure 37: Steps for implementation and enforcement of BAT

The Urban Unit has already proposed Best Available Techniques (BAT) for the following five industries, which can play an integral role in rolling out cleaner and more sustainable industrial practices in Punjab: Leather Tanneries, Textile Industry, Coal Power Plants, Brick Kilns, and Cement Manufacturing.

6.6 Permitting System

- Develop a robust and streamlined permitting system for industries to ensure that they are legally required to comply with air and water pollution control measures, in the first phase. This system should include pre-approval for construction, operational licenses, and periodic renewals based on environmental performance. Permitting shall take into account local conditions for industrial installations on case specific basis.
- Ensure that industries are issued pollution control permits as part of the permitting process, setting limits on emissions based on environmental registers of each sector. These permits should be regularly reviewed and updated based on the latest environmental data and advancements in pollution control technologies.
- Make permitting data accessible to the public through an online platform to promote transparency in environmental governance. Communities and local stakeholders should be able to track industrial compliance with emission limits and other regulatory requirements.

6.7 Emission Trading

- Introduce an Emission Trading System (ETS) as a market-based approach to control industrial air pollution. This system would set a cap on the total amount of emissions allowed from industrial sources, and industries would be able to trade emission allowances. Industries with lower emissions can sell their allowances to higher-emitting industries.
- Provide support and guidance to industries on how to participate in the ETS, including understanding how the system works, tracking emissions, and buying or selling allowances. Facilitate industry workshops and training to ensure smooth adoption of the system.
- Establish an independent monitoring and verification system to ensure that emissions data provided by industries is accurate and reliable. This system should prevent industries from exceeding their

emission allowances and ensure that trading activities are transparent and fair.

- Allocate the revenue generated from the sale of emissions allowances to fund environmental programs, such as air quality monitoring, pollution reduction initiatives, and community health programs. This will help offset the costs of implementing stricter air quality regulations and incentivize further environmental improvements.

6.8 Implementation of Pollution Charge in Punjab

- Introduce a pollution charge/tax as a regulatory measure to reduce industrial emissions, following the Polluter Pays Principle (PPP), ensuring that industries compensate for their environmental impact.
- Design the pollution charge as a flexible market-based mechanism, allowing industries to determine the most cost-effective methods for reducing emissions, including process modifications, cleaner inputs, recycling, and technological upgrades.
- Utilize the existing legal framework under PEPA (2012) S6(2)(d) to implement pollution-related taxes, duties, and levies while also offering incentives such as tax exemptions and subsidies for industries adopting cleaner technologies.
- Establish a dynamic tax structure, with periodic adjustments based on pollution reduction targets, ensuring its effectiveness in achieving environmental goals.
- Align the pollution charge with marginal abatement cost principles, ensuring that industries with varying pollution control costs optimize their emission reductions in an economically efficient manner.
- Revenue generated from the pollution charge should be reinvested into environmental improvement programs, such as industrial emission monitoring, cleaner production initiatives, and the adoption of Best Available Techniques (BAT).
- Conduct a phased rollout of the pollution charge, starting with high-emission industries, to facilitate smooth implementation and compliance.

6.9 Foster Collaborations with Key Stakeholders

- Facilitate collaboration among key industry associations (e.g., All Pakistan Tanners Association (PTA), Pakistan Textile Exporters Association (PTEA), Pakistan Textile Mills Association (APTMA), All Pakistan Textile Processing Mills Association (APTPMA), Pakistan Leather Garments Manufacturers and Exporters Association (PLGMEA), Chamber of Commerce and Industries, and government agencies (e.g., EPA, WASA) to improve environmental compliance through joint research, training, and forums.
- Promote active engagement of non-governmental organizations (NGOs; including INGOs), academic institutions, and civil society in the greening of industries. This collaboration can include advocacy, research, capacity-building programs, public awareness campaigns, and community-driven projects to address environmental challenges. By fostering partnerships between these stakeholders and government agencies, innovative solutions can be developed, ensuring broader participation in the formulation and implementation of sustainable environmental policies and practices.
- Develop mechanisms to minimize communication gaps between communities and environmental authorities, establishing city-wide partnership forums for environmental issue resolution.

6.10 Capacity Building and Awareness Raising

- Provide educational resources and compliance tools to assist communities and small businesses in reducing pollution. Specially to enhance the monitoring and enforcement capabilities of the Environmental Protection Agency (EPA), it is essential to provide sector-specific training for EPA inspectors. This training should focus on the use of environmental and safety registers, improving their ability to identify issues and ensure compliance within different sectors.

- Launch awareness campaigns and actively involve the local community, academia, civil society, non-profit organizations, and local governments to highlight the link between industrial pollution and public health.
- Establish platforms for dialogue between industries, local communities, and environmental groups to discuss air quality concerns and solutions.
- Offer training programs to industrial stakeholders (e.g., managers, operators) on the best practices for reducing air pollution, using cleaner technologies, and complying with air quality regulations.
- Provide certification or recognition for industries that adopt best practices for air pollution control, creating an incentive for others to follow suit, and encouraging industries to take responsibility for their emissions.

6.11 Transition to Circular Economy and Waste Reduction

- Promote the adoption of circular economy principles to reduce waste generation, which can contribute to air pollution (e.g., from open burning of waste).
- Encourage industries to minimize waste by adopting zero-waste strategies and reusing industrial by-products to avoid incineration or improper disposal that can result in air pollution.

6.12 Regulation of Industrial Waste Disposal Practices

- Implement regulations for the proper disposal of industrial waste, ensuring that improper disposal methods do not result in the release of harmful air pollutants (e.g., open burning of industrial waste).
- Require industries to adopt waste management plans that minimize air pollution from hazardous waste disposal.

6.13 Sustainable Transportation within Industrial Areas

- Implement measures to reduce emissions from transportation within industrial areas by promoting the use of electric vehicles (EVs) or cleaner fuels for industrial transport fleets.
- Develop dedicated transport routes for goods and employees within industrial zones to reduce traffic congestion, air pollution, and overall emissions in surrounding areas.

ANNEXURES

Annexure - I: Survey Form

Environment Protection and Climate Change Department
Government of The Punjab

The Urban Unit

SURVEY FORM

Environmental Mapping of Industries in Lahore, Faisalabad & Gujranwala Divisions by the Urban Unit and EPA Punjab

Date: ____________

Module 1: Basic Information				
1. Name of Industrial Unit:			2. Year of Installation:	
3. GPS Coordinates (X,Y):			4. Complete Address:	
5. Area of Industry:	*(marla)*		6. Picture: 🖼	
7. Type of Industry:	Sector: 🖼		Group: 🖼	Class: 🖼
8. Operational hours/day:			9. Operational Category:	Seasonal: Annual:
10. Type of Raw Material:	*Raw material 1, 2, 3* *Annual Quantity 000 kgs/tonnes*		11. Type of Major Products:	*Top Products 1 & 2* *Annual Quantity 000 kgs/tonnes*
12. Electricity Connection:	☐ Yes ☐ No		13. Gas Connection: 🖼	☐ Yes ☐ No
14. Water Connection: 🖼	☐ Yes ☐ No		15. Quality Control Testing Laboratories: 🖼	☐ Yes ☐ No
16. Human Resource: 🖼	*Number:*		*Male:*	*Female:*
17. Building type 🖼	☐ Residential	☐ Offices	☐ Product Storage	☐ Treatment Facility
	☐ Factory	☐ Raw Material Storage	Others: ________	
18. Building Storeys:			Building Condition with pictures 🖼	A | B | C | D
19. Exporting	☐ Yes ☐ No		20. Exporting to Countries	US, UK, Europe, GCC, Africa, Others____
21. Owner/CEO Occupier Name:			22. Owner/CEO/Occupier's Contact No.	
Module 2: Environmental Data Record Sheet				
23. Boilers: 🖼	☐ Yes ☐ No *If yes, then write the number* ________________		24. Types of Boilers: 🖼	☐ Dry Bottom Boiler ☐ Wet Bottom Boiler ☐ Fluid Bed Boiler ☐ Gas Turbine ☐ Stationary Engine ☐ Critical/Sub Critical Boiler ☐ Others_______

25. Picture of Boilers ☐		Boiler Condition with pictures ☐	A	B	C	D
26. Capacity of Boiler						
27. Furnaces: ☐	☐ Yes ☐ No *If yes, then write the number* ________________	28. Type of Furnaces: ☐	☐ Process Furnace ☐ Induction Furnace ☐ Heating Furnace ☐ Compressed Ignition ☐ Others_________			
29. Picture of Furnaces ☐		Furnaces Condition with pictures ☐	A	B	C	D
30. Fuel Used: ☐ *For Boilers and Furnaces separately*	☐ Coal ☐ Petrol ☐ Diesel ☐ Residual Fuel Oil/HFO ☐ Biomass (Corn cob, husk, Wood) etc. ☐ Sub Standard Fuel (Carbon Black (Pyro-carbon) and Rugs etc.) ☐ RLNG / Natural Gas ☐ Others: _________	31. Sources of Air Pollution: ☐	☐ Chimney ☐ Exhaust ☐ Kiln ☐ Waste Burning ☐ Dust ☐ Obnoxious Odors ☐ Others: ________			
32. Power Generator	☐ Yes ☐ No	33. Capacity and Type of Generator				
34. No of Stacks: ☐		35. Stack Height:				
36. Picture of Stacks ☐		37. Stack Condition:	A	B	C	D
38. Emission Control System (ECS) installed ☐		☐ Yes ☐ No				
39. If yes, then write number ____________						

40. Type of ECS: ☐	☐ Bag filter/bag house	☐ Dry Scrubber	☐ Wet Scrubber	☐ Combination of Cyclone + Water Scrubber	☐ Electrostatic Precipitator
	☐ Cyclone Separator	☐ Fabric Filter	☐ Biofilter	☐ Absorption Beds	☐ Mist Eliminator
	☐ Gas Absorption Tower		☐ Others: ________________________________		
41. ECS Operational Status ☐	☐ Fully operational	☐ Partially operational		☐ Non-operational	

42. ECS Conditional Assessment:	A	B	C	D	Details:				
43. Picture of ECS ☐									
44. Water Consumption	*(liters or gallons or m^3 per day)*				45. Water Source				
46. Number of Tubewells : ☐	☐ Yes ☐ No *If yes, then write the number and Capacity*_________				47. Tube Well Condition: ☐	A	B	C	D

