



GMS Core Environment Program

Estimating Industrial Pollution in Lao PDR

Final Report

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Produced by the GMS Environment Operations
Center

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Abbreviations

ADB	–	Asian Development Bank
AEC	–	ASEAN Economic Community
AFTA	–	ASEAN Free Trade Agreement
AIRS	–	Aerometric Information Retrieval System
ASM	–	Annual Survey of Manufacturers
BOD	–	biological oxygen demand
CM	–	Census of Manufacturers
DOA	–	Department of Agriculture
DOIH	–	Department of Industry and Handicrafts
HHED	–	Human Health and Ecotoxicity Database
GDP	–	gross domestic product
GIS	–	geographic information system
IPPS	–	industrial pollution projection system
IPL	–	investment promotion law
FDI	–	foreign direct investment
ISIC	–	International Standard Industrial Classification
Lao PDR	–	Lao People's Democratic Republic
LRD	–	Longitudinal Research Database
LSB	–	Lao Statistics Bureau
LSIC	–	Lao Standard Industrial Classification
MAF	–	Ministry of Agriculture and Forestry
MOIC	–	Ministry of Industry and Commerce
MoNRE	–	Ministry of Natural Resources and Environment
NEM	–	New Economic Mechanism
NO ₂	–	nitrogen dioxide
NPDES	–	National Pollutant Discharge Elimination System

PM10	–	particulate matters of size less than 10 microns
PCD	–	Pollution Control Department
SEZs	–	Special Economic Zone and Specific Economic Zone
SO ₂	–	sulfur dioxide
TRI	–	Toxics Release Inventory
TSS	–	total suspended solids
UNIDO	–	United Nations Industrial Development Organization
USEPA	–	United States Environmental Protection Agency
VOC	–	volatile organic compounds
WTO	–	World Trade Organization

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I. Summary

Three decades of economic development and diversification have resulted in a growing industrial sector in Lao People's Democratic Republic (Lao PDR). At the same time, production technologies used are often old, maintenance limited, and compliance with pollution standards is assumed to be generally lacking.

For the government of Lao PDR to be able to respond efficiently and effectively with industrial pollution regulations and law enforcement, it needs to be able to identify problematic manufacturing sectors and facilities, and tailor interventions to them. This is particularly important in a situation where the agencies with authority to control industrial pollution in Lao PDR – namely the Pollution Control Department of the Ministry of Natural Resources and Environment (MONRE) and the Department of Industry and Handicraft of the Ministry of Industry and Commerce (MOIC) – face significant resource constraints, including staff, budget and technology. Plant-level monitoring of air, water, and toxic emissions is at best done in a sporadic fashion, monitoring protocols and methods may not be applied consistently, monitoring equipment is often obsolete, data management and archiving procedures may not be strictly followed, and there is a lack of trained and empowered staff to actually perform site-level checks, and undertake data analysis for purpose of setting priority actions.

Such situation is not unique to Lao PDR. It is generally recognized that environmental regulators in developing countries often lack vital information on where the main pollution hotspots are found, and which manufacturing sectors and specific enterprises are the main emitters to set priorities, strategies, and action plans for purpose of controlling industrial pollution. As a result, strategic level planning has very little relevant information on pollution that could inform and support priority setting for industrial pollution control, development of strategies, and improvement of policies and law enforcement.

As a response to this insufficiency of information, the former Infrastructure and Environment team of the Development Research Group of the World Bank has developed an Excel based tool known as the Industrial Pollution Projection System (IPPS). This tool exploits the fact that industrial pollution is heavily affected by the scale of industrial activity and its sectoral composition. IPPS operates through sector estimates of pollution intensity (usually defined as pollution per unit of output or pollution per unit of employment).¹ Results from IPPS have been used in various countries where insufficient data on industrial pollution proved to be an impediment to setting-up pollution control strategies and prioritization of activities.²

Chapter 1 presents a rapid overview of the set-up for controlling industrial pollution in Lao PDR. In chapter 2, we briefly describe IPPS and discuss challenges and limitations with the use of IPPS in Lao PDR. With these limitations in mind, we present the characterization of industrial pollution in Lao PDR using IPPS in chapter 3. It is shown that a large percentage of industrial pollution is accounted for by a very limited number of industrial sectors, and within those sectors, by a very limited number of industrial facilities. It is also shown that a large share of industrial pollution originates from a very limited number of provinces in Lao PDR. These results suggest that large overall reductions in the discharges of industrial pollution in Lao PDR could be achieved by focusing resources to a relatively small number of industrial facilities and areas. Finally, in chapter 4 we provide brief recommendations and concluding remarks.

¹ See Hettige et al. (1994) for details.

² For example, IPPS has been used to estimate industrial pollution in Brazil and Mexico (Dasgupta et al. 2000), Latvia (Laplante and Smits 1998), Nigeria (Etim 2012, and Odesanya 2012), Thailand (Laplante and Meisner 2001), and Viet Nam (Dore et al. 2008).

1. Industrial Development in Lao PDR

Background

In 1986 Lao PDR launched the New Economic Mechanism (NEM), aimed to transform its centrally-planned economy to a market-oriented economy. The strategy “Industrialization and Modernization 2001-2020” was released in 2002 with the intent to develop the industrial sector as an engine of economic growth (Nolintha and Jajri, 2015). The strategy’s focus was hydropower, agricultural manufacturing, tourism, mining, and construction materials (Oraboune, 2011). In 2003 Lao PDR prepared a medium-term Strategy and Action Plan for Industrial Development with the United Nations Industrial Development Organization (UNIDO). In 2009 the Investment Promotion Law (IPL) was formalized, providing a clear policy on managing domestic and foreign direct investment (FDI). This was followed in 2010 by the Prime Minister Decree on Special Economic Zone and Specific Economic Zone Development, a subordinate legislation to the IPL meant to attract investment in Lao PDR (Nolintha and Jajri, 2015). Lao PDR achieved greater regional and global economic integration by joining the ASEAN Free Trade Agreement (AFTA) in 1998 and the World Trade Organization (WTO) in 2013. Lao PDR will join the ASEAN Economic Community (AEC) in late 2015.

Between 2003 and 2010, the number of Special Economic Zones (SEZs) increased from 2 to 10. Of these, 50% of are located in Vientiane Capital, 30% in the Central region (Khammuane and Savannakhet provinces) and 20% in the Northern region (Luangnamtha and Bokeo provinces). The industrial sector in Lao PDR has grown 12% annually. The industrial sector³ GDP share has grown from 18.4% to 31.2% 2002–2012, of which manufacturing industry accounted for 8% and 10% in the same period.

Major manufacturing activities include food and beverage, construction materials, wood processing, and garment and motorcycle assembly industries. The latest statistics show that a majority of enterprise in Lao PDR is small- and household-scale, accounting for more than 95% (31,910 enterprises out of 33,066). Medium- and large-scale enterprises comprise 4% and 1% (645 and 511 enterprises out of 33,066) of all enterprises. The industrial sector provides employment to more than 100,000 people in 2013.

Pollution Control Mandate and Capacity

Industrial development contributes to air, water and toxin pollution. Lao PDR has only a chapter on pollution control in the Environment Protection Law issued in 2013. Environmental Standards were released in 2010 and Guidelines on Pollution Control were endorsed in 2015, but need revision to address the specific challenges raised by manufacturing industry.

Several ministries are involved in aspects of pollution monitoring and enforcement:

- (i) The Ministry of Natural Resources and Environment (MONRE) Pollution Control Department (PCD) is mandated to work on pollution prevention and pollution control (Ongley, 2014).
- (ii) The Ministry of Industry and Commerce (MOIC) Department of Industry and Handicrafts (DOIH) is mandated to “mitigate the impacts of industry on the environment.”

³The industrial sector in Lao PDR is sub-divided into (i) Mining and Quarrying, (ii) Manufacturing, (iii) Electricity and Water and (iv) Construction.

- (iii) The Ministry of Agriculture and Forestry (MAF) Department of Agriculture (DOA) is mandated to assess and respond to pollution from agriculture.

It is unsurprising that this distribution of mandates, in combination with a vague definition of specific tasks and responsibilities, leads to uncertainties and repetition of monitoring and enforcement tasks. Additionally, the staffs of both PCD and DOIH have been absorbed from their former ministries and therefore do not always have a background on pollution monitoring and control. This lack of capacity is also found at province and district level. Last but not least, there is no clear mechanism for coordinating and reporting compliance to PCD and DOIH as a basis to carry out pollution control inspections.

One of PCD's core responsibilities is to maintain an inventory on pollution sources. Currently only a fraction of potential pollution sources is captured in paper form, often with gaps, and then manually transcribed into electronic form (Ongley, 2015). DOIH collects and updates their enterprise database with the help of province staff, a process that has also led to data inconsistencies and gaps.

2. The Industrial Pollution Projection System

Overview

The Industrial Pollution Projection System (IPPS) combines data from industrial activity such as production and employment with data on pollution emissions to calculate pollution intensity factors, representing the level of pollution emissions per unit of industrial activity⁴. As illustrated in Appendix Figure 1, pollution intensities have been calculated with data available from the US Manufacturing Census and the US Environmental Protection Agency (USEPA). The Manufacturing Census maintains the Longitudinal Research Database (LRD), which contains information from the Census of Manufactures (CM) and the Annual Survey of Manufactures (ASM). While the CM contains information on all manufacturing establishments in the United States, the ASM seeks further and more detailed information on a subset of those companies. Once an establishment has been selected to be part of the ASM, information is collected from the chosen company annually for a period of 5 years. The LRD contains detailed information on approximately 200,000 plants.

The USEPA maintains a number of databases on pollution emissions. These include the Toxics Release Inventory (TRI), the Aerometric Information Retrieval System (AIRS), the National Pollutant Discharge Elimination System (NPDES), and the Human Health and Ecotoxicity Database (HHED). These datasets have been used in the calculation of pollution intensities.⁵ After combining the LRD and EPA databases, it was possible to calculate pollution intensity factors for approximately 20,000 plants.

The USEPA contains emissions information for a number of pollutants and chemical substances known to be harmful to both human health and the environment. IPPS coefficients are available for selected air pollutants—sulfur dioxide (SO₂), nitrogen dioxide (NO₂), volatile organic compounds (VOC), total suspended particulates (TSP), particulate matter of size less

⁴ See Hettige et al. (1994) for details.

⁵ The TRI contains information on annual emissions for more than 300 chemicals toxic to the environment. Manufacturing establishments that (i) employ 10 full-time employees or more and (ii) produce, import or process 25,000 pounds or more of any listed chemical must report the nature and quantity of the chemical produced, imported, or processed. In 1987, approximately 20,000 enterprises reported their release of such chemicals. The AIRS is the US national database for ambient air quality, air emissions and compliance data with the U.S. Clean Air Act. The NPDES contains the self-reported data of plants facing standards for water emissions. Finally, the HHED contains various indices of toxicological potency.

than 10 microns (PM10)—and selected water pollutants including biological oxygen demand (BOD) and total suspended solids (TSS). IPPS also includes pollution intensities for over 240 priority chemicals and metals generally known to be toxic to human health, and metals known to be bio-accumulative.

For each of the air and water pollutants and the 240 toxic chemicals and metals, IPPS provides a lower bound, inter-quartile, and upper bound mean value for their pollution intensity factors. In this study estimates of pollution load are based on the lower bound value, but more important are the ranking of industrial sectors in terms of pollution discharges and ranking of geographical areas. These rankings remain the same whether lower bound, inter-quartile or upper bound values are used.

Pollution intensity factors are calculated as the total amount of pollution discharge for a given pollutant divided by the manufacturing indicator (output value, value-added or employment). In the case of an employment-based indicator, the factor is the number of kilograms of pollutant per unit of employment.

A difficulty of the calculation of pollution intensity factors is the variable used to capture the extent of manufacturing activity. While physical volume of output would be the ideal unit of measurement, industries and even establishments within an industry often use different units to report their volume of production. This does not allow for comparison across industries. However, the values of output and plant-level employment do offer such common units of measurement—the ranking of industrial sectors is almost identical whether the value of output or employment is used.⁶ In the United States, the choice of unit of measurement does not appear to impact the ranking of industrial sectors by pollution load. For the purpose of policy-making, it is this ranking that is most relevant.