<table>
<tr><td colspan="6">48. In the case of Surface water consumption: Capacity of Consumption</td><td>(liters or gallons or m^3 per day)</td></tr>
<tr><td>49. Waste Water Discharge</td><td colspan="4">☐ Yes ☐ No</td><td></td><td></td></tr>
<tr><td>50. Waste Water Treatment Plant Installed</td><td colspan="4">☐ Yes ☐ No</td><td>51. WWTP Capacity</td><td></td></tr>
<tr><td>52. WWTP Operational Status</td><td colspan="4">☐ Fully operational</td><td>☐ Partially operational</td><td>☐ Non-operational</td></tr>
<tr><td>53. WWTP Conditional Assessment:</td><td>A</td><td>B</td><td>C</td><td>D</td><td colspan="2">Details:</td></tr>
<tr><td rowspan="4">54. Type of WWTP</td><td colspan="4">☐ Sedimentation Tanks (STP)</td><td>☐ Activated Sludge Process (ASP)</td><td>☐ Trickling Filters</td></tr>
<tr><td colspan="4">☐Coagulation or Neutralization Process</td><td>☐ Biological Treatment Units</td><td>☐ Advanced Oxidation Processes (AOPs)</td></tr>
<tr><td colspan="4">☐ Membrane Bioreactors (MBRs)</td><td>☐ Septic System</td><td>☐ Others ________________</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="5">55. Pictures of WWTP</td><td colspan="2"></td></tr>
<tr><td colspan="5">56. Waste Water Disposal Point:</td><td colspan="2">☐ Water Channel ☐ Open Land ☐ Agriculture ☐ WASA drain
☐ Open Drain ☐ Others: _________</td></tr>
<tr><td colspan="5">57. Waste Water Generation Capacity:</td><td colspan="2">(liters or gallons or m^3 per day)</td></tr>
<tr><td>58. Material Storage Availability</td><td colspan="4">☐ Yes ☐ No</td><td>59. Storage Type</td><td>☐ Raw Materials
☐ Final Products
☐ Others</td></tr>
<tr><td>60. Material Storage Condition:</td><td>A</td><td>B</td><td>C</td><td>D</td><td colspan="2">Details:</td></tr>
<tr><td colspan="5">61. Pictures of Material Storage Facility</td><td colspan="2"></td></tr>
<tr><td>62. No. of Trees:</td><td colspan="6"></td></tr>
<tr><td>63. Picture of Lab reports</td><td colspan="6"></td></tr>
</table>

Annexure - II: Boiler Pictures





Annexure - III: Furnace Pictures

Annexure - IV: Emission Control System Pictures






Annexure - V: Generator Pictures


Allied


VISA

Annexure - VI: Waste Water Treatment Plant (WWTP) Pictures

Annexure - VII: Environmental Industrial Mapping Survey Progress Dashboard (User Manual)

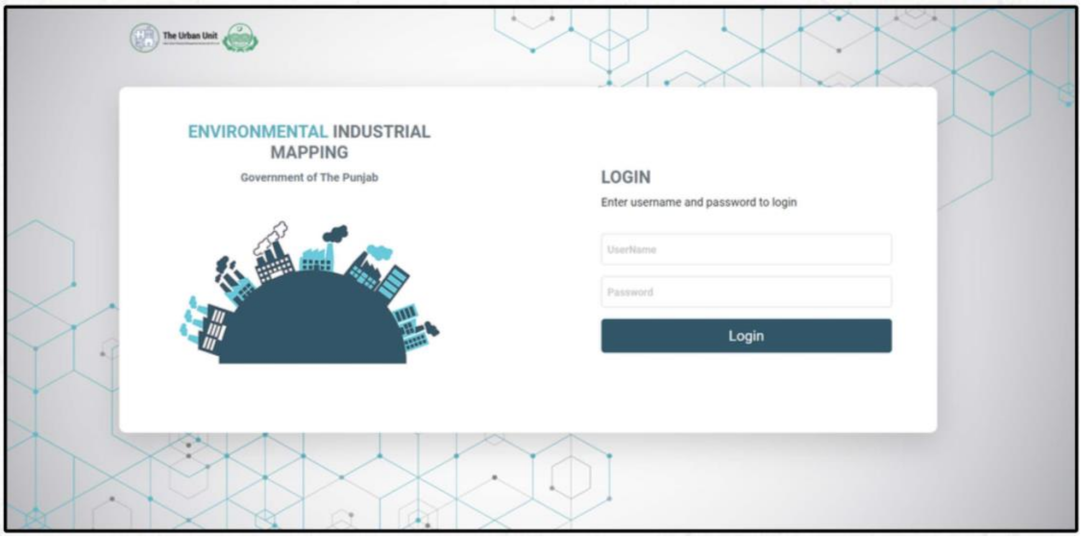
Introduction

The Urban Unit and EPA Punjab aims to create a comprehensive environmental profile of industrial activity in three major divisions of Punjab: Lahore, Faisalabad, and Gujranwala. This will involve mapping industrial locations and analyzing their potential impact on air and water quality. The project is part of a larger initiative to improve environmental management and urban planning in Punjab. In this regard a Environmental Industrial System has been developed by the ICT team of the Urban Unit, a detailed overview of the system is explained below:

The system allows different users to login to access different features based on the categories of the users. Each category of user is provided with separate login credentials. The users can be divided into five categories:

1. Viewer
2. GIS QC Manager
3. Environment QC Manager
4. GIS QC User
5. Environment QC User

We will go through each of the user accessibility of the system in detail to explore all the features available to different users.

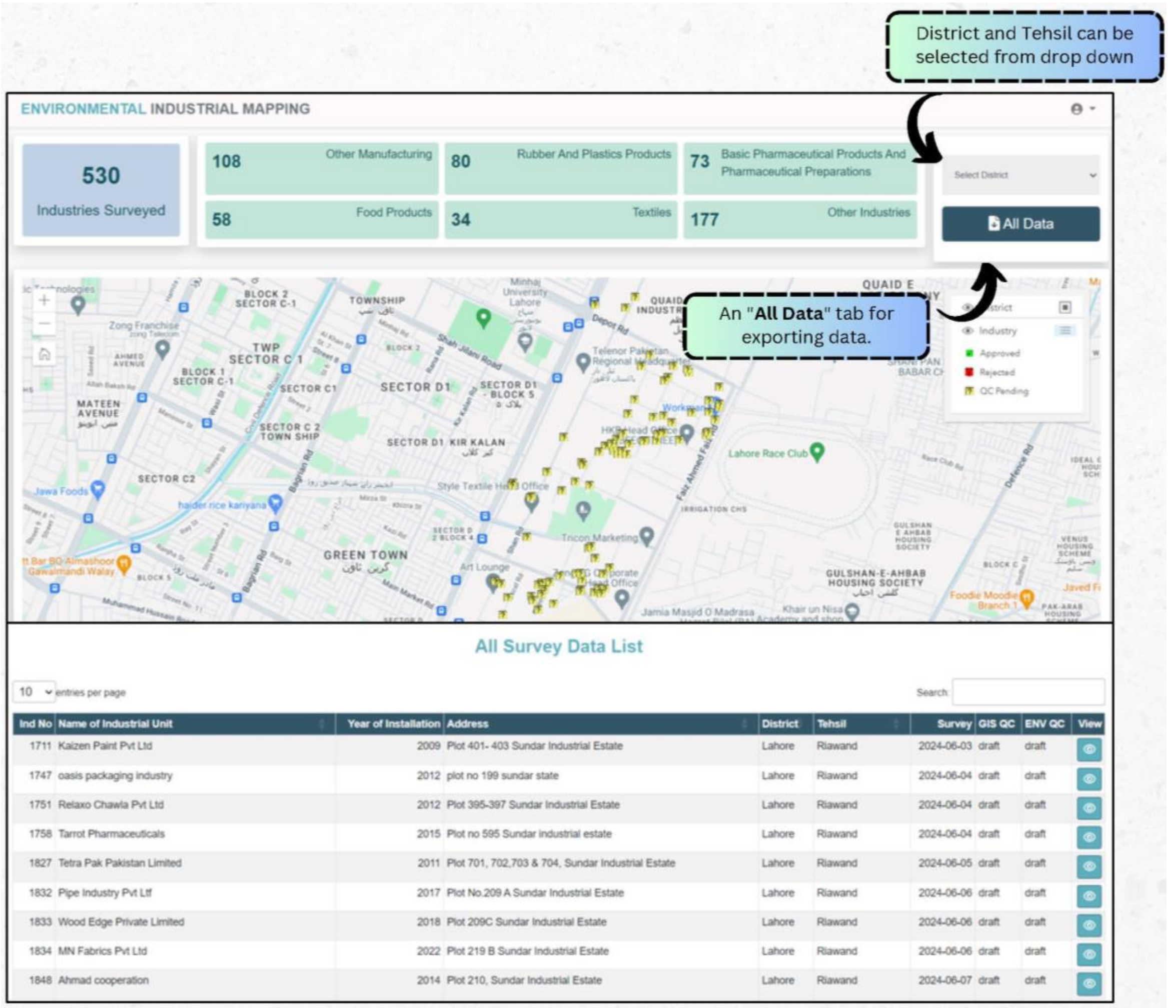


Viewer (View only user)

First we will go through the options available to view only user.

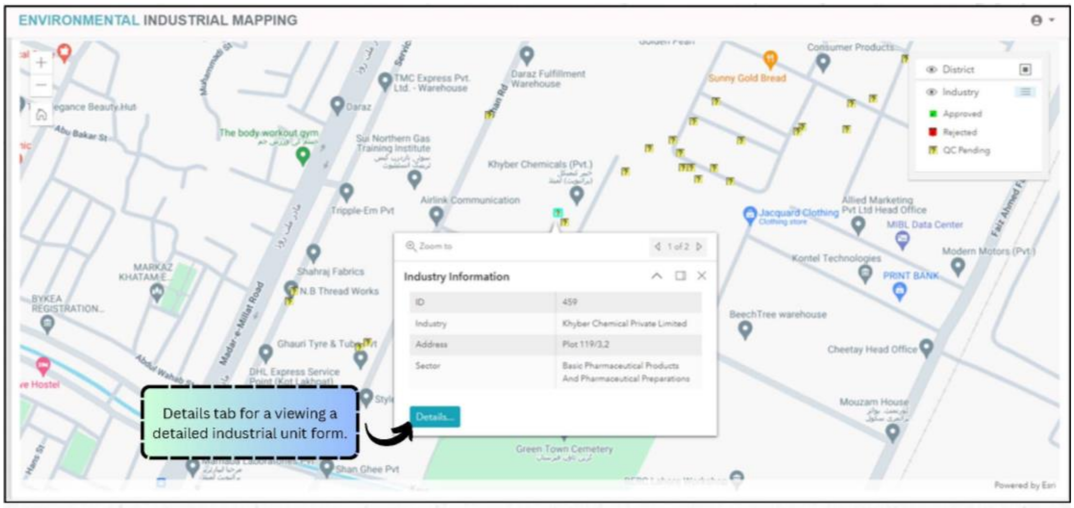
- **Statistics Summary**: A summary section displays key statistics:
  - 530 industries surveyed.
  - Categories of different industries with counts
- **Filters Option:** Filters for selecting district and tehsil (administrative divisions).
- An "**All Data**" button for downloading and exporting data.
- **Map Visualization:** A map showing the locations of industries surveyed, marked by red dots.

- The map includes a legend indicating districts and industry locations.
- **Survey Data List:** A table listing detailed information about each industry:
  - Columns: Industries No (Industry Number), Name of Industrial Unit, Year of Installation, Address, District, Tehsil, Survey Datetime.
  - The action column allows to view the detailed the Industrial Unit Form.
  - Search functionality for filtering the table content.

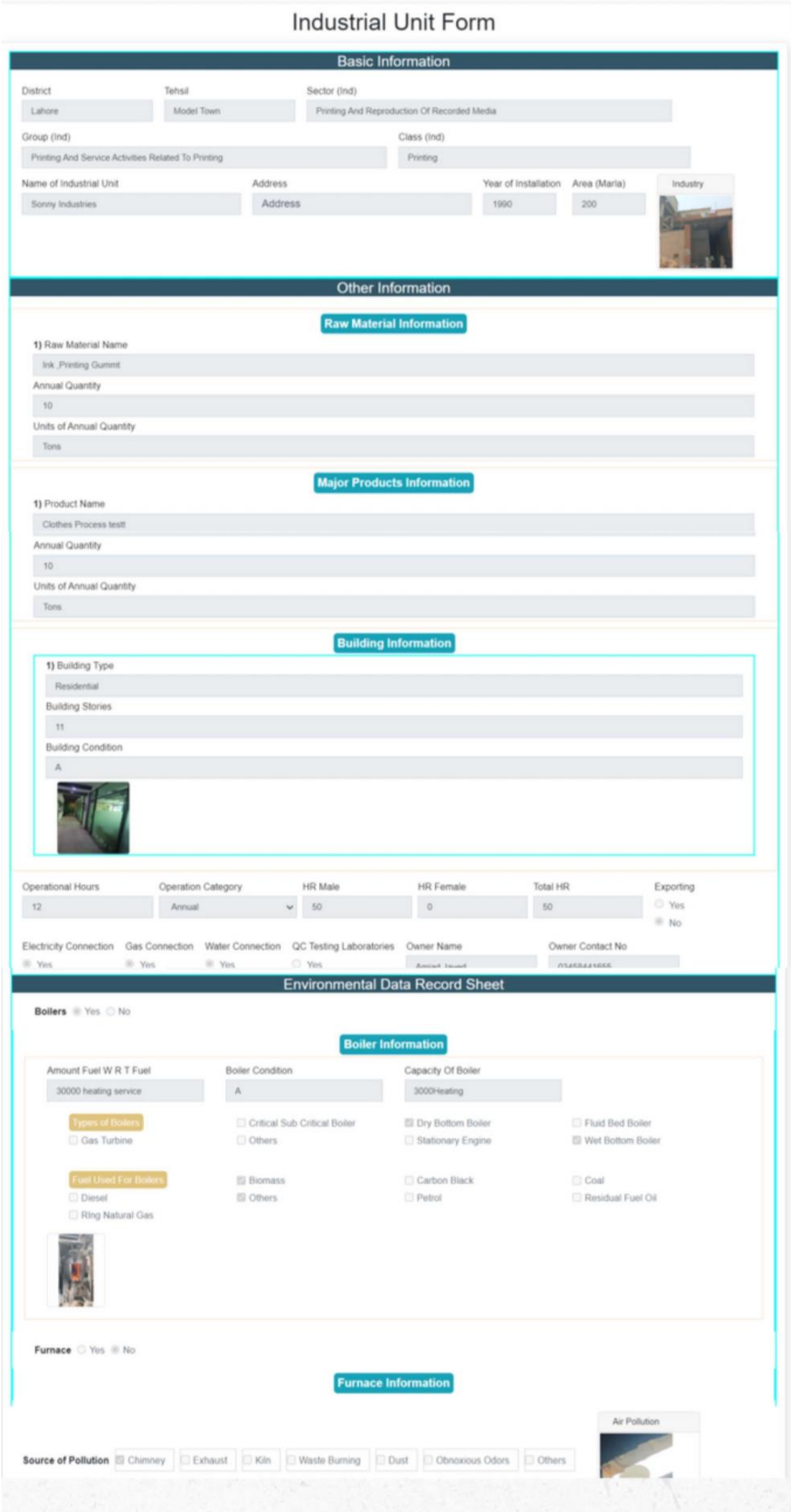


- **Map Controls (Right Side)**

Use the map to locate surveyed industries. Zoom in/out to get a better view of specific areas. The district tool on the map toggles the visibility of district boundaries on the map. Use the layers panel to toggle the visibility of districts and industry markers. The industry tool on the map toggles the visibility of industry markers green, red and yellow representing **approved, rejected and qc pending** on the map. By clicking on any marker, it displays the industry information and an added option for details is provided. The details option further provides extensive details of the industry. This tool helps in visualizing the environmental impact of industries within a specific area by providing comprehensive data and an interactive map.



The details tab displays the basic information, raw material, major products information, building information, boiler information, furnace information and information related to waste water treatment plant. This form is shown below:



Industrial Unit Form

Basic Information

District: Lahore
Tehsil: Model Town
Sector (Ind): Printing And Reproduction Of Recorded Media
Group (Ind): Printing And Service Activities Related To Printing
Class (Ind): Printing
Name of Industrial Unit: Sonny Industries
Address: Address
Year of Installation: 1990
Area (Marla): 200
Industry

Other Information

Raw Material Information

1) Raw Material Name: Ink ,Printing Gumnt
Annual Quantity: 10
Units of Annual Quantity: Tons

Major Products Information

1) Product Name: Clothes Process testt
Annual Quantity: 10
Units of Annual Quantity: Tons

Building Information

1) Building Type: Residential
Building Stories: 11
Building Condition: A

Operational Hours: 12
Operation Category: Annual
HR Male: 50
HR Female: 0
Total HR: 50
Exporting: Yes / No

Electricity Connection: Yes
Gas Connection: Yes
Water Connection: Yes
QC Testing Laboratories: Yes
Owner Name
Owner Contact No

Environmental Data Record Sheet

Boilers: Yes / No

Boiler Information

Amount Fuel W R T Fuel: 30000 heating service
Boiler Condition: A
Capacity Of Boiler: 3000Heating

Types of Boilers: Critical Sub Critical Boiler; Dry Bottom Boiler; Fluid Bed Boiler; Gas Turbine; Others; Stationary Engine; Wet Bottom Boiler

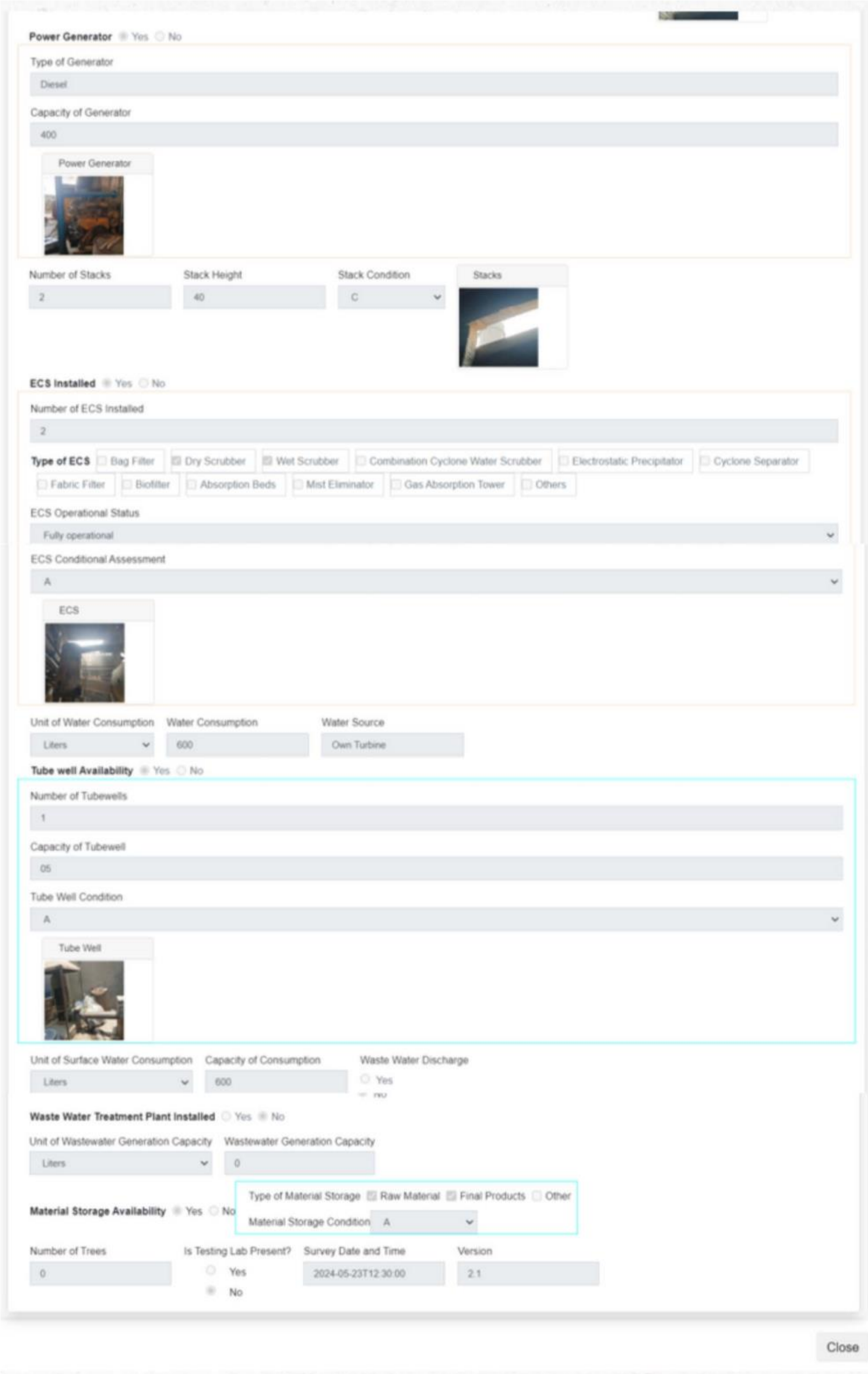
Fuel Used For Boilers: Biomass; Carbon Black; Coal; Diesel; Others; Petrol; Residual Fuel Oil; Rlng Natural Gas

Furnace: Yes / No

Furnace Information

Source of Pollution: Chimney; Exhaust; Kiln; Waste Burning; Dust; Obnoxious Odors; Others

Air Pollution



Note:

At a time only one user should login, multiple users should not login the dashboard.

Annexure - VIII: Environmental Industrial Mapping Survey Quality Control (QC) Dashboard

ENVIRONMENTAL INDUSTRIAL MAPPING SURVEY QUALITY CONTROL (QC) DASHBOARD USER MANUAL

http://web.urbanunit.gov.pk/industry_qc.php

Introduction

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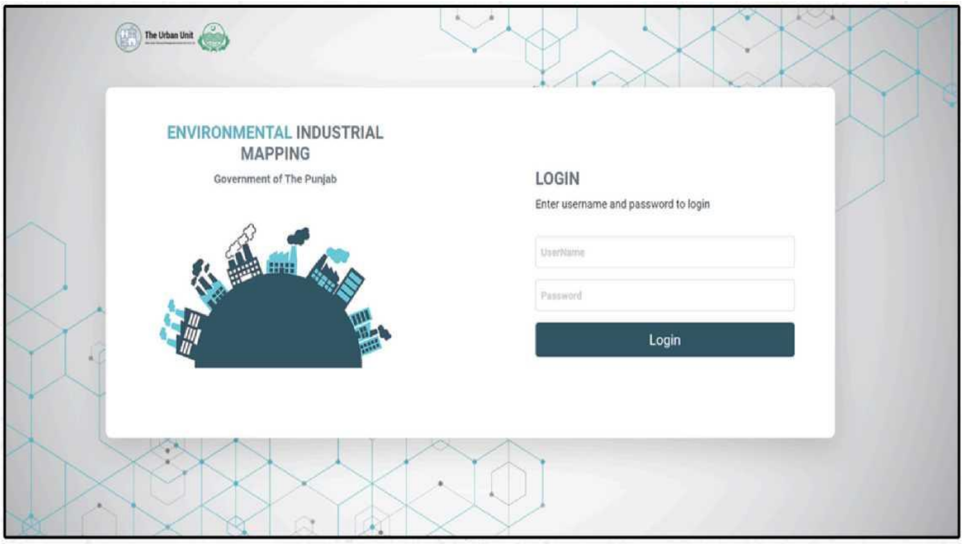
Note: At a time only one user should login, multiple users should not login the dashboard.