The income elasticity of pollution per unit of output and the income elasticity of labor per unit of output are both negative, and not significantly different from one another. This suggests that while developing economies generate more pollution per unit of output than developed economies, they employ more labor per unit of output in the same proportion. Therefore this study uses pollution discharge per unit of labor as the pollution intensity factor.

Challenges in Implementing IPPS in Lao PDR

The implementation of IPPS in Lao PDR encountered three challenges:

- (i) matching industrial facilities to specific industrial sectors;
- (ii) inaccurate employee data; and
- (iii) lack of standardized coordinates used to locate industrial facilities.

IPPS relies on matching an industrial facility to a specific industrial sector for which pollution intensity factors are available. The standard approach of classifying economic activities is known as the International Standard Industrial Classification (ISIC, Appendix Box 1). While most countries use ISIC codes to classify economic activities, it is common to observe in developing countries the use of hybrid systems combining ISIC with a national system of classification.

In Lao PDR, MOIC maintains the Lao Enterprise database. The latest official endorsement of the database was in 2012. While MOIC encourages the use the latest revision of ISIC (Revision 4), data collected through and provided by districts and provinces include 3- and 2-digit, instead of 4-digit, classification, and also include the use of Lao Standard Industrial Classification (LSIC). Approximately 47% of entries use LSIC and approximately 50% use

⁶ Hettige et al (1994). For the U.S. study, the rank correlation coefficient between intensity factors using the value of output and using employment is 0.98 thus indicating an almost identical ranking.

ISIC Revision 4. In the latter case some entries reported using the second or third revision of ISIC.⁷ Another 3% of the entries included no classification. Nine provinces out of 17 reported LSIC code in their database; of these four used solely LSIC while five used a combination of LSIC and ISIC codes.

To address this, the study developed tables of concordance to match codes from LSIC to ISIC. Where codes were absent, the study used a facility's description of economic activity to attach an ISIC code. This process may not have been without error as activity description was found to be generic. In aggregate this should not bias results at the national level, since a small percentage of entries was missing industrial codes. However it may bias results for specific industrial sectors or provinces. For example, Xiengkhuang province did not report any industrial code classification for its enterprises.

Employee data provided in the database may not be accurate. The reporting of employee numbers by industrial activity may have been difficult in case of seasonal manufacturing. A number of employee data entries were left blank or reported zero employees. There is no possibility for the study to validate the number of employees reported in the database, and in circumstances of no or "zero" entry these facilities were not included in the analysis.

Finally, the database does not comprise standardized coordinates to locate each industrial facility in the country; hence village names were used to compensate for missing locations. However, for 53 records even village names are missing from the database. For approximately 11% of the data entries, matching codes could not be identified from the geographic information system (GIS). While this has no impact at the national level, the geographical distribution of industrial pollution presented in Section 3 may not be completely accurate.

As a result of these constraints and IPPS's own limitations, it is important to indicate that the estimates of industrial pollution presented in Section 3 should be used solely as a ranking device—of industrial sectors discharging air, water, or toxic pollutants (from more to less important), and of provinces by industrial discharge of air, water, and toxic pollutants.

The results presented in Section 3 should not be used to assess compliance by specific industrial facilities with national industrial regulations and standards. Similarly, if a system of industrial pollution fees is established in Lao PDR in the future, the results presented in Section 3 should not be used to assess fees to be paid by individual enterprise. However, the results can and should be used to guide and focus the monitoring of industrial pollution in Lao PDR.

3. Results

The MOIC data file contained 12,172 entries, but as shown in Appendix Table 1 not all were used for this analysis. 6,797 entries reported a number of employees of 1 or 2, and discussion with officials indicated that these were likely not manufacturing facilities but shops selling products from the manufacturing sector. These entries were excluded from the analysis.⁸ Other entries were deleted for reasons shown in Appendix Table 1. The final number of entries included in the analysis is 4,881 enterprises, distributed across 2006 locations (villages) in Lao PDR (Appendix Figure 2).

⁷ Revision 2 was published in 1968 and Revision 3 was published in 1989.

⁸The study team performed another set of estimates including these enterprises with reported "1" or "2" employees. At the national level, the estimated pollution from these enterprises is less than 7% of the total estimated pollution. Hence at the national level we would suggest that excluding such enterprises does not alter results in any meaningful way.

Industrial Activity and Distribution

Grain mill products, furniture, and soft drinks represent approximately 40% of all enterprises in Lao PDR. Note that in Table 2 sectors with less than 1% of enterprises or less than 1% of employees have been combined into the category “others combined”.

From the point of view of industrial pollution, the most important feature of Appendix Table 2 is the distribution of employment across industrial sectors. While “grain mill products” represents 18.05% (881) of all enterprises it represents only 4.28% of all industrial employment. “Wearing apparel” represents only 5.12% of all enterprises but represents 27.24% of all industrial employment. This distribution is important since pollution coefficients used in this analysis are employee-based. Hence the distribution of employment is of much greater significance than the distribution of the number of enterprises across industrial sectors.

Similarly, the distribution of enterprises is examined geographically. As shown in Table 3, approximately 56% of all enterprises are located in three provinces: Borikhamxay, Savannakhet and Vientiane Capital. Vientiane Capital accounts for 32.8% of all enterprises. However, while approximately 1/3 of enterprises are located in Vientiane Capital these represent more than half (52.84%) of all industrial employment. While Savannakhet represents 15.6% of all enterprises, it represents only 7.9% of all industrial employment. This is significant given that pollution intensity factors are employment-based.

The distribution of industrial activities can be examined in detail in two different ways:

- (i) The distribution of the most important industrial sectors (identified in Appendix Table 2) can be examined across provinces.
- (ii) These industrial sectors can be examined by predominance in the most important industrial provinces (identified in Appendix Table 3).

Identifying the distribution of industrial activities in these ways further explains the distribution of industrial pollution examined below. As indicated in Appendix Table 2, the identification of the most important industrial sectors is not the same if one uses number of enterprises or number of employees as ranking criteria. The following figures focus on five provinces that rank highest in terms of number of enterprises.

“Grain mill products” is the most important sector in the country, representing 18.05% of all enterprises. This sector is predominantly (47%) located in Savannakhet (Appendix Figure 3). Of the “furniture and fixtures” sector, 27% of enterprises are located in Vientiane Capital (Appendix Figure 4). Enterprises of the “soft drink and carbonated waters” sector are mostly (39%) located in Vientiane Capital (Appendix Figure 5). Approximately 52% of all enterprises of the “non-metallic mineral product” sector are located in Savannakhet (29%) and Vientiane Capital (23%). 23% of enterprises in the structural clay products sector are located in Champasack (Appendix Figure 8). Borikhamxay and Xayabury each represent 19% of all enterprises (Appendix Figure 6).

Examination of industrial sectors by predominance in the most important industrial provinces reveals that 49% of all industrial enterprises in Vientiane Capital belong to the “wearing apparel” sector (Appendix Figure 9). “Grain mill products” represents the largest number of enterprises in Savannakhet (Appendix Figure 10). In Borikhamxay “sawmills, planing, and other wood mills” is the largest industrial sector (Appendix Figure 11). In Khammuane 33.1% of all enterprises belong to the “wood and cork products” sector (Appendix Figure 12). In Xayabury 50% of all enterprises belong to “sawmills, planing, and other wood mills” sector (Appendix Figure 13). Finally, in Vientiane Capital approximately 30% of all enterprises are in the “furniture and fixtures” industrial sector (Appendix Figure 14).

Industrial Pollution by Sector

As shown in Appendix Table 4, across all air pollutant emissions the “cement, lime, and plaster” sector is the largest emitter in aggregate. It is also the largest emitter of SO₂, NO₂, PM₁₀, and TSP. This sector represents less than 1% of all enterprises in the dataset and 1.62% of all industrial employment, but contributes a majority of industrial air emissions in the country. The “basic industrial chemicals” and “non-ferrous metal basic industries” sectors are the next-largest emitters of air pollutants. The sectors producing the largest quantities of VOC are different than those producing other air pollutants.

Within each sector for each air pollutant (Appendix Table 5) the largest 10 emitters produce a majority of pollution. The largest 10 enterprises in the “cement, lime, and plaster” sector produce 80.87% of its SO₂, NO₂, PM₁₀, and TSP emissions, and the largest 25 enterprises produce almost all of the sector’s air pollution. This indicates that significant reduction in aggregate emissions of air pollutants could be achieved if a limited number of enterprises were to reduce their emissions.

Three sectors account for the bulk of toxic metal pollution discharges—“non-ferrous metal basic industries,” “iron and steel basic industries,” and “basic industrial chemicals” (Appendix Table 6). All other sectors make insignificant contributions to such discharges. Within these three sectors most discharges are accounted for by a relatively small number of facilities (Appendix Table 7). In “non-ferrous metal basic industries” the largest 10 enterprises account for more than 70% of all toxic metal discharges. The same three sectors account for the largest share of discharges of toxic pollution (Appendix Table 8).

Appendix Table 9 indicates emitters of organic water pollution. “Iron and steel basic industries,” “non-ferrous metal basic industries” and “pulp, paper and paperboard” are the largest dischargers of TSS, with “iron and steel basic industries” representing more than 60% of all industrial discharge. “Pulp, paper and paperboard,” “basic industrial chemicals” and “dairy products” are the largest dischargers of BOD. In the “pulp, paper and paperboard” sector fewer than 10 enterprises account for 100% of both TSS and BOD discharge.

All of the above results clearly indicate that the industrial discharges of air, water, and toxic pollutants in Lao PDR originates from a limited number of industrial sectors and, within those sectors, from a limited number of industrial facilities.

Industrial Pollution by Geography

As shown in Appendix Table 11, Figure 15 and Figure 19, the largest quantity and share of industrial air pollution takes place in Khammuane, Vientiane and Vientiane Capital. This is consistent with the distribution of industrial activities across the country. A majority of toxic metal, toxic pollutant and water pollutant emissions originate in Khammuane, Savannakhet and Vientiane Capital provinces (Appendix Tables 12, 13, 14; Figures 16, 17, 18, 20, 21 and 22).

These results indicate a concentration of industrial pollution discharges in the country. It should be noted that such discharges may or may not be source of environmental degradation in the province in which discharges are taking place. A full account of such damage requires the use of pollution dispersion models.

4. Conclusions and Recommendations

Environmental regulators in numerous developing economies, including Lao PDR, find themselves with insufficient capacity, staffing and resources to adequately address industrial pollution. In particular the lack of monitoring resources—staff, budget and technology—often prevents the accounting of plant-specific industrial discharges. This presents an obstacle to the enforcement of national pollution control regulations and standards.

The application of IPPS in Lao PDR provided a characterization of the country's manufacturing sector and estimation of associated industrial pollution. It has been shown that a high percentage of industrial pollution is generated by a limited number of industrial sectors. The "cement, lime and plaster" sector alone accounts for approximately 42% of total industrial air pollution emissions in the country. This sector comprises only 28 industrial facilities among the 4,881 facilities included in the dataset. The "iron and steel basic industries" sector accounts for approximately 55% of total industrial water pollution discharges; when combined with "non-ferrous metal basic industries" and "pulp, paper and paperboard" these three sectors account for approximately 78% of total industrial water pollution discharges, yet comprise an estimated 171 industrial facilities among the 4,881 included in this analysis. Three sectors—"non-ferrous metal basic industries," "iron and steel basic industries," and "basic industrial chemicals"—comprising 226 facilities produce approximately 90% of all toxic metal pollution. These same sectors account for 67% of all toxic pollution.

Within these sectors a disproportionate share of industrial pollution is accounted for by a limited number of industrial facilities. Just 10 enterprises contribute to approximately 80% of all air pollution emissions from the "cement, lime and plaster" sector. Given that the sector contributes to 42% of air pollution emissions, these 10 enterprises alone account for more than 30% of all industrial air pollution emissions in the country.

It has also been shown that a majority of industrial pollution originates from a limited number of provinces in Lao PDR—Borikhamxay, Khammuane, Savannakhet, Vientiane Capital, and Vientiane province. These results are encouraging as they suggest large overall reductions in industrial pollution discharge could be achieved by focusing attention and resources on a limited number of industrial facilities located in few geographical areas.