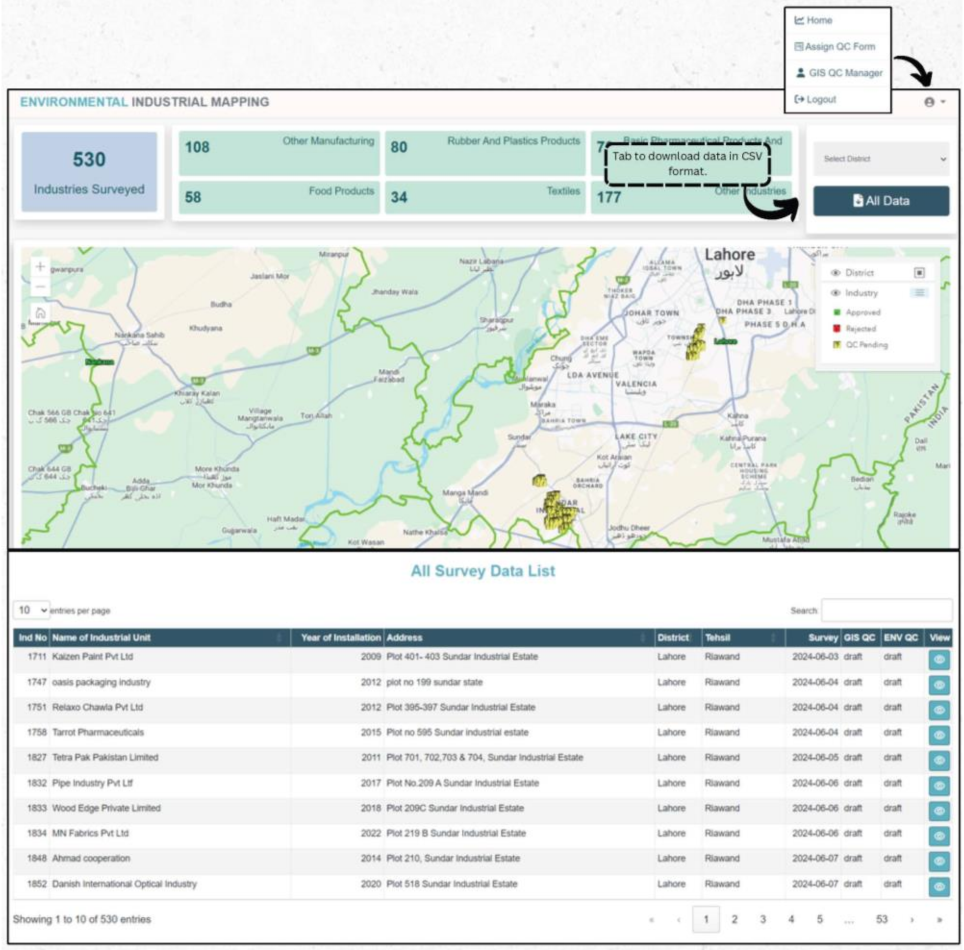


GIS QC Manager

Now we will go through the second category user which is **GIS QC Manager**. This user has some additional features available in addition to the viewer user. We will explore them in detail. Here are the key aspects:

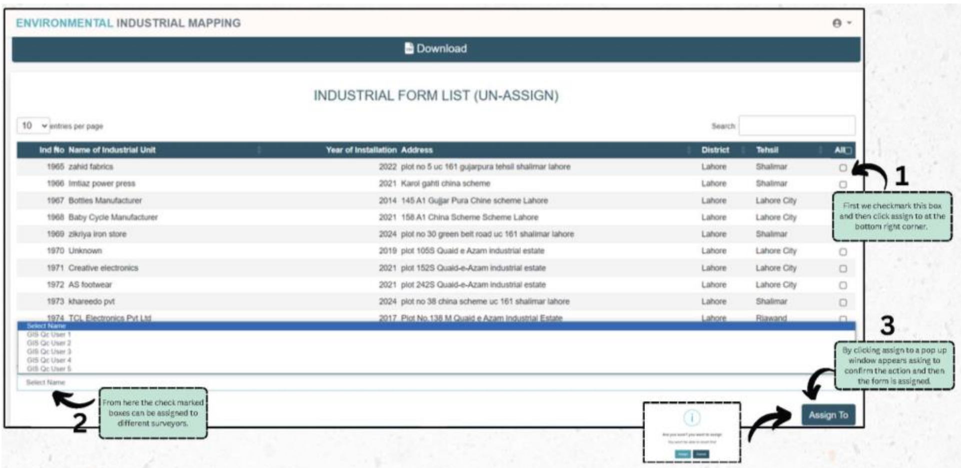
- Download Option: There is an additional “All Data” tab to download the data in CSV format, for further analysis.

- Pop in window from the profile tab allows the GIS QC Manager to view, edit and **assign QC form** to the different QC users.

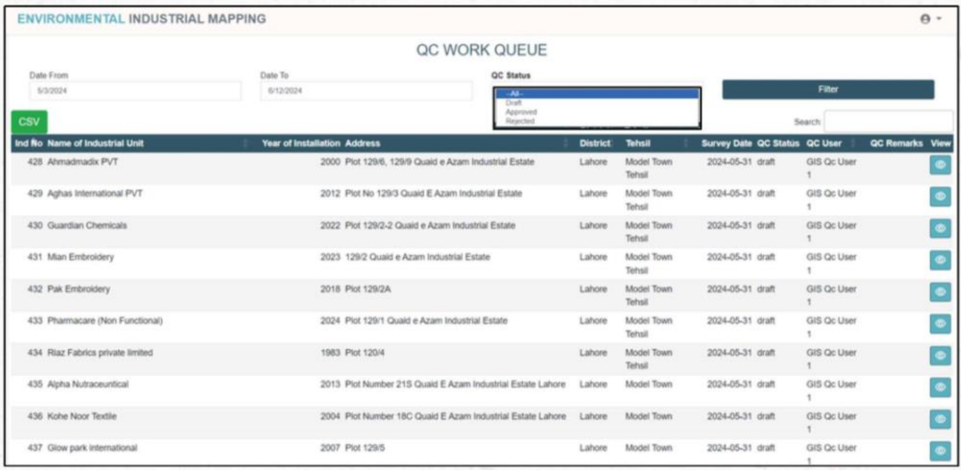


- **Assigning QC form**

The popup tab of the assign QC form opens a new window where the **GIS QC Manager** can assign any number of forms to the different QC users. The Manager can assign multiple forms to different surveyors. There is also a search bar to search any relevant information to the forms. The process of assigning the QC form is explained below:



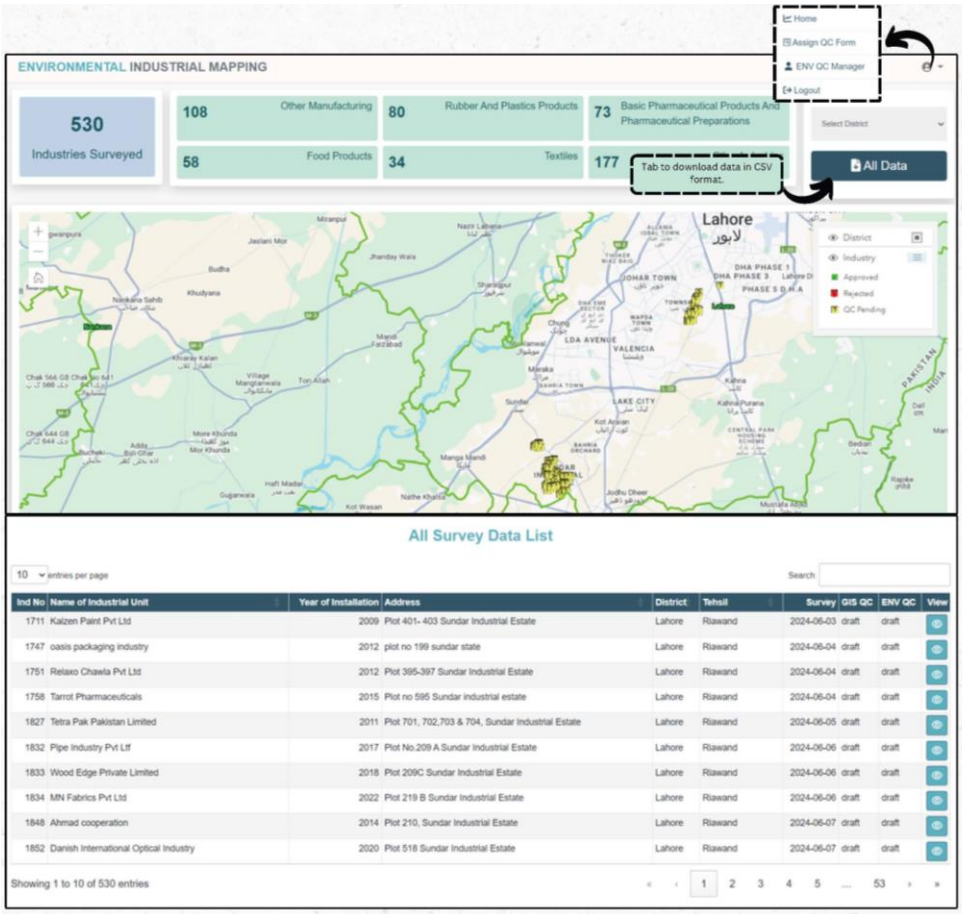
The bottom half of the GIS QC form displays the QC work queue where data can be searched based on different filters like date and QC status and after that data can be downloaded in csv format. There is also a search bar to search any relevant information to the forms.



Environment QC Manager

Now we will go through the third category user which is **Environment QC Manager**. This user has some additional features available in addition to the viewer user. We will explore them in detail. Here are the key aspects:

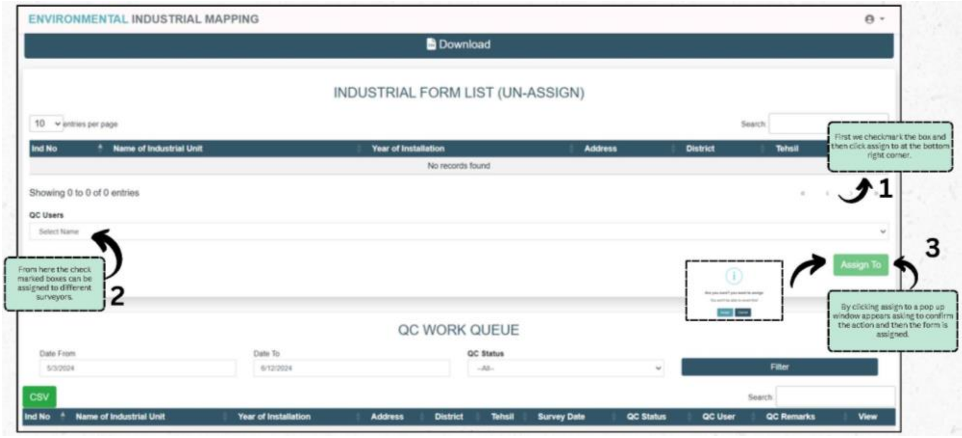
- **Download Option:** There is an additional “All Data” tab to download the data in CSV format, for further analysis.
- Pop in window from the profile tab allows the **Environment QC Manager** to view, edit and assign QC form to the different QC users.



Assigning QC form

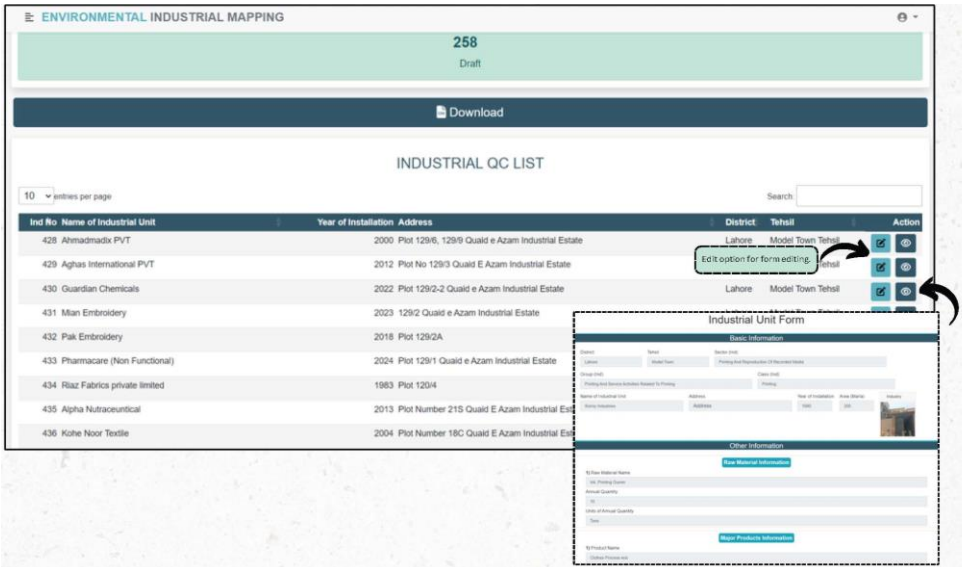
The popup tab of the assign QC form opens a new window where the **Environment QC Manager** can assign any number of forms to the different QC users. The Manager can assign multiple forms to different surveyors. There is also a search bar to search any relevant information to the forms. The bottom half of the Environment QC form displays the QC work queue where data can be searched based on different filters like date and QC status and after that data can be downloaded in csv format. There is also a search bar to search any relevant information to the forms.

The process of assigning the form is explained below:



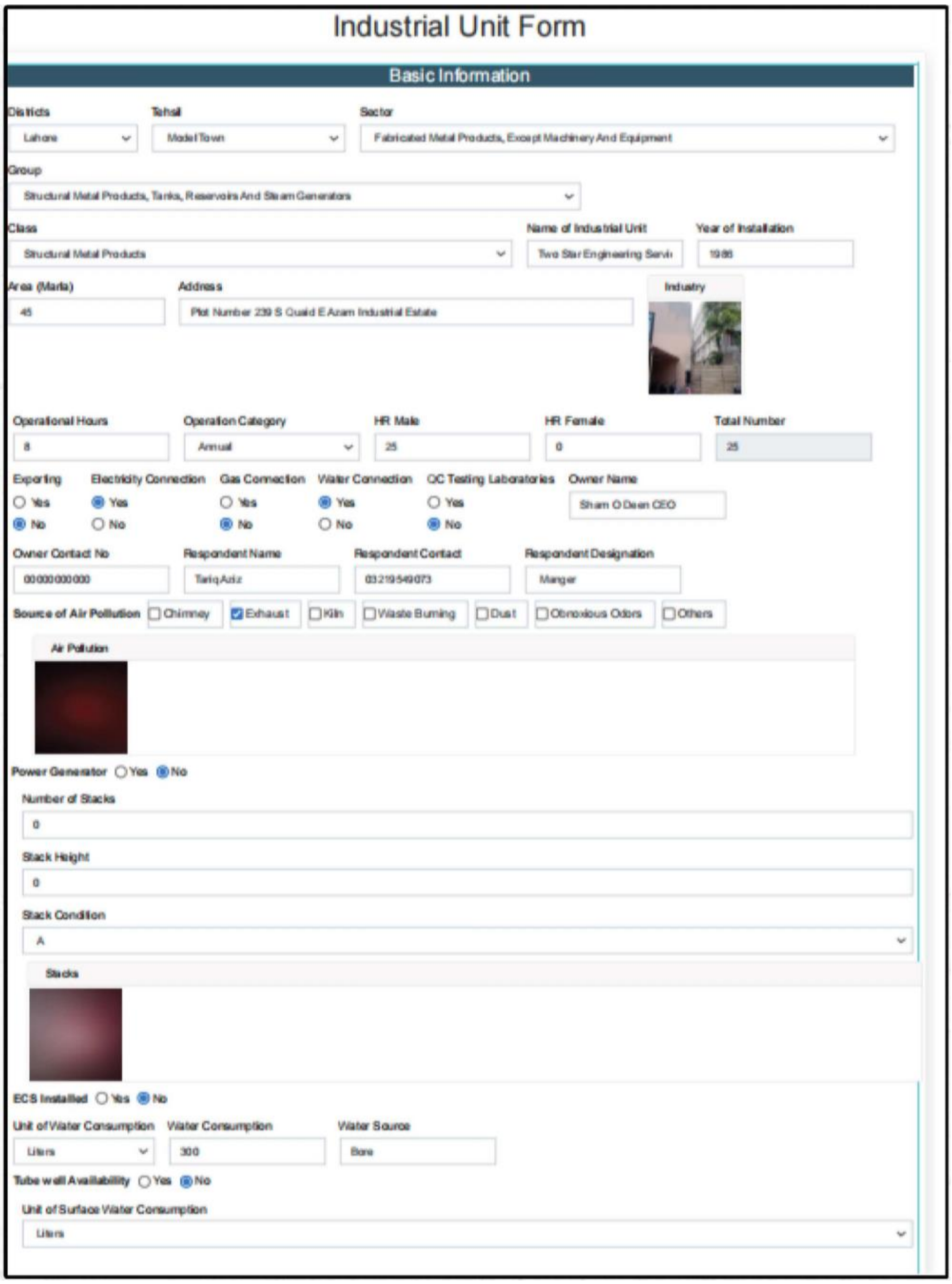
GIS QC User

Now we will go through the fourth category which is GIS QC User. The assigned form by the GIS QC Manager can be seen by the GIS QC User depicting all the details. At the top draft count is displayed which shows the number of forms drafted. The view option displays a detailed Industrial Unit Form depicting the basic information, raw material, major products information, building information, boiler information, furnace information and information related to waste water treatment plant. There is also a search bar to search any relevant information to the forms. The option next to view is of edit which can be used to edit the form.



The bottom half shows the QC completed and the option to download data in csv format.

The option next to view is of edit. The edit option can be used to edit the Industrial Unit Form depicting the basic information, raw material, major products information, building information, boiler information, furnace information and information related to waste water treatment plant. After editing all the information in the form at the end there is an update and submit option which is compulsory to be clicked otherwise the form will not be updated.



Industrial Unit Form

Basic Information

Districts: Lahore | Tehsil: Model Town | Sector: Fabricated Metal Products, Except Machinery And Equipment

Group: Structural Metal Products, Tanks, Reservoirs And Steam Generators

Class: Structural Metal Products | Name of Industrial Unit: Two Star Engineering Servi | Year of Installation: 1986

Area (Marla): 45 | Address: Plot Number 239 S Quaid E Azam Industrial Estate | Industry

Operational Hours: 8 | Operation Category: Annual | HR Male: 25 | HR Female: 0 | Total Number: 25

Exporting: Yes / No | Electricity Connection: Yes / No | Gas Connection: Yes / No | Water Connection: Yes / No | QC Testing Laboratories: Yes / No | Owner Name: Sham O Deen CEO

Owner Contact No: 00000000000 | Respondent Name: Tariq Aziz | Respondent Contact: 03219549073 | Respondent Designation: Manger

Source of Air Pollution: Chimney, Exhaust, Kiln, Waste Burning, Dust, Obnoxious Odors, Others