This information should be used as a basis to review and revise present resource allocation for industrial pollution control at the national and provincial level. Plotting available resources and their current use against the results of the IPPS should help authorities identify gaps and shift resources to better align to those areas and sectors where industrial pollution is estimated to be concentrated.

These results should also support the design and implementation of industrial pollution audits of facilities identified to be the largest producers of air, water and toxic pollutants in Lao PDR. Such audits should identify not only the quantity of pollution emissions and discharges, but also the facilities' production technologies and pollution control and abatement processes. These audits can then be used to identify where pollution may be reduced at least cost and also where opportunities may exist to decrease overall production costs, increasing enterprises' profitability and competitiveness.

Finally IPPS results should be used to review whether current pollution control legislation properly reflects the geographic and sector distribution of pollution estimated in this paper, and to recommend policy updates and adjustments.

Beyond the immediate use of IPPS to optimize the use of pollution control resources, these results may be used by planners of those sectors or areas that are adversely affected by

industrial pollution—such as urban planners and health authorities—to advocate for stronger and more empowered pollution control authorities.

In this context it is important to recognize some limitations of the exercise described in this report, and the need for improvements. First, three challenges have been identified:

- (i) The use of industrial sector classification (ISIC coding) is not rigorously implemented throughout the country.
- (ii) Employee data provided in the database may not be accurate.
- (iii) The database does not comprise standardized coordinates to locate each industrial facility in the country.

Each of these should be addressed in the near term by relevant authorities. Given the limited resources available to pollution control activities it is important for the pollution control department to recognize that an adequate and reliable national industrial activity database is key to rapidly achieving greater efficiency and effectiveness by authorities. In this respect there may be opportunity for inter-ministerial collaboration, which would benefit both industrial promotion and pollution control authorities.

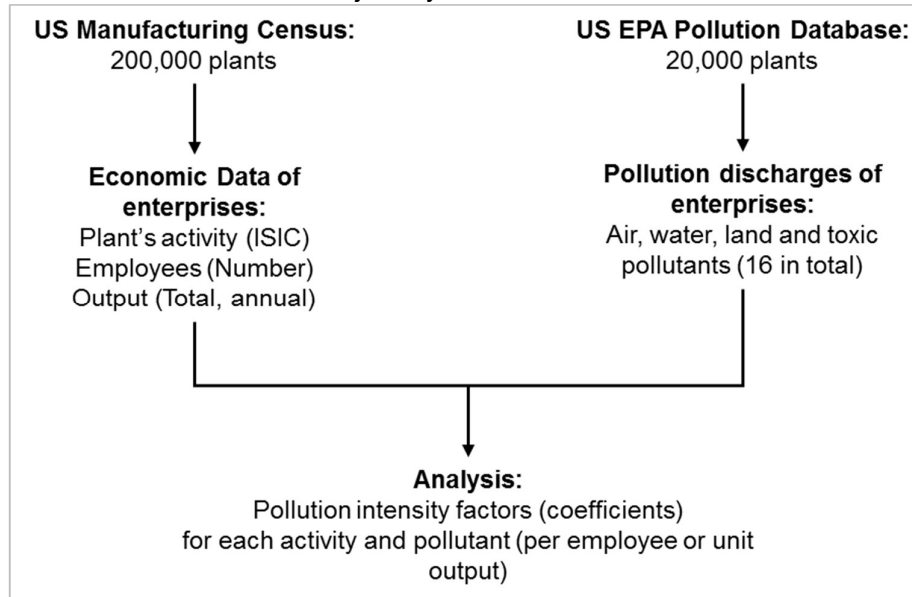
Second, it must be recognized that the estimates presented in this report should not be used to assess compliance with national regulatory standards or to assess pollution discharge fees, if there were to be such policy. These results simply point to specific industrial sectors and, within these sectors, to specific firms in well-defined areas where pollution may reach higher levels. While the results presented in this paper may serve to better focus limited monitoring and enforcement resources, they should not be used in lieu of actual monitoring data for purpose of enforcement of pollution control regulations.

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Appendix

Figure 1: The Industrial Pollution Project System



Box 1: The International Standard Industrial Classification

The International Standard Industrial Classification of All Economic Activities (ISIC) is a United Nations system for classifying economic data and is the international reference classification of productive activities. Its main purpose is to provide a set of activity categories that can be utilized for the collection and reporting of statistics according to such activities. It provides a comprehensive framework within which economic data can be collected and reported in a format that is designed for purposes of economic analysis, decision taking and policy-making. The classification structure represents a standard format to organize detailed information about the state of an economy according to economic principles and perceptions. These economic activities are subdivided in a hierarchical, four-level structure of mutually exclusive categories, facilitating data collection, presentation and analysis at detailed levels of the economy in an internationally comparable, standardized way.

ISIC was first adopted in 1948 and has been subjected to 4 significant revisions, the latest (Revision 4) dating to 2008.

The ISIC is subdivided in a hierarchical, four-level structure. The categories at the highest level are called sections. The two-digit of the code identify the division, the third digit identifies the group, and the fourth digit identifies the class.

Section	C	Manufacturing
Division	13	Manufacture of Textiles
Group	139	Manufacture of Other Textiles
Class	1393	Manufacture of Carpets and Rugs

Details about ISIC are provided at the following site:
<http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27>

Figure 2: Distribution of villages covered by Enterprise Database

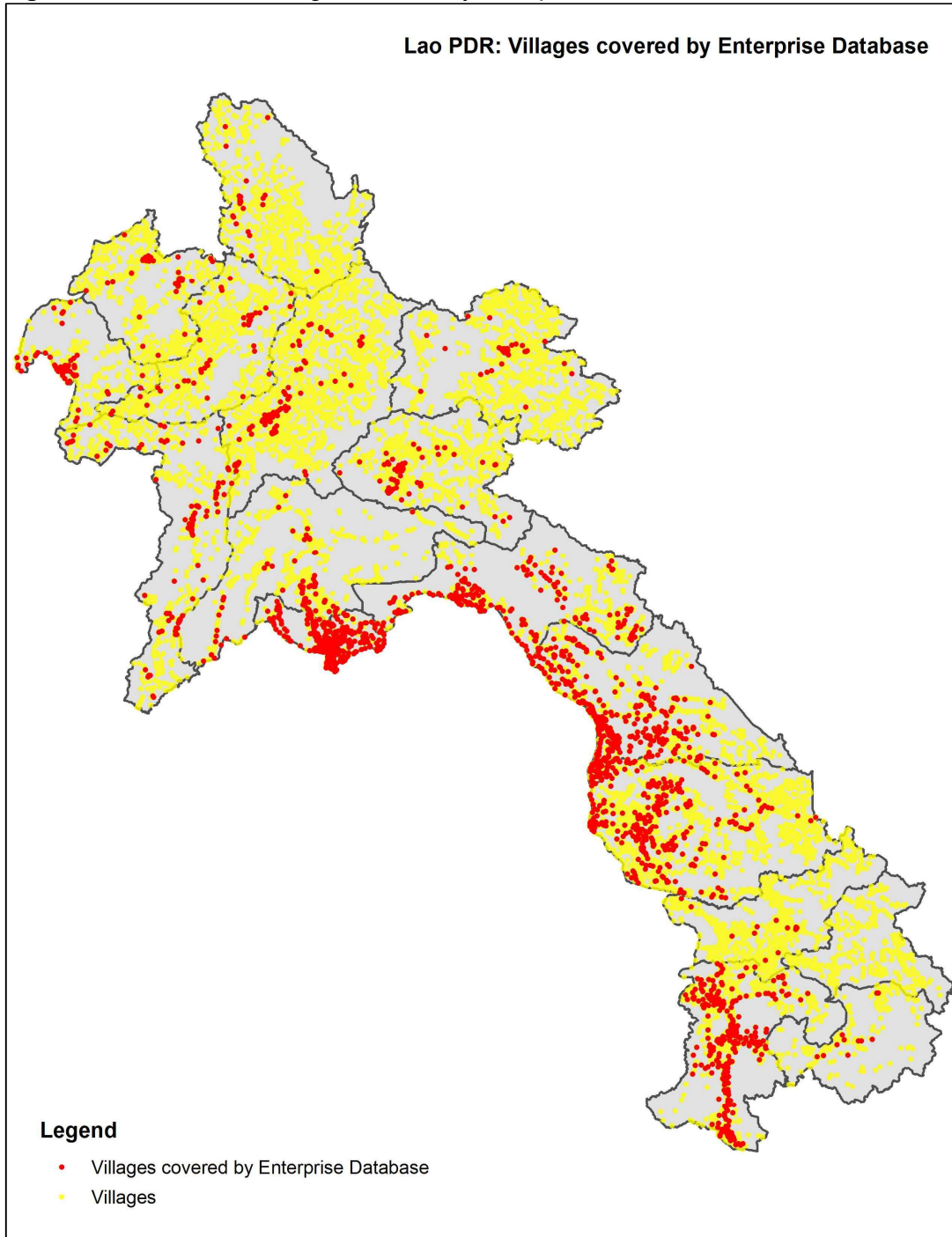


Table 1: Number of Observations Used for Analysis

Items	Number of observations
Number of observations in original dataset	12,172
Number of observations with 0, 1, or 2 employees	6,797
Number of observations with no entry for employees	219
Number of observations with other information missing	275
Number of observations included in analysis	4,881

Table 2: Distribution of Enterprises and Industrial Employment by Industrial Sectors (Red: 3 most important; yellow: 3 next most important)

Name of Industrial Sector	Number of Enterprise		Number of Employees	
	Total	%	Total	%
Grain mill products	881	18.05	4,263	4.28
Furniture and fixtures (non-metal)	627	12.85	10,430	10.46
Soft drinks and carbonated waters industries	515	10.55	4,361	4.37
Non-metallic mineral products	348	7.13	4,184	4.20
Sawmills, planing and other wood mills	306	6.27	8,725	8.75
Structural clay products	294	6.02	3,024	3.03
Wearing apparel, except footwear	250	5.12	27,154	27.24
Wood and cork products	237	4.86	5,162	5.18
Dairy products	149	3.05		-
Food product	130	2.66	1,802	1.81
Slaughtering, preparing and preserving meat	130	2.66		-
Iron and steel basic industries	103	2.11	1,743	1.75
Tobacco manufactures	83	1.70	1,444	1.45
Spinning, weaving and finishing textiles	80	1.64	2,405	2.41
Bakery products	66	1.35		-
Basic industrial chemicals except fertilizers	63	1.29	1,630	1.64
Non-ferrous metal basic industries	60	1.23	1,512	1.52
Plastic products not elsewhere classified	53	1.09	1,546	1.55
Glass and glass products	52	1.07		-
Cement, lime and plaster		-	1,615	1.62
Motorcycles and bicycles		-	1,389	1.39
Radio, television and communication equipment		-	1,282	1.29
Malt liquors and malt		-	1,189	1.19
Footwear		-	1,153	1.16
Printing, publishing and allied industries		-	1,008	1.01
Others combined	454	9.30	12,665	12.70
Total	4,881	100.00	99,686	100.00

Table 3: Distribution of Enterprises and Industrial Employment by Provinces (Red: 3 most important; Yellow: 3 next most important)

Province	Number of Enterprise		Number of Employees	
	Total	%	Total	%
Vientiane Capital	1,601	32.80	52,673	52.84
Savannakhet	762	15.61	7,901	7.93
Borikhamxay	398	8.15	4,739	4.75
Champasack	335	6.86	2,694	2.70
Khammuane	269	5.51	7,460	7.48
Xayabury	221	4.53	3,993	4.01
Luangprabang	205	4.20	2,752	2.76
Saravane	194	3.97	2,258	2.27
Vientiane	178	3.65	4,027	4.04
Xiengkhuang	146	2.99	2,191	2.20
Huaphanh	107	2.19	2,155	2.16
Bokeo	106	2.17	1,600	1.61
Oudomxay	106	2.17	1,321	1.33
Sekong	85	1.74	1,414	1.42
Attapeu	75	1.54	1,636	1.64
Luangnamtha	50	1.02	653	0.66
Phongsaly	43	0.88	219	0.22
Total	4,881	100.00	99,686	100.00