Air Pollution

Power Generator: Yes / No

Number of Stacks: 0

Stack Height: 0

Stack Condition: A

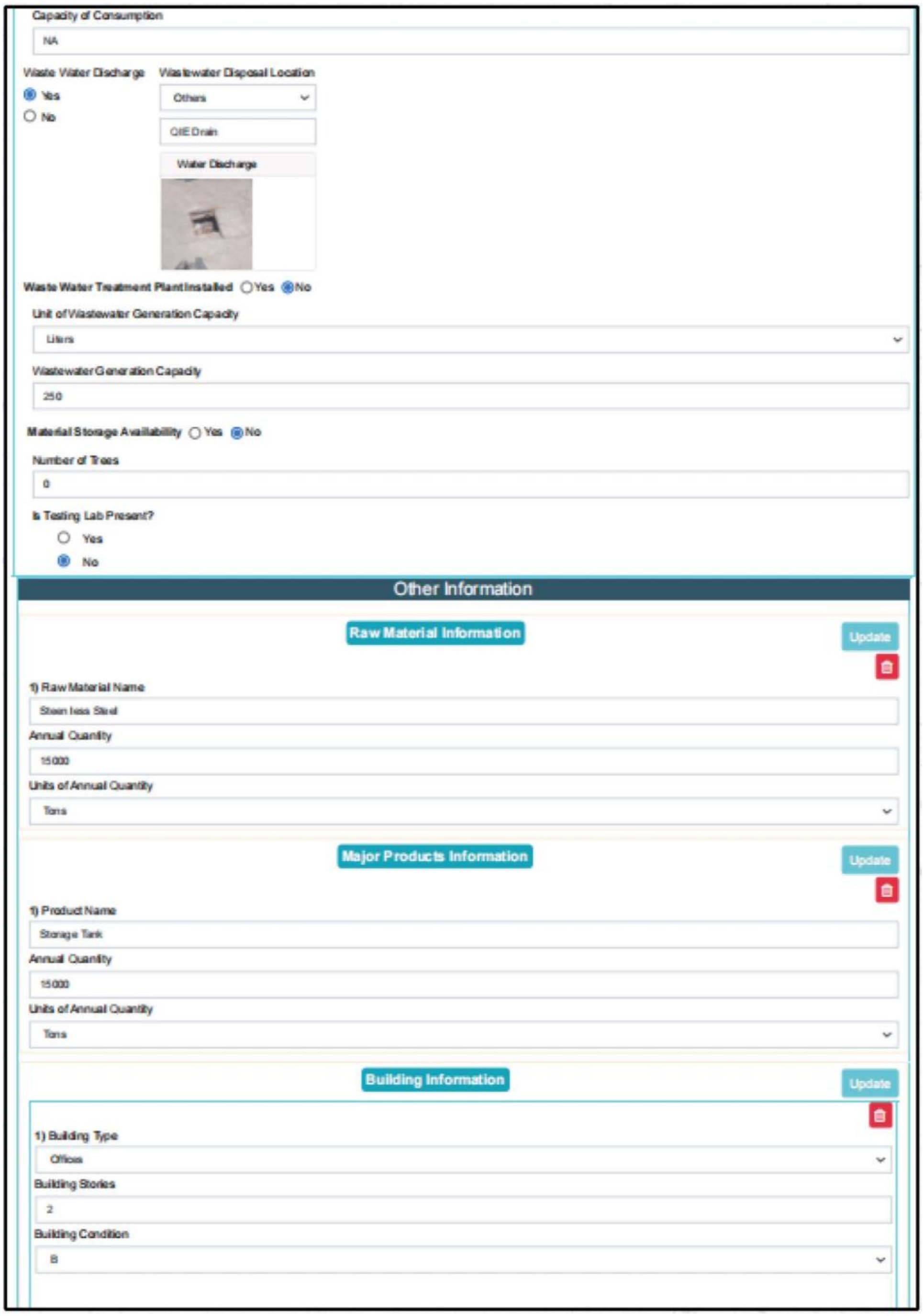
Stacks

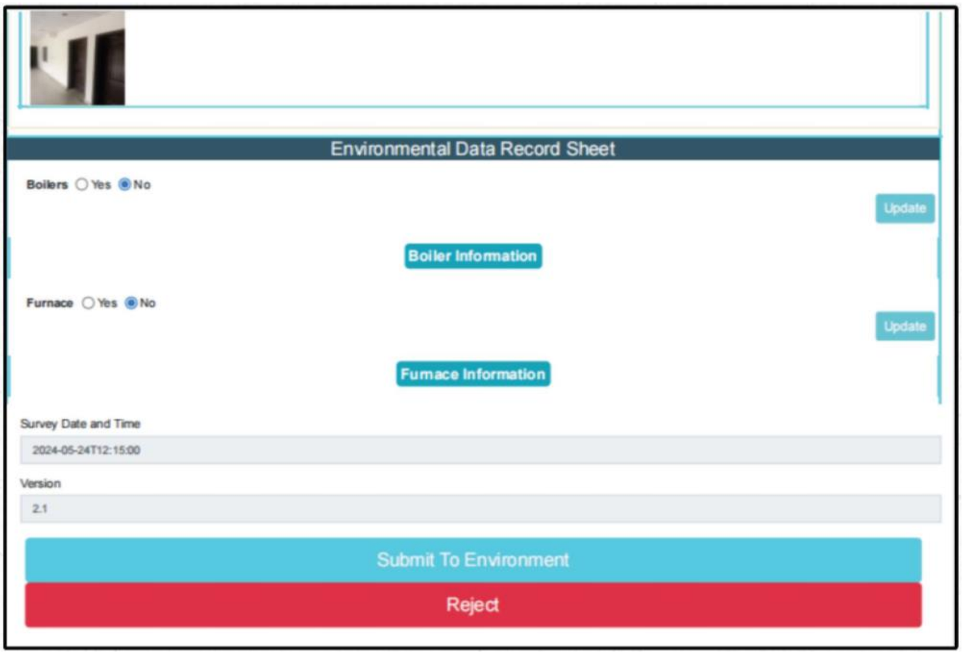
ECS Installed: Yes / No

Unit of Water Consumption: Liters | Water Consumption: 300 | Water Source: Bore

Tube well Availability: Yes / No

Unit of Surface Water Consumption: Liters

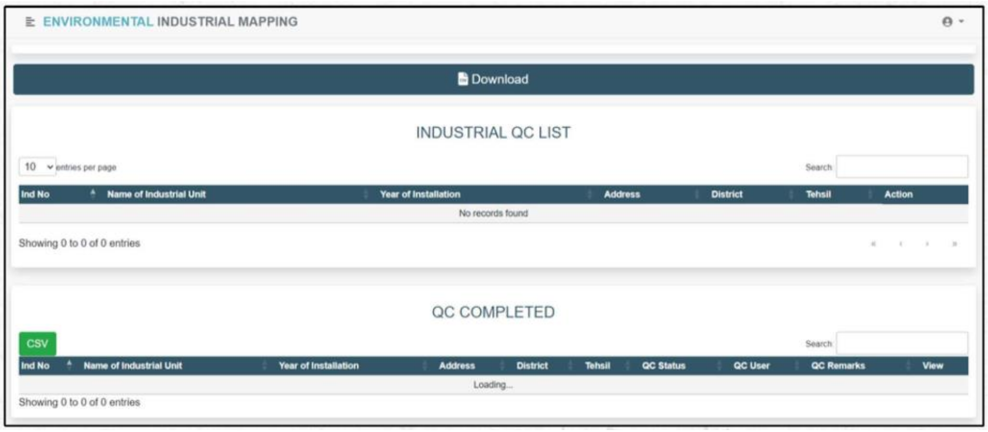

Capacity of Consumption
NA
Waste Water Discharge
Wastewater Disposal Location
Yes
No
Others
QIE Drain
Water Discharge
Waste Water Treatment Plant Installed Yes No
Unit of Wastewater Generation Capacity
Liters
Wastewater Generation Capacity
250
Material Storage Availability Yes No
Number of Trees
0
Is Testing Lab Present?
Yes
No
Other Information
Raw Material Information
Update
1) Raw Material Name
Steen less Steel
Annual Quantity
15000
Units of Annual Quantity
Tons
Major Products Information
Update
1) Product Name
Storage Tank
Annual Quantity
15000
Units of Annual Quantity
Tons
Building Information
Update
1) Building Type
Offices
Building Stories
2
Building Condition
B



Note: After editing all the information in the form at the end there is an **update and submit option** which is compulsory to be clicked otherwise the form will not be saved and updated.

Environment QC User

The assigned form by the Environment GIS QC Manager can be seen by the **Environment QC User** depicting all the details. Same like GIS QC User when the data will be added the view and edit option for the industrial unit form will appear on the system. Same like GIS QC user, the Environment QC user is also required to update and submit after editing the industrial unit form.



Worldwide reported Efficient technologies and Smart practices for industries

Efficient technologies and smart practices are transforming industries worldwide, driving sustainability, cost savings, and higher productivity.[3] These innovations focus on automating processes, optimizing resource use, and reducing waste, making them crucial in the era of climate change and digital transformation. Below are key efficient technologies and smart practices across various industries[4].

Boiler and Furnace Maintenance

a. Predictive Maintenance with IoT and AI

- **IoT Sensors:** These sensors monitor key performance indicators (KPIs) like temperature, pressure, and fuel consumption in real-time. They help detect irregularities and potential failures before they occur, allowing for timely maintenance.
- **AI and Machine Learning**: AI-powered systems analyze data from sensors to predict when maintenance is needed. This avoids unplanned downtime and extends the equipment's lifespan.
- **Vibration Monitoring:** Sensors detect abnormal vibrations in moving parts (like pumps or fans), indicating potential issues such as imbalance or misalignment that need fixing.
- **Thermal Imaging:** Thermal cameras can identify hot spots or areas where heat is escaping, pointing to insulation problems or areas in need of repair.

b. Automated Cleaning Systems

- **Soot Blowers:** Automated soot blowers use high-pressure steam or air to clean soot and ash deposits from boiler tubes, improving heat transfer efficiency and preventing corrosion.
- **Chemical Cleaning:** Automated chemical injection systems clean scale and mineral deposits from furnace and boiler surfaces without the need for manual intervention, which improves efficiency and reduces fuel consumption.

c. Boiler Control Systems

- **Advanced Combustion Controls:** These systems adjust the air-fuel ratio based on real-time monitoring of oxygen levels, ensuring optimal combustion and reducing fuel wastage.
- **Flue Gas Recirculation (FGR):** This technique recirculates part of the flue gases back into the combustion chamber to lower temperatures and reduce nitrogen oxide (NOx) emissions.
- **Variable Speed Drives (VSDs):** VSDs are installed on fans, pumps, and other auxiliary systems to adjust their speed based on demand, improving energy efficiency.

d. Energy Efficiency Enhancements

- **Heat Recovery Systems:** These systems capture waste heat from the boiler's flue gas and reuse it to preheat water or air, improving overall efficiency. Examples include economizers and air preheaters.
- **Condensing Boilers:** These advanced systems capture the latent heat from the exhaust gases, significantly improving energy efficiency and reducing fuel consumption.

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[3] *Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, 1-10.*
[4] *De Beer, J. (2013). Potential for industrial energy-efficiency improvement in the long term (Vol. 5). Springer Science & Business Media.*

e. Digital Twin Technology

Digital twins[5] create a virtual model of the boiler or furnace system, allowing operators to simulate performance under different conditions and optimize maintenance schedules, fuel usage, and emissions control.

Energy Recovery from Wastewater:

- **Thermal Heat Pumps:** Wastewater carries thermal energy that can be recovered and reused for heating purposes. Heat pumps extract this energy, reducing the need for additional heating sources.
- **Microbial Fuel Cells (MFCs):** An emerging technology[6] that generates electricity directly from wastewater by using the natural metabolic processes of microbes.

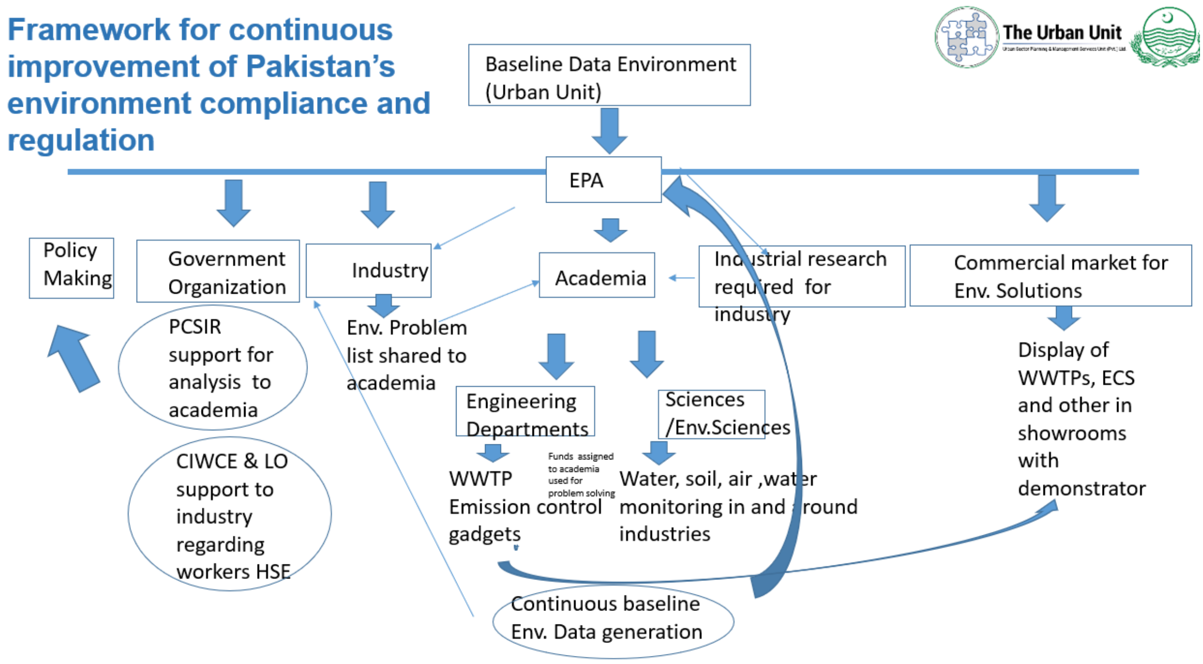
Smart Water Grids[7]

- **Intelligent Control Systems**: These systems optimize the distribution and treatment of water through the use of IoT sensors, real-time data, and advanced algorithms. They reduce energy consumption by predicting demand and preventing leaks or overflows in wastewater networks.
- **Dynamic Pump Scheduling:** This technology optimizes the operation of pumps based on real-time demand, reducing energy usage in the wastewater transportation process.

5 Yang, K. X., Wang, Y., Deng, Z. C., Sun, M., Ding, G., & Li, L. (2021, December). Research on digital twin construction technology and application of large capacity utility boiler. In 2021 International Conference on Power System Technology (POWERCON) (pp. 2139-2145). IEEE.

6 Do, M. H., Ngo, H. H., Guo, W. S., Liu, Y., Chang, S. W., Nguyen, D. D., ... & Ni, B. J. (2018). Challenges in the application of microbial fuel cells to wastewater treatment and energy production: a mini review. Science of the Total Environment, 639, 910-920.

7 Lee, S. W., Sarp, S., Jeon, D. J., & Kim, J. H. (2015). Smart water grid: the future water management platform. Desalination and Water Treatment, 55(2), 339-346.



Integrated approach of data sharing and collaboration among industry, academia and Government and non-government departments for Continuous improvement in environment of Pakistan

BEST PRACTICES FOR INDUSTRY

Generalized Best practices for Industry	
Steam systems	
Boiler process control	Boiler maintenance
Reduction of Flue gas quantities	Minimizing blow down
Reduction of Excess air	Blow down steam recovey
Improved boiler insulation	Flue gas heat recovery
Condensation Return	Burner replacement

steam distribution system	
steam distribution controls	steam trap maintenance
improved insulation	steam trap monitoring
insulation maintenance	leak repair
steam trap improvement	Flash steam recovery

Reference: Kramer, K. J., Masanet, E., Xu, T., & Worrell, E. (2009). Energy efficiency improvement and cost saving opportunities for the pulp and paper industry. *Berkeley, CA: Lawrence Berkeley National Laboratory*.

BEST Practices for water and energy saving in textile

Best Practices for Textile

WATER SAVING PRACTICES

- Eliminate water leaks and reduce hose pipe use[a]
- Reuse cooling water from dyeing machine
- Reuse process water from rinsing[b]

ENERGY SAVING PRACTICES

- Steam management[c]
- Insulate pipes, valves, flanges[d]
- Recover heat from drying operations[e]

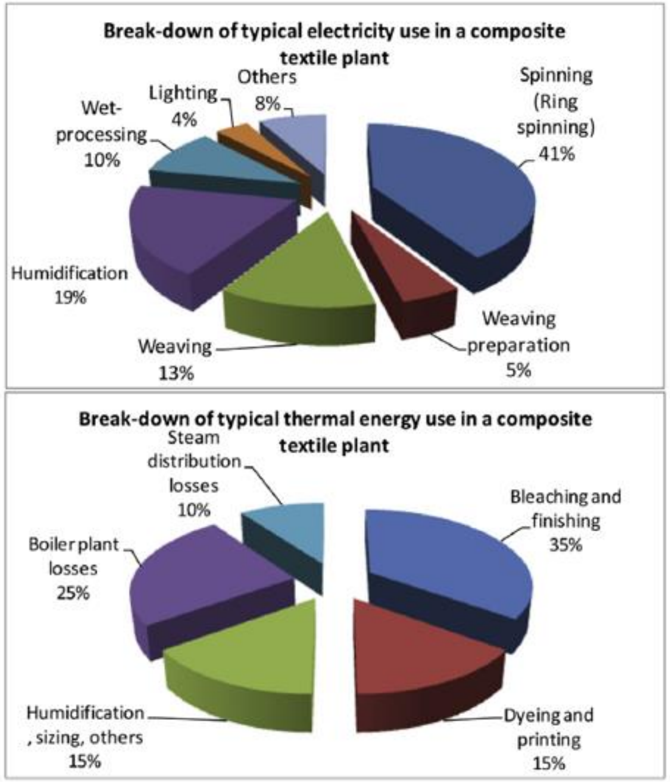


Fig. 1. Breakdown of typical electricity and thermal energy use in a composite textile plant (Sathaye et al., 2005).

Reference, Taken from work of RESET Energy, Hong Kong for NRDC, 2011, 2012.
Linda Greer, Susan Egan Keane, Zixin Lin, *NRDC's Ten Best Practices for Textile Mills to Save Money and Reduce Pollution*, February 2010, at 11.
Ali Hasanbeigi, Ernest Orlando Lawrence Berkeley National Laboratory, *Energy-Efficiency Improvement Opportunities for the Textile Industry* (September 2010).
A PRACTICAL GUIDE FOR RESPONSIBLE SOURCING
December 2012
The accompanying Best Practice Guide is available at www.nrdc.org/ cleanbydesign For more information please contact Avinash Kar akar@nrdc.org (415) 875-6122 Authors: Avinash Kar, Susan Egan Keane, Linda Greer

Energy efficient technologies for Pulp and paper industry

Table 5.4: Summary of water efficiency measures presented in this Energy Guide

Basic Water Efficiency Measures (Chapter 19)	
General and Facilities Water Efficiency Measures	
Strategic water management program	Once-through cooling water reuse
Good housekeeping	Minimizing hose water use
Cooling towers	Use of water efficient building fixtures
Reducing cooling tower bleed-off	
Process Water Savings	
Dry debarking	Direct white water reuse
Optimizing shower water use	Mechanical pump seals
Water efficient bleaching	Chemi (belt) washer
Improving white water quality	Carbon dioxide brownstock washing
Vacuum pump seal water conservation	

Emerging Energy-Efficient Technologies (Chapter 18)	
Black liquor gasification	Biotreatment
Magnetically coupled ASDs	Electrohydraulic contaminant removal
Laser-ultrasonic web stiffness sensor	Lateral corrugator
Steam cycle washer for unbleached pulp	Multiport dryer technology
Microwaving logs	Direct green liquor utilization pulping
Gas-fired paper dryer	Impulse drying
Advanced fibrous fillers	

Reference: Kramer, K. J., Masanet, E., Xu, T., & Worrell, E. (2009). Energy efficiency improvement and cost saving opportunities for the pulp and paper industry. *Berkeley, CA: Lawrence Berkeley National Laboratory*.

Industrial Ecology Concept Integration in Existing and Upcoming Industrial Estates of Pakistan

Industrial Ecology (IE) is an interdisciplinary field that focuses on the sustainable interaction between industrial systems and the natural environment. It promotes the concept of industrial systems functioning similarly to natural ecosystems, where waste from one process can serve as a resource for another.[8] The ultimate goal of industrial ecology is to optimize resource use, minimize waste, and reduce the overall environmental impact of industrial activities.

Examples of Industrial Ecology in Practice

a. Kalundborg Symbiosis (Denmark)

The Kalundborg industrial ecosystem is a globally renowned example of industrial symbiosis. In this system, waste heat from a power plant is used by local industries and for district heating. Sludge from a fish farm is used as fertilizer, and gypsum from a power station's flue gas desulfurization process is sold to a nearby wallboard manufacturer. This collaboration reduces waste, conserves resources, and benefits all participants economically.

b. Eco-Industrial Parks

Around the world, many eco-industrial parks apply industrial ecology principles. These parks encourage companies to share resources, such as heat, water, materials, and waste. For example, in an EIP, one company's waste might serve as raw material for another, thereby reducing the overall environmental impact.

Key Practices in Industrial Ecology

a. Material Flow Analysis (MFA)

MFA is a tool used to track the flow of materials through an industrial system. It helps identify opportunities for resource efficiency, waste reduction, and recycling. MFA provides a clear understanding of how materials move from extraction through production, consumption, and disposal.

b. Design for Environment (DfE)

DfE focuses on designing products that minimize environmental impacts throughout their life cycles. This includes selecting materials that are easy to recycle, reducing energy consumption during production and use, and designing for product disassembly.

c. Circular Economy Integration

Industrial ecology supports the circular economy model, where resources are kept in use for as long as possible, and products are designed for easy recycling or reuse. The goal is to eliminate waste by closing material loops within industrial systems.

[8] *Shah, A., Che Mat, C. R., Ibrahim, A., Zhang, Y., & Muzammil, S. (2024). Introduction to Industrial Ecology. In Industrial Ecology: A Fusion of Material and Energy in Green Supply Chain Context (pp. 1-19). Singapore: Springer Nature Singapore.*

Annexure - IX: CASE STUDY

RAZIQ INDUSTRIAL ENTERPRISES (PVT) LTD

A Metal Recycling Industry in Sunder Industrial Estate Lahore

Written By: Dr. Sidra Waheed

PhD Environmental sciences QAU, Islamabad

Former research fellow Lancaster Env. Center UK

Environmental pollution Identification and Control Measures

Background

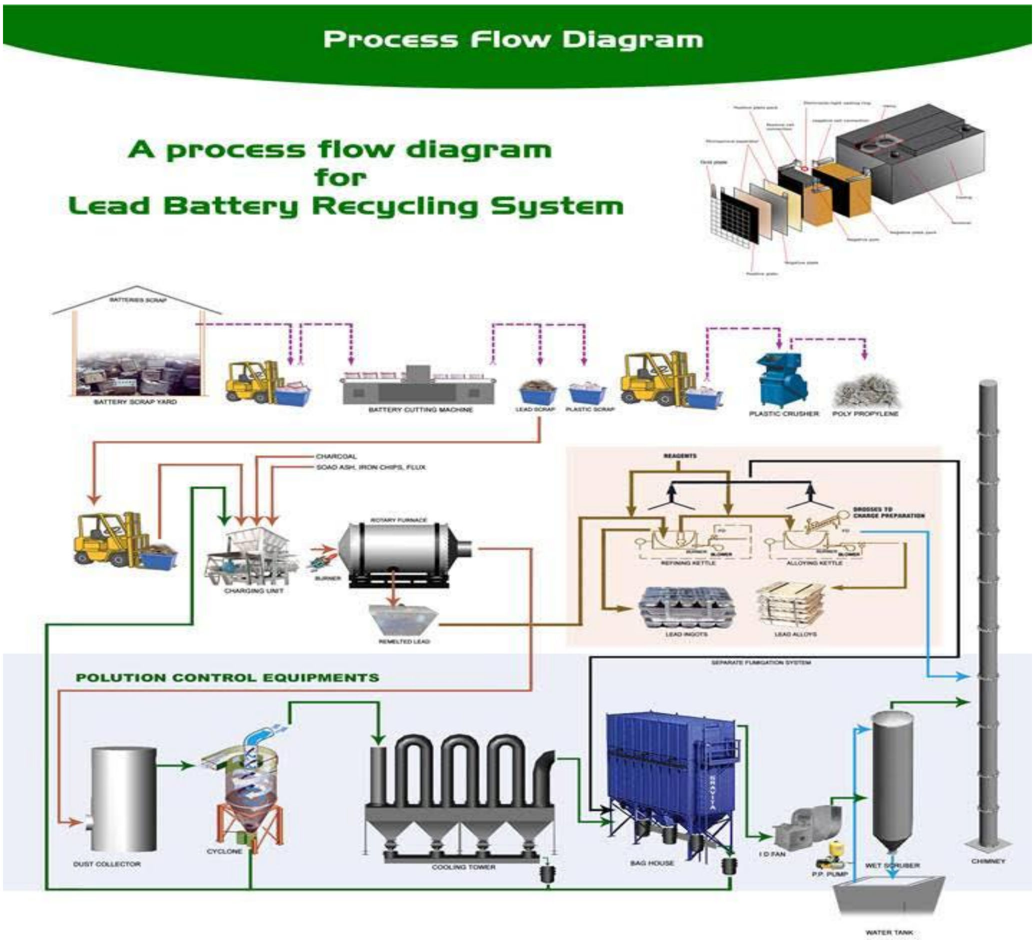
Justification of recycling lead (Pb):