Figure 3: Distribution of Grain Mill Products (by number of enterprises)

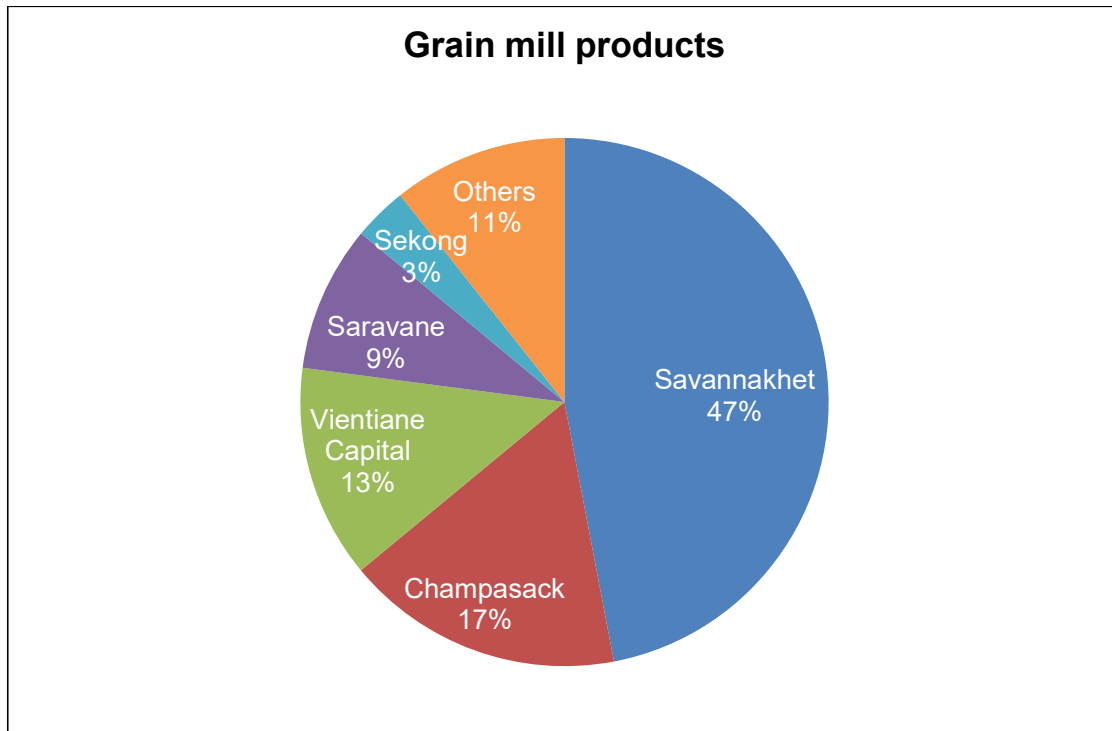


Figure 4: Distribution of Furniture and Fixtures (by number of enterprises)

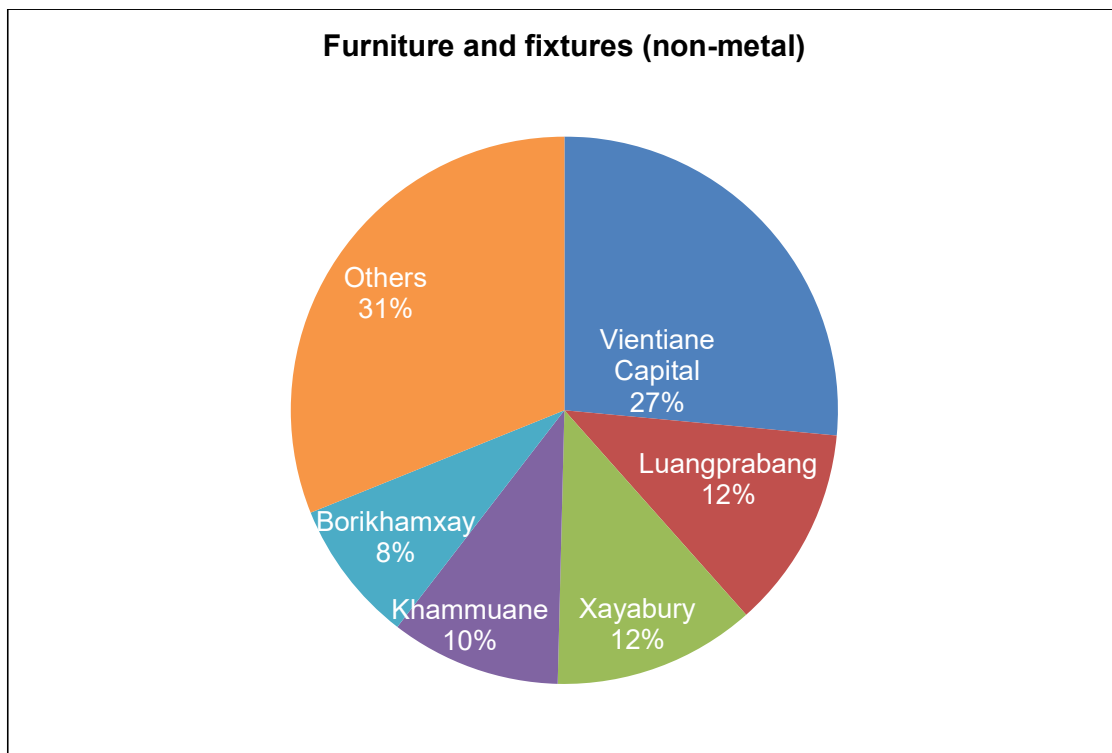


Figure 5: Distribution of Soft Drinks and Carbonated Waters Industry (by number of enterprises)

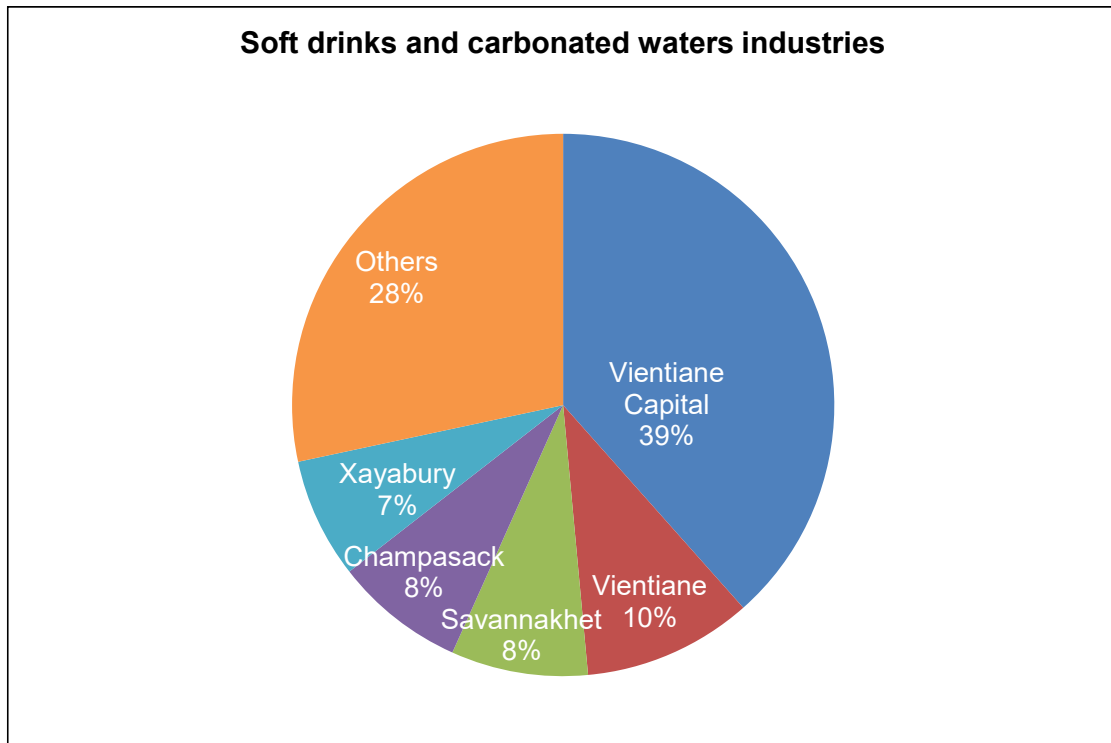


Figure 6: Distribution of Non-Metallic Mineral Products (by number of enterprises)

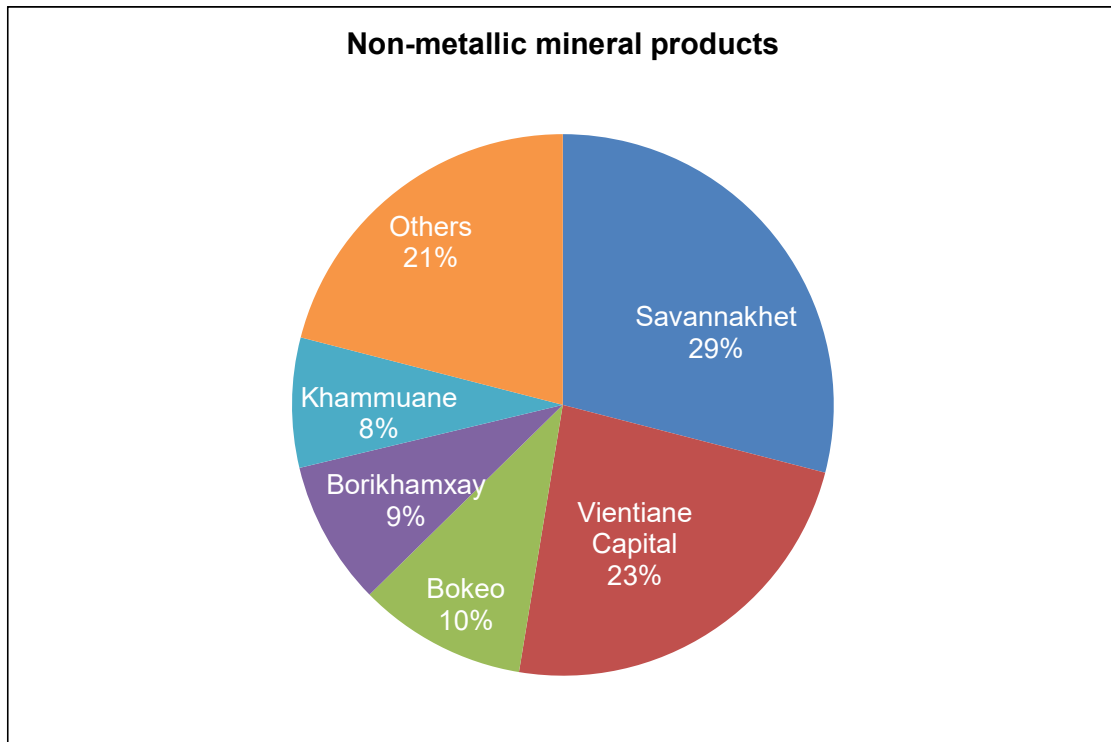


Figure 7: Distribution of Sawmills, Planing and Other Wood Mills (by number of enterprises)

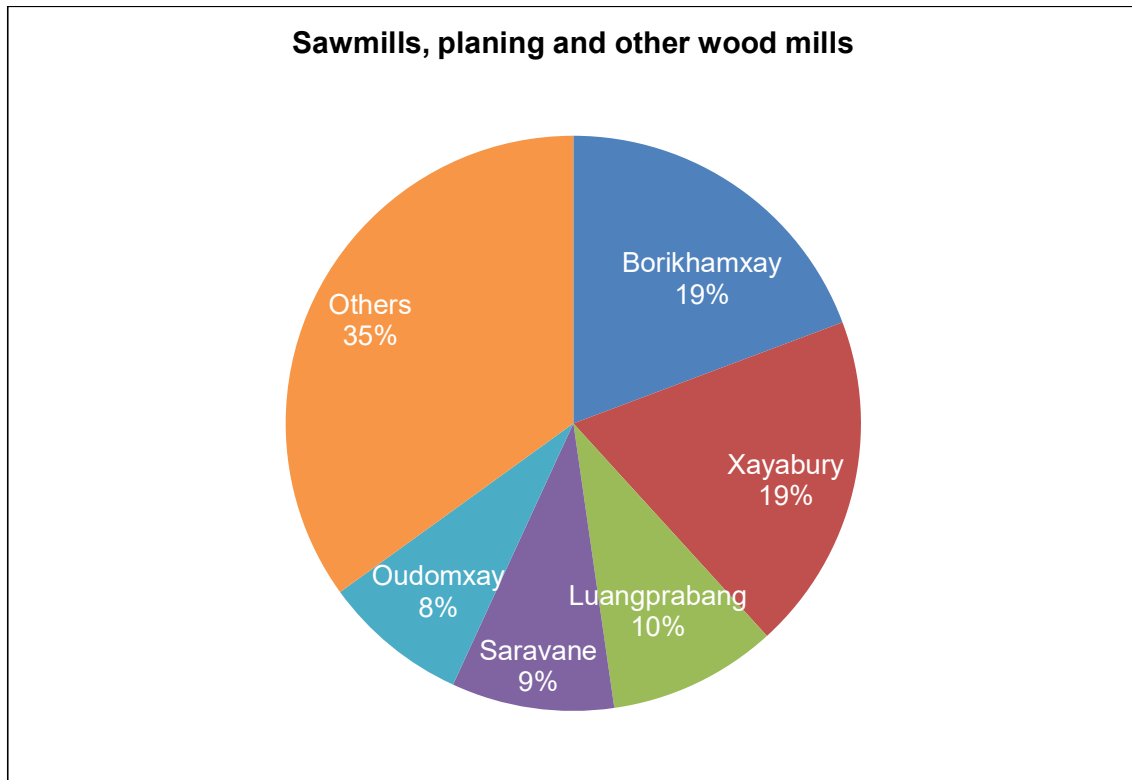


Figure 8: Distribution of Structural Clay Products (by number of enterprises)

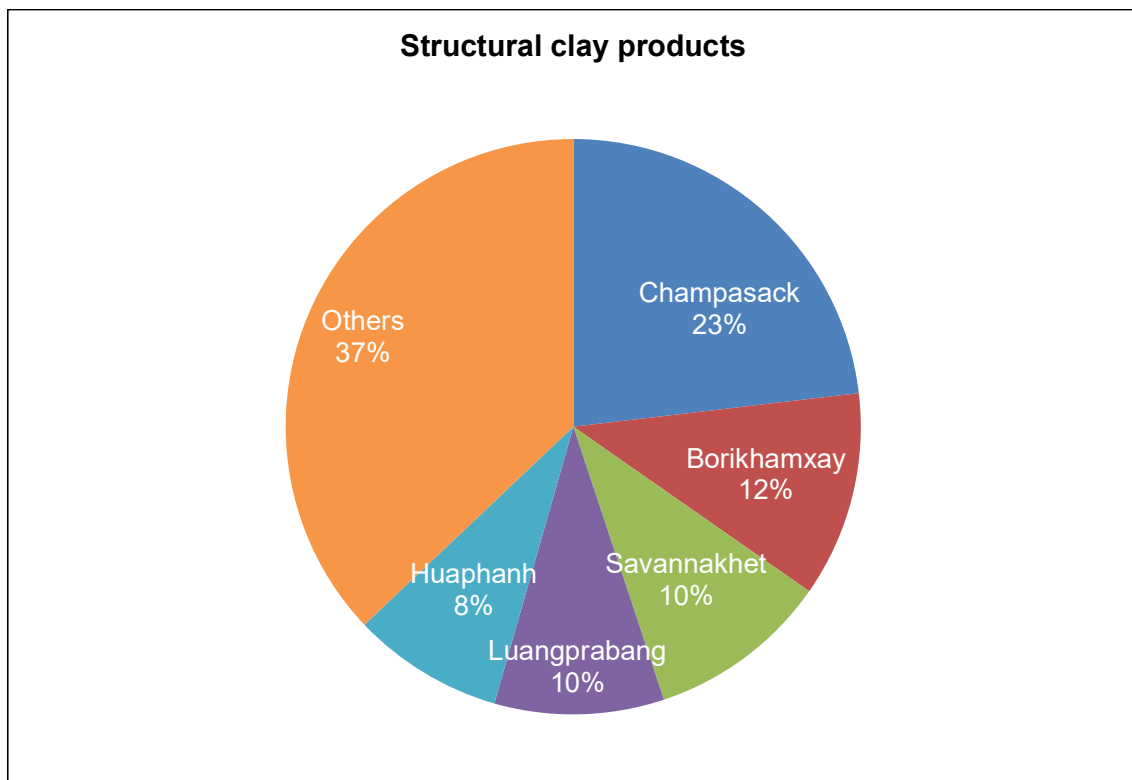


Figure 9: Distribution of Industrial Activities in Vientiane Capital (by number of enterprises)

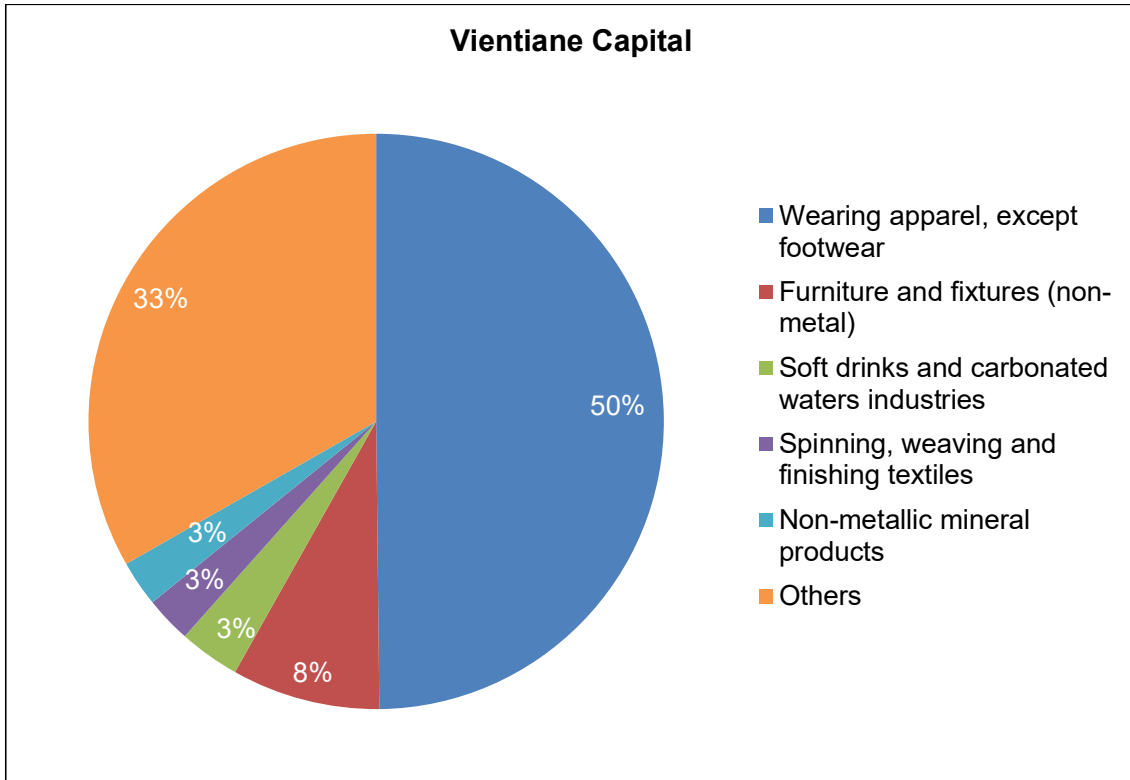


Figure 10: Distribution of Industrial Activities in Savannakhet (by number of enterprises)

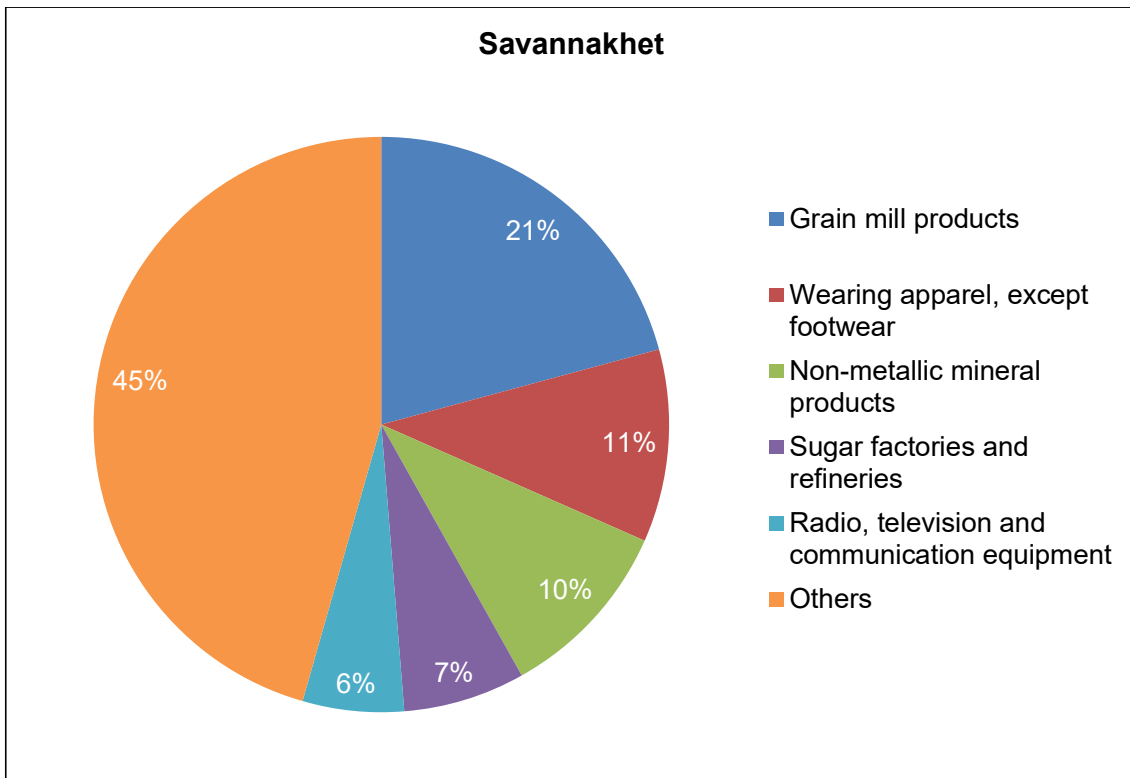


Figure 11: Distribution of Industrial Activities in Borikhamxay (by number of enterprises)

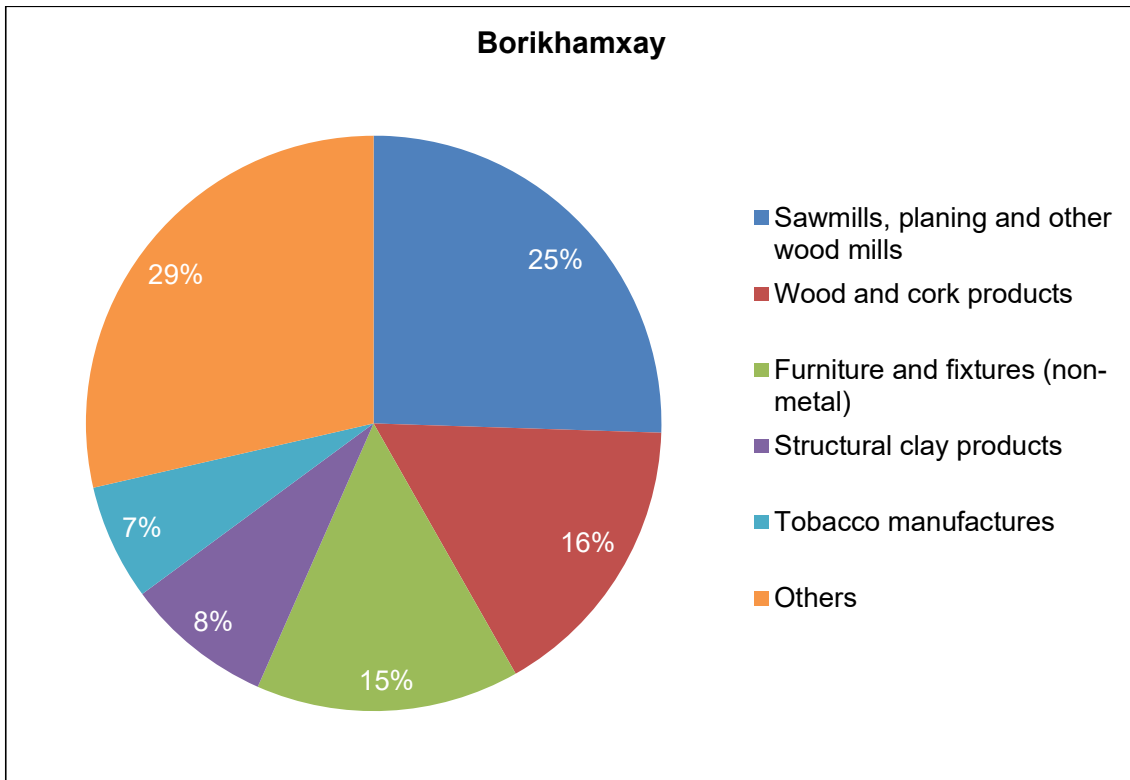


Figure 12: Distribution of Industrial Activities in Khammuane (by number of enterprises)