Metallic lead does occur in nature, but it is rare. The most economically important lead ore is called galena which contains 86.6% lead by weight. Ore is crushed and concentrated using ‘froth flotation’. Roasting drives off unwanted water and converts the lead sulphide ore to lead oxide. The by-product is sulfur dioxide. Only 40% of lead is being produced via ore refining. The environmental hazards associated with Mining waste (tailings) are frequently composed of waste water, di thiophosphate, zinc and sulfides. Risks of contamination of soil and water supply ensues, particularly when a mine closes. Furthermore, Sulfur dioxide from roasting galena. Sox is a major greenhouse gas. Lead recycling makes an important contribution to sustainable development, easing the pressure on non-renewable resources and reducing carbon emissions through a simple and energy efficient recovery process. In fact, the quality of recycled lead is often similar to that of metal obtained from mining. Lead has one of the highest recycling rates in the world, higher even than better known recycled items such as glass or newspaper.

Informal Sector Scenario Verses Controlled Recycling:

Around 60% of lead production is from recycled lead. Industrial recycling facilities in developing countries employ many manual techniques due to cheap labor. Batteries are often broken up, emptied, separated and charged to the furnaces by hand. The lead extracted is refined and cast into ingots manually. This creates a potential hazard for the workers, the surrounding population and the environment (soil, ground, water resources, etc.) in general. The other parts of the battery are simply dumped in the environment. The informal sector, in contrast, often only uses the metallic parts of old batteries (grids, terminals, bridges) to produce articles such as solders or weights for fishing nets. On the other hand, properly designed lead recycling facilities provide environmentally sustainable approach to utilize and process lead bearing materials.

Non-regulated, informal (“backyard” or “cottage”) recycling practices occur and have resulted in lead exposure and poisoning, with young children being particularly at risk.



Warehouse for storage and segregation of waste:

Raw Material

Sources of Raw Material

The major source of raw material for lead recycling are starter batteries from motor vehicles. Modern car batteries consist of a PP (polypropylene) casing, plates (grids and paste), connectors/poles and bridges, and PP-separators as insulators between the plates.

6.13.1 Cutting /Shearing Top Cover of Scrap Batteries to separate lead bearing material

Twin Rotating wheel type Battery cutting Machine with TCT Non-Ferrous Metal Cutting Steel Blade are being used to shear the top cover from scrap batteries. The cutting machine is rotating at high speed fitted on a rigid base frame structure. Forward movement of batteries against blade is facilitated with Belt Conveyor with variable speed mounted on long base frame. The drained scrap batteries are placed on feeding roller table of the Belt conveyor where these are carried against rotating twin wheels. The sheared scrap batteries are unloaded from discharge table of belt conveyor. The lead bearing material is emptied in the storing bins as sorted battery fractions, e.g. grids and lead paste by upside down the sheared scrap battery.

6.13.2 Occupational Risk and Waste Management

- At the very first step Raziq is using machine-based approach to cut and segregate waste rather than manual handling to avoid occupational exposure hazards associated with this step.

- Raziq industries mostly discourages to buy pre-sorted battery fractions as this practice is very harmful in environmental terms. Through the dispersed pre-sorting activities, lead containing residues and wastes arise in many places and it becomes impossible to control their proper disposal.
- Empty PP boxes and top covers are sent to PP crusher section for chipping off into small chips. Plastic industry are the main buyers of Plastic casings as separator waste produced. This is an example of industrial symbiosis.
- ALRAZIK BATERY Recyclers, are quite aware that older type of batteries in hard rubber casing and PVC separator comes in with battery scrap. Consequently, Ebonite boxes are sent to dispose of.

Smelting Section

Metallurgical aspects of lead recycling from battery scrap

Lead bearing raw materials extracted from lead-acid battery scrap are:

PbO (PbO_2) lead oxides, part of the paste

$PbSO_4$ lead sulphate, part of the paste

Aforementioned components, have to be converted by chemical/metallurgical processes to obtain lead metal, which takes place in the furnace.

The first type of chemical reaction converts PbO (PbO_2) into Pb through a reduction process:

$2\ PbO + C \rightarrow 2\ Pb + CO_2$ $PbO_2 + C \rightarrow Pb + CO_2$

The second type converts $PbSO_4$ into PbS, again through a reduction process:

$PbSO_4 + 2\ C \rightarrow PbS + 2\ CO_2$

To transform the lead bearing materials from the battery cutting system into metallic lead it is necessary that some chemical reactions are carried out in a Rotary furnace in the presence of some reagents at temperature of 700 degree Celsius to 800 degrees Celsius which removes the oxygen and sulphur elements from lead oxide and sulphate in the lead bearing material. These are known as reducing agents.

The anthracite or the metallurgical coke (Charcoal) and the iron chips are the most commonly used reducing agents in the lead recycling industry.

Slag production

As a result of the chemical reactions carried out in the furnace a slag is formed which is having higher melting point and viscous in fluidity. In order to make its melting point lower and have good fluidity a fluxing agent Fluorspar along with soda ash or sodium carbonate is added in specified quantity before materials are fed into the furnace. It is necessary to prepare charge where all the reagents are mixed in specific ratio with lead bearing materials to have better results via the smelting cycle.

Solid Waste Management

- Slag and dust reprocessing, production and disposal

Al-Raziq industries are producing 8-12 tons of slag per 300 metric tons of battery scrap. After a number of productions cycles the amount of slag in the furnace remain too low to continue the operation. Slag is recycled till the time it is converted to a brittle and lighter in weight. Lead blast furnace slag, tapped out of the reactor with repetitive cycles generates an inert slag for disposal, and a zinc/lead/iron oxidized fume product. inert slag that is further being sent to a certified Asian environmental laboratory for pb analysis. As the concentration of Pb is too low in reprocessed slag, so it is disposed of in waste disposal facility.

Refining Section

Afterwards, lead metal is forwarded for refining, the slag has to be dumped.

- Off-gas and flue dust from the operation is sucked of and treated in the off-gas cleaning system.

Air pollution control devices:

The gases & fumes generated in the system are effectively controlled by the Pollution control equipment. Raziq Industry deployed a wide range of customized air pollution control equipment including

i. Duct Chamber
ii. Dust Collectors
iii. Cyclones
iv. Cooling Tower
v. Filter Bag Houses 1 & 2
vi. Induced Draft Fans
vii. Wet Scrubbers
viii. Water Recovery Tank
ix. Stack

The amount of Lead content emitted with these gases is being collected at every stage of pollution control equipment.

- SOX – Sulphur content present in the gases are being treated with wet scrubber.
- CO, Lead Dust, Lead Ash etc. – These are controlled by different sections of Pollution Control devices including dust collectors, dust chambers, cyclones, filter bag house.
- NOX – Not formed because of the lower level of temperatures of the furnace

Refining or Casting section

The molten lead produced, settles at the bottom part of the furnace. When enough lead has accumulated, it is tapped into a mobile ladle and transported in liquid stage to the refining kettle. The refining processes and the purity of the refined lead are monitored by chemical analysis.

Pollution Control Devices for Casting Section

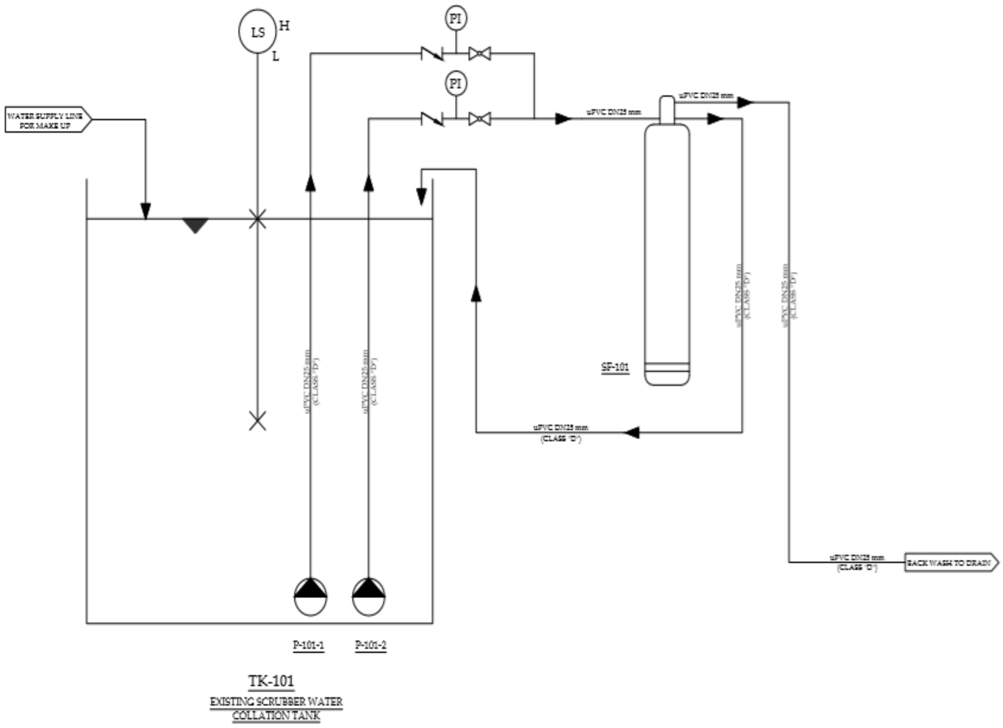
i. Suction Hoods
ii. Bag House 1 & Bag House 2
iii. Induced Draft Fans
iv. Stack

Combined Pollution Control Devices

i. Suction Hoods
ii. Industrial Fans
iii. Fugitive Emissions Bag House
iv. Wet Scrubbers
v. Stack

Waste water treatment:

Very less quantity of water is used in lead recycling industry. The water required for wet scrubbers are being used repeatedly and finally treated with sand filter plant. The system is based on a moving bed sand filter. A film is formed on the sand grains after inoculation with charcoal sheet. Passage of the wastewater over these sheets leads to the binding of the metals to the layers and consequently the removal of the metals from the wastewater. sand filters are efficient in turbidity and heavy metal removal because after the effluent is passed from the sand filters, the turbidity values and heavy metal concentration are observed under permissible limits



Flow diagram for waste water treatment: sand filtration plant

Emission Control Measures installed at Al-Raziq industries (Pictorial evidences collected during Walk through survey)

Dust Collection Cooling Tower

Wet Scrubber

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