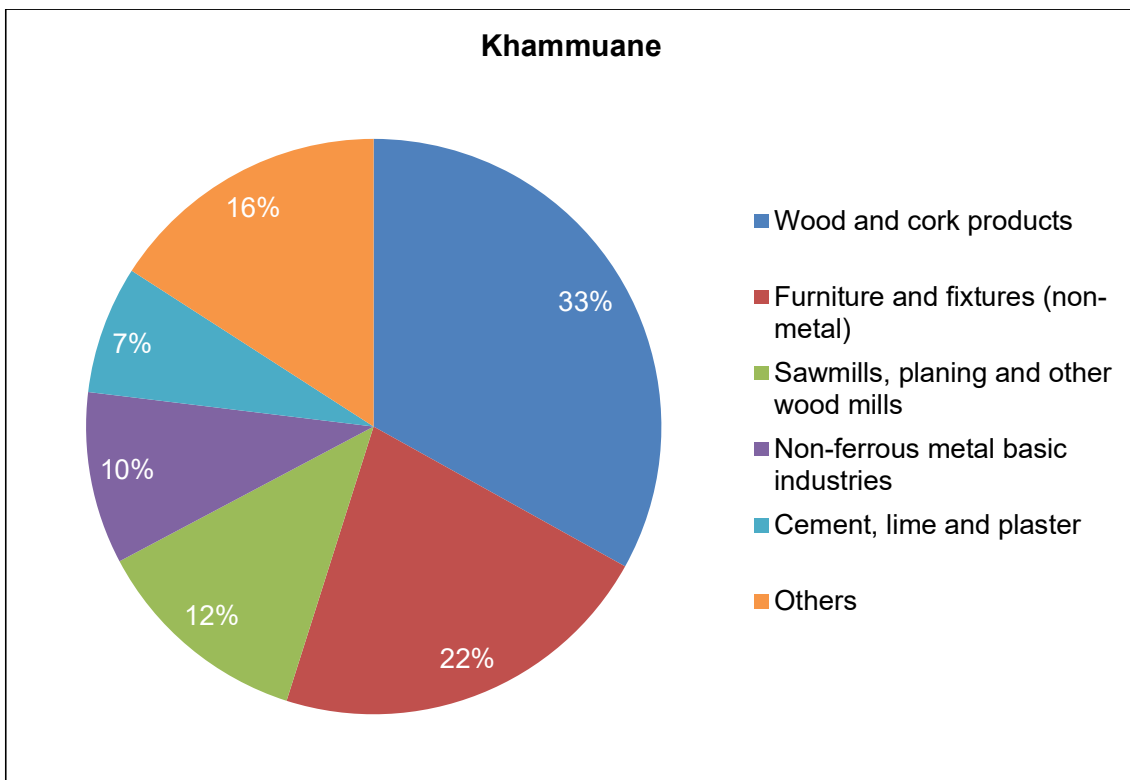


Figure 13: Distribution of Industrial Activities in Xayabury (by number of enterprises)

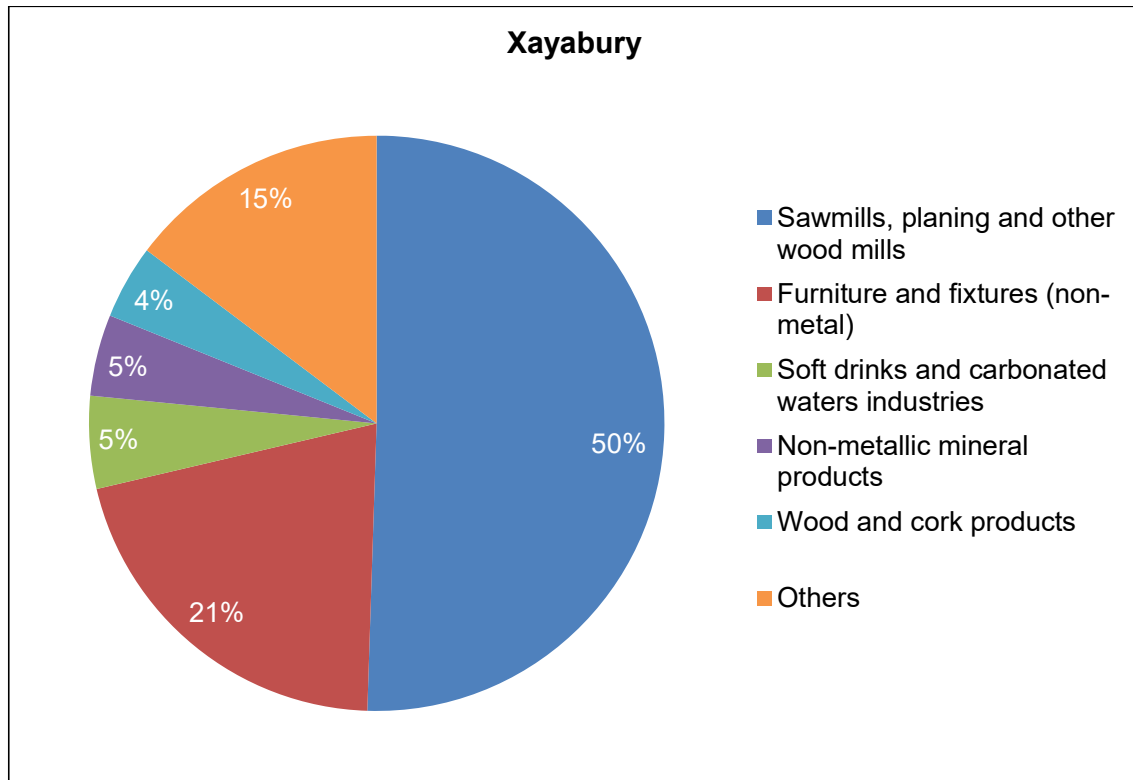


Figure 14: Distribution of Industrial Activities in Vientiane (by number of enterprises)

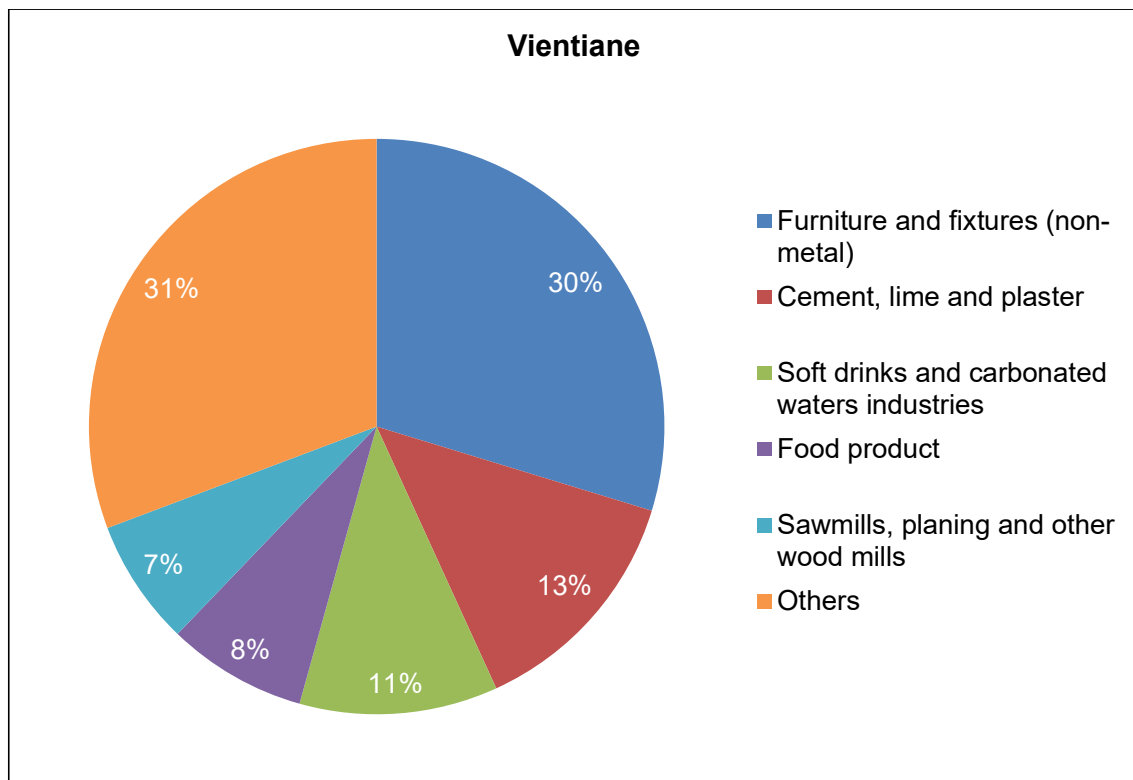


Table 4: Air Pollution Emissions by Industrial Sector (kg). Red: 3 most important; Yellow: 3 next most important.

Industrial Sector	Total	SO2	NO2	CO	VOC	PM10	TSP
Cement, lime and plaster	54,651,378	19,252,956	8,939,293	1,088,076	50,892	16,008,739	9,311,423
Basic industrial chemicals except fertilizers	8,385,561	2,712,472	2,014,787	1,556,115	1,574,345	91,963	435,880
Non-ferrous metal basic industries	8,371,060	5,144,140	167,553	2,392,929	187,142	47,263	432,031
Iron and steel basic industries	8,178,282	2,250,068	977,380	3,506,417	301,198	621,886	521,332
Structural clay products	8,051,930	352,026	3,401,399	807,997	276,371	544,100	2,670,036
Sawmills, planing and other wood mills	6,653,724	455,519	1,029,148	2,593,668	1,102,752	40,605	1,432,031
Pulp, paper and paperboard	5,243,568	1,705,512	889,868	1,946,686	269,489	96,833	335,179
Soft drinks and carbonated waters industries	3,590,730	1,818,354	1,432,273	88,697	148,750	2,767	99,889
Wood and cork products	3,213,983	451,515	292,451	652,926	884,944	266,932	665,216
Non-metallic mineral products	3,019,830	740,275	330,289	158,507	90,898	452,521	1,247,340
Sugar factories and refineries	2,603,438	782,321	751,032	402,404	133,123	16,371	518,188
Furniture and fixtures (non-metal)	2,224,161	79,277	56,015	59,440	1,798,691	52,282	178,457
Grain mill products	2,026,581	215,890	172,972	33,449	182,615	356,891	1,064,764
Distilling, rectifying and blending spirits	1,974,971	396,941	137,959	25,786	1,363,715	17,348	33,221
Petroleum refineries	1,486,301	545,935	314,041	283,609	289,040	5,513	48,164
Vegetable and animal oils and fats	1,364,695	405,574	145,173	32,414	111,114	254,969	415,451
Chemical products not elsewhere classified	1,135,547	88,321	27,572	897,697	68,408	22,719	30,829
Synthetic resins, plastic materials & man-made fibres	1,097,930	181,808	472,537	69,868	345,796	147	27,774
Malt liquors and malt	978,991	495,763	390,500	24,183	40,556	755	27,234
Spinning, weaving and finishing textiles	779,561	247,544	341,558	45,839	93,698	6,626	44,297
Motorcycles and bicycles	768,245	25,146	14,652	4,158	709,042	-	15,246
Tobacco manufactures	736,997	385,978	233,582	30,426	76,772	3,031	7,209
Fertilizers and pesticides	361,366	106,709	102,782	20,457	97,264	4,499	29,654
Drugs and medicines	292,911	135,149	57,351	6,730	67,230	937	25,513
Slaughtering, preparing and preserving meat	242,430	17,069	175,259	43,782	889	488	4,944
Food products	226,024	83,445	72,966	15,400	22,813	1,806	29,593
Tire and tube industries	200,741	79,501	27,472	3,371	80,471	1,136	8,791
Glass and glass products	179,298	42,463	84,494	22,759	10,839	1,791	16,952
Soap, perfumes, cosmetics	129,760	33,014	39,327	13,614	12,734	13,397	17,675
Electrical apparatus and supplies	125,547	13,140	28,410	59,512	13,851	371	10,263
Paints, varnishes and lacquers	63,551	6,164	5,447	766	45,646	1,869	3,660
Prepared animal feeds	58,514	16,272	4,474	1,221	516	6,727	29,305

Plastic products not elsewhere classified	57,608	4,153	904	297	50,121	867	1,267
Dairy products	47,016	14,512	20,405	3,638	940	47	7,474
Printing, publishing and allied industries	45,795	1,111	1,444	5,562	37,066	15	597
Agricultural machinery and equipment	40,475	17,045	4,638	5,932	10,008	1	2,850
Fabricated metal products	39,697	1,573	3,538	18,066	15,194	66	1,260
Containers and boxes of paper and paperboard	38,870	3,115	22,752	5,277	6,891	126	710
Wearing apparel, except footwear	38,466	21,518	8,104	2,266	5,370	197	1,010
Radio, television and communication equipment	33,778	4,316	2,158	561	26,249	168	327
Canning and preserving of fruits and vegetables	24,963	13,158	6,696	1,285	2,428	90	1,306
Structural metal products	23,188	1,963	8,288	3,318	9,059	131	430
Jewelry and related articles	19,756	9,818	3,286	822	2,685	-	3,146
Pulp, paper and paperboard articles	15,738	5,079	1,553	474	8,513	1	118
Electrical appliances and housewares	14,110	39	291	49	13,702	19	10
Manufacture of motor vehicles	13,770	1,867	942	1,263	8,682	79	938
Electrical industrial machinery and apparatus	13,564	9,121	2,400	375	1,493	5	169
Knitting mills	12,046	4,618	1,910	797	1,552	274	2,894
Wooden and cane containers and small cane ware	9,562	279	205	251	6,439	278	2,109
Textiles not elsewhere classified	8,963	894	370	67	7,100	-	532
Bakery products	6,926	1,068	1,445	254	3,492	21	646
Footwear	4,636	476	56	-	4,076	-	28
Furniture and fixtures primarily of metal	3,982	58	48	19	3,822	-	36
Manufacturing industries not elsewhere classified	3,111	190	92	71	2,710	-	49
Pottery, china and earthenware	2,527	365	183	127	1,422	-	431
Rubber products	2,526	8	31	8	2,457	8	15
Made-up textile goods except wearing apparel	1,676	162	100	23	1,152	-	239
Musical instruments	713	20	149	35	464	13	33
Products of leather except footwear	577	-	30	5	523	-	19
Ship building and repairing	469	72	32	4	266	72	22
Office, computing and accounting machinery	349	21	18	2	298	-	9
Cutlery, hand tools and general hardware	323	33	211	17	53	-	9
Canning, preserving & processing of fish & seafood	195	116	51	4	1	1	22
Scientific equipment	154	27	46	6	67	-	8
Grand Total	128,943,130	39,383,050	23,222,391	16,939,776	10,685,898	18,945,758	19,766,257

Table 5: Emissions of Top 10 and Top 25 enterprises in sectors producing largest quantities of air pollutants

Emissions	Top 3 Industrial Sectors	Contribution of Top 3 Industrial Sectors	% of Top 10 Enterprises	% of Top 25 Enterprises
SO₂	Cement, lime and plaster	48.89	80.87	99.07
	Non-ferrous metal basic industries	13.06	71.16	87.50
	Basic industrial chemicals except fertilizers	6.89	51.04	76.20
NO₂	Cement, lime and plaster	38.49	80.87	99.07
	Structural clay products	14.65	20.37	29.99
	Basic industrial chemicals except fertilizers	8.68	51.04	76.20
CO	Iron and steel basic industries	20.70	49.45	76.99
	Sawmills, planing and other wood mills	15.31	21.09	34.22
	Non-ferrous metal basic industries	14.13	71.16	87.50
VOC	Furniture and fixtures (non-metal)	16.83	18.19	29.62
	Basic industrial chemicals except fertilizers	14.73	51.04	76.20
	Distilling, rectifying and blending spirits	12.76	92.59	100.00
PM₁₀	Cement, lime and plaster	84.50	80.87	99.07
	Iron and steel basic industries	3.28	49.45	76.99
	Structural clay products	2.87	20.37	29.99
TSP	Cement, lime and plaster	47.11	80.87	99.07
	Structural clay products	13.51	20.37	29.99
	Sawmills, planing and other wood mills	7.24	21.09	34.22

Table 6: Toxic Metal Discharges by Industrial Sector (Red: 3 most important; Yellow: 3 next most important)

Industrial Sector	Tox Met Total	Tox Met Air	Tox Met Land	Tox Met Water
Non-ferrous metal basic industries	939,841	27,521	911,772	548
Iron and steel basic industries	494,069	21,297	469,553	3,220
Basic industrial chemicals except fertilizers	229,475	6,823	216,315	6,337
Structural clay products	43,254	1,576	41,566	112
Fertilizers and pesticides	27,124	382	26,676	66
Soft drinks and carbonated waters industries	22,765	71	22,688	7
Electrical apparatus and supplies	16,178	415	15,748	15
Sawmills, planing and other wood mills	14,590	1,020	13,549	21
Non-metallic mineral products	12,885	1,598	11,275	13
Synthetic resins, plastic materials and man-made fibers	8,856	55	8,621	180
Spinning, weaving and finishing textiles	6,297	296	5,981	20
Malt liquors and malt	6,207	19	6,186	2
Cement, lime and plaster	6,168	147	6,021	0
Radio, television and communication equipment	4,763	54	4,698	10
Fabricated metal products	4,503	97	4,372	33
Tire and tube industries	4,478	112	4,361	6
Motorcycles and bicycles	3,777	436	3,168	173
Paints, varnishes and lacquers	3,006	345	2,659	2
Petroleum refineries	2,271	213	1,973	85
Drugs and medicines	2,114	18	2,085	11
Rubber products	2,011	21	1,988	2
Soap, perfumes, cosmetics	1,830	24	1,790	16
Pulp, paper and paperboard	1,692	23	1,146	523
Plastic products	1,362	33	1,259	71
Manufacture of structural metal products	1,357	82	1,257	18
Grain mill products	1,050	40	1,010	-
Furniture and fixtures (non-metal)	887	285	602	-
Vegetable and animal oils and fats	838	3	835	1
Glass and glass products	627	276	351	1
Manufacturing industries not elsewhere classified	602	51	549	2
Wearing apparel, except footwear	582	7	575	-
Jewelry and related articles	563	13	537	13
Pottery, china and earthenware	352	4	348	1
Chemical products not elsewhere classified	348	18	274	57
Electrical appliances and housewares	311	3	308	1
Motor vehicles	285	13	272	0
Pulp, paper and paperboard articles	272	117	150	6

Electrical industrial machinery and apparatus	253	30	219	4
Sugar factories and refineries	134	-	134	-
Food products	111	1	55	55
Wood and cork products	110	10	100	-
Made-up textile goods except wearing apparel	84	21	62	-
Agricultural machinery and equipment	82	9	73	1
Printing, publishing and allied industries	60	1	59	0
Slaughtering, preparing and preserving meat	35	-	2	32
Scientific equipment	33	0	32	0
Cutlery, hand tools and general hardware	32	3	29	0
Furniture and fixtures primarily of metal	30	2	28	0
Textiles not elsewhere classified	28	1	27	0
Knitting mills	27	-	27	-
Office, computing and accounting machinery	23	0	22	0
Prepared animal feeds	20	9	11	-
Ship building and repairing	16	10	7	0
Canning and preserving of fruits and vegetables	12	-	10	2
Musical instruments	12	1	11	-
Wooden and cane containers and small cane ware	6	1	5	-
Dairy products	2	2	-	-
Bakery products	1	0	0	1
Containers and boxes of paper and paperboard	1	-	1	-
Grand Total	1,868,704	63,607	1,793,432	11,665

Table 7: Emissions of Top 10 and Top 25 Enterprises in Sectors Producing Largest Quantities of Toxics Metal

Emissions	Top 3 Industrial Sectors	Contribution of Top 3 Industrial Sectors	% of Top 10 Enterprises	% of Top 25 Enterprises
Toxic Metal Air	Basic industrial chemicals except fertilizers	31.13	51.04	76.20
	Furniture and fixtures (non-metal)	10.25	18.19	29.62
	Non-ferrous metal basic industries	8.98	71.16	87.50
Toxic Metal Land	Basic industrial chemicals except fertilizers	57.65	51.04	76.20
	Non-ferrous metal basic industries	12.69	71.16	87.50
	Iron and steel basic industries	8.56	49.45	76.99
Toxic Metal Water	Basic industrial chemicals except fertilizers	75.05	51.04	76.20
	Iron and steel basic industries	8.69	100.00	100.00
	Non-ferrous metal basic industries	4.75	49.45	76.99

Table 8: Toxic Discharges by Industrial Sector (Red: 3 most important; Yellow: 3 next most important)

Industrial Sector	Tox Total	Tox Air	Tox Land	Tox Water
Basic industrial chemicals except fertilizers	6,863,276	1,378,520	4,788,305	696,451
Non-ferrous metal basic industries	1,467,591	397,773	1,054,368	15,450
Iron and steel basic industries	879,314	124,064	711,154	44,096
Fertilizers and pesticides	547,818	228,038	309,082	10,698
Furniture and fixtures (non-metal)	495,195	453,974	40,899	326
Pulp, paper and paperboard	433,835	241,779	111,443	80,613
Synthetic resins, plastic materials and man-made fibers	379,630	199,582	165,455	14,593
Drugs and medicines	272,452	107,459	160,841	4,152
Non-metallic mineral products	256,716	96,825	159,408	480
Wood and cork products	247,807	226,668	21,117	19
Plastic products not elsewhere classified	182,461	140,493	41,624	343
Structural clay products	159,143	110,304	48,620	219
Soft drinks and carbonated waters industries	148,651	93,136	50,240	5,278
Petroleum refineries	139,145	26,204	110,964	1,976
Paints, varnishes and lacquers	138,432	40,689	97,637	106
Sawmills, planing and other wood mills	131,570	99,751	31,340	479
Tobacco manufactures	91,699	82,918	8,217	563
Radio, television and communication equipment	89,982	47,087	42,479	416
Spinning, weaving and finishing textiles	87,495	35,872	33,342	18,280
Soap, perfumes, cosmetics	68,300	25,230	42,707	363
Chemical products not elsewhere classified	50,589	34,085	15,483	1,021
Vegetable and animal oils and fats	50,034	6,982	40,794	2,258
Motorcycles and bicycles	48,093	22,572	16,384	9,136
Electrical apparatus and supplies	43,128	13,937	28,844	347
Malt liquors and malt	40,529	25,393	13,698	1,439
Sugar factories and refineries	39,109	6,736	32,185	188
Dairy products	31,632	3,191	26,142	2,298
Food products not elsewhere classified	29,215	8,870	19,286	1,058
Fabricated metal products	27,018	11,982	14,635	402
Pulp, paper and paperboard articles	24,281	19,333	4,874	73
Cement, lime and plaster	22,574	4,182	11,933	6,459
Printing, publishing and allied industries	20,158	17,759	2,399	1
Rubber products not elsewhere classified	15,539	11,241	4,295	3
Footwear	14,745	14,320	423	2
Wearing apparel, except footwear	11,935	8,659	3,264	-

Jewelry and related articles	10,354	7,095	2,554	704
Knitting mills	9,082	2,979	5,829	275
Structural metal products	8,754	3,681	4,148	925
Slaughtering, preparing and preserving meat	8,681	4,166	3,891	624
Containers and boxes of paper and paperboard	8,063	6,731	1,230	102
Tire and tube industries	7,924	2,884	4,980	60
Textiles not elsewhere classified	7,697	6,281	1,415	1
Distilling, rectifying and blending spirits	6,668	147	1,523	4,998
Electrical appliances and housewares	6,329	4,006	2,322	1
Canning and preserving of fruits and vegetables	5,517	1,155	4,038	325
Grain mill products	5,368	3,775	1,595	-
Manufacturing industries not elsewhere classified	4,825	3,295	1,502	27
Glass and glass products	4,586	2,659	1,711	216
Motor vehicles	4,345	2,982	1,348	15
Made-up textile goods except wearing apparel	2,631	2,225	375	30
Agricultural machinery and equipment	2,178	1,659	458	62
Electrical industrial machinery and apparatus	1,822	1,215	601	6
Wooden and cane containers and small cane ware	1,760	1,614	144	1
Pottery, china and earthenware	1,487	564	922	1
Furniture and fixtures primarily of metal	1,220	806	412	2
Prepared animal feeds	1,064	444	583	38
Scientific equipment	900	604	295	2
Office, computing and accounting machinery	707	522	185	0
Ship building and repairing	483	422	61	0
Bakery products	443	175	262	6
Musical instruments	340	194	146	-
Cutlery, hand tools and general hardware	230	148	81	1
Products of leather and leather substitutes	159	150	9	-
Canning, preserving and processing of fish and seafood	16	8	9	-
Grand Total	13,662,723	4,428,193	8,306,514	928,006

Table 9: Discharges of Water Pollutants by Industrial Sector (Red: 3 most important; Yellow: 3 next most important)

Industrial Sector	Total	BOD	TSS
Iron and steel basic industries	24,525,054	1,665	24,523,390
Non-ferrous metal basic industries	6,095,665	394,412	5,701,254
Pulp, paper and paperboard	4,030,024	916,669	3,113,355
Basic industrial chemicals except fertilizers	2,362,964	928,223	1,434,741
Distilling, rectifying and blending spirits	1,557,096	556,636	1,000,459
Jewelry and related articles	1,274,119	-	1,274,119
Drugs and medicines	1,138,405	4,523	1,133,883
Dairy products	935,245	817,496	117,749
Manufacture of fertilizers and pesticides	846,738	4,329	842,409
Sugar factories and refineries	631,133	259,324	371,810
Cement, lime and plaster	387,305	177	387,129
Sawmills, planing and other wood mills	251,416	43,989	207,427
Soft drinks and carbonated waters industries	81,142	24,504	56,638
Petroleum refineries	41,067	6,823	34,244
Plastic products not elsewhere classified	39,235	38,405	830
Synthetic resins, plastic materials and man-made fibers	31,421	7,426	23,995
Spinning, weaving and finishing textiles	25,619	10,035	15,584
Food products not elsewhere classified	24,939	9,852	15,088
Malt liquors and malt	22,123	6,681	15,442
Rubber products not elsewhere classified	20,969	4	20,965
Soap, perfumes, cosmetics	18,435	7,642	10,793
Vegetable and animal oils and fats	16,133	7,575	8,558
Canning and preserving of fruits and vegetables	13,854	5,375	8,479
Non-metallic mineral products not elsewhere	13,392	5,428	7,963
Fabricated metal products	7,813	262	7,551
Radio, television and communication equipment	6,207	2,604	3,603
Slaughtering, preparing and preserving meat	6,196	2,766	3,430
Footwear	6,041	3,050	2,991
Pulp, paper and paperboard articles	5,748	2,894	2,854
Containers and boxes of paper and paperboard	3,509	1,292	2,218
Motorcycles and bicycles	2,824	407	2,417
Structural clay products	1,217	65	1,153
Canning, preserving and processing of fish and seafood	1,042	385	657
Tobacco manufactures	1,039	468	571
Chemical products not elsewhere classified	532	218	314
Printing, publishing and allied industries	270	175	96
Tire and tube industries	198	0	197
Pottery, china and earthenware	192	55	137
Glass and glass products	149	18	130
Knitting mills	117	39	78

Electrical apparatus and supplies	86	12	74
Grain mill products	85	6	79
Wooden and cane containers and small cane ware	70	25	45
Prepared animal feeds	62	25	37
Structural metal products	38	16	22
Paints, varnishes and lacquers	33	6	27
Agricultural machinery and equipment	33	-	33
Electrical industrial machinery and apparatus	19	3	16
Bakery products	12	7	4
Motor vehicles	9	2	8
Furniture and fixtures (non-metal)	9	1	8
Manufacturing industries not elsewhere classified	4	1	3
Textiles not elsewhere classified	4	-	4
Scientific equipment	3	1	2
Office, computing and accounting machinery	3	0	3
Products of leather and leather substitutes	2	-	2
Furniture and fixtures primarily of metal	1	-	1
Ship building and repairing	0	0	0
Cutlery, hand tools and general hardware	0	-	0
Grand Total	44,427,062	4,071,995	40,355,067

Table 10: Emissions of Top 10 and Top 25 Enterprises in Sectors Producing Largest Quantities of Water Pollutants

Emissions	Top 3 Industrial Sectors	Contribution of Top 3 Industrial Sectors	% of Top 10 Enterprises	% of Top 25 Enterprises
BOD	Basic industrial chemicals except fertilizers	22.80	51.04	76.20
	Pulp, paper and paperboard	22.51	100.00	100.00
	Dairy products	20.08	24.82	40.28
TSS	Iron and steel basic industries	60.77	49.45	76.99
	Non-ferrous metal basic industries	14.13	71.16	87.50
	Pulp, paper and paperboard	7.71	100.00	100.00

Table 11: Discharges of Air Pollutants by Provinces (Red: 3 most important; Yellow: 3 next most important)

Province	Total	SO2	NO2	CO	VOC	PM10	TSP
Vientiane Capital	27,286,952	8,777,674	4,794,203	4,203,137	3,540,564	2,771,821	3,199,553
Khammuane	26,928,302	9,712,077	3,836,315	2,480,003	1,221,152	5,571,175	4,107,580
Vientiane	21,705,116	7,392,212	3,629,528	1,164,199	605,094	5,468,304	3,445,780
Savannakhet	11,371,080	3,342,024	2,170,728	2,024,513	1,043,609	967,373	1,822,834
Luangprabang	9,994,710	3,242,511	1,880,300	580,345	253,771	2,277,730	1,760,055
Huaphanh	5,381,945	1,449,115	1,219,401	1,470,003	501,979	143,182	598,266
Borikhamxay	5,064,339	968,174	1,090,906	1,232,735	661,388	250,215	860,920
Saravane	4,759,331	1,331,554	830,015	577,481	419,978	813,503	786,801
Bokeo	3,531,159	889,108	865,931	775,629	460,273	106,353	433,864
Xayabury	3,412,827	584,291	477,053	736,347	849,874	145,928	619,334
Champasack	2,731,869	572,172	838,634	269,516	188,381	175,441	687,725
Xiengkhuang	2,298,269	369,747	519,061	505,111	358,892	94,376	451,082
Attapeu	1,777,478	397,905	396,681	348,861	250,096	33,130	350,804
Sekong	1,015,331	79,072	223,432	250,385	147,276	42,458	272,709
Oudomxay	863,661	124,571	180,868	209,173	124,265	38,849	185,935
Luangnamtha	595,171	128,109	195,998	85,722	32,567	32,725	120,051
Phongsaly	225,588	22,733	73,338	26,616	26,742	13,197	62,963
Grand Total	28,943,130	39,383,050	23,222,391	16,939,776	10,685,898	18,945,758	19,766,257

Figure 15: Provincial Share of Industrial Air Pollution

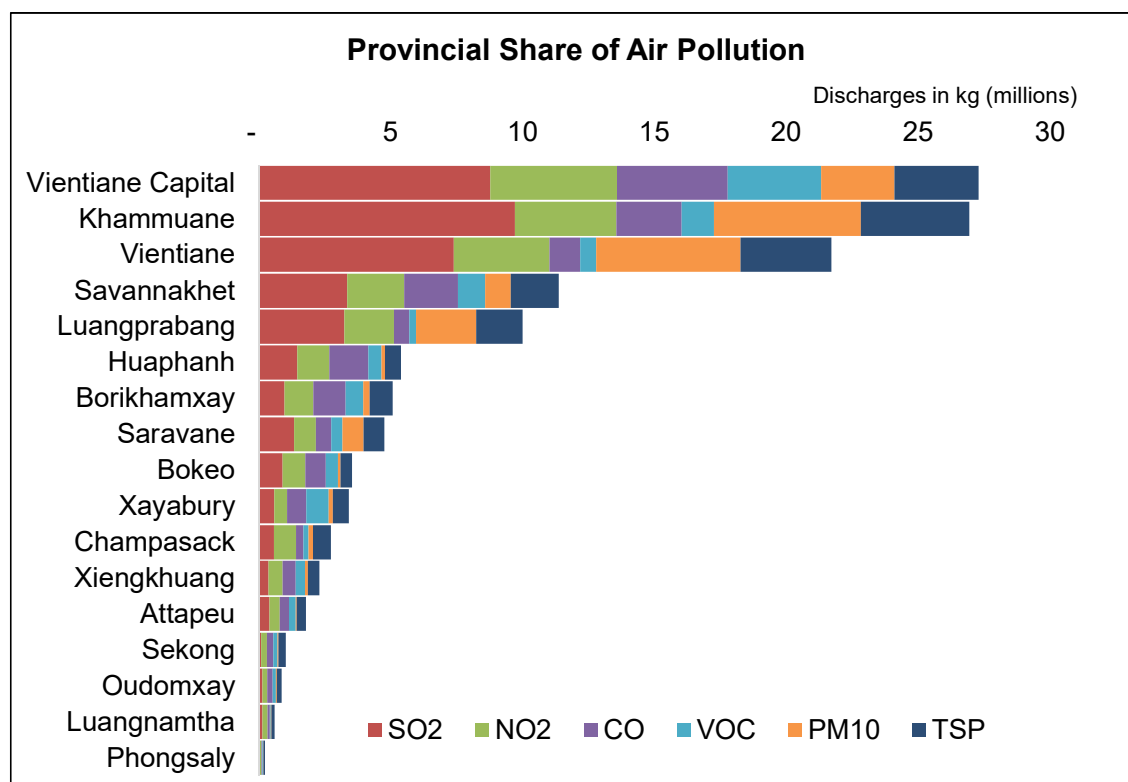


Table 12: Discharges of Toxic Metal Pollutants by Provinces (Red: 3 most important; Yellow: 3 next most important)

Provinces	Total Toxic Metal	Toxic Metal - Air	Toxic Metal - Land	Toxic Metal - Water
Vientiane Capital	665,929	24,324	638,181	3,424
Khammuane	507,688	15,206	491,150	1,332
Savannakhet	258,142	8,579	247,438	2,125
Borikhamxay	101,905	4,163	96,745	997
Vientiane	64,453	2,194	61,380	880
Huaphanh	50,019	1,550	47,211	1,258
Luangprabang	49,807	1,636	47,993	178
Champasack	41,851	1,318	40,375	157
Xiengkhuang	39,229	1,527	37,558	144
Bokeo	34,384	973	33,111	300
Saravane	27,408	886	25,827	695
Luangnamtha	9,609	379	9,174	56
Xayabury	8,026	402	7,543	81
Oudomxay	4,352	191	4,134	27
Sekong	4,201	179	4,015	7
Phongsaly	929	40	885	4
Attapeu	771	59	712	1
Grand Total	1,868,704	63,607	1,793,432	11,665

Figure 16: Provincial Share of Industrial Toxic Metal Pollution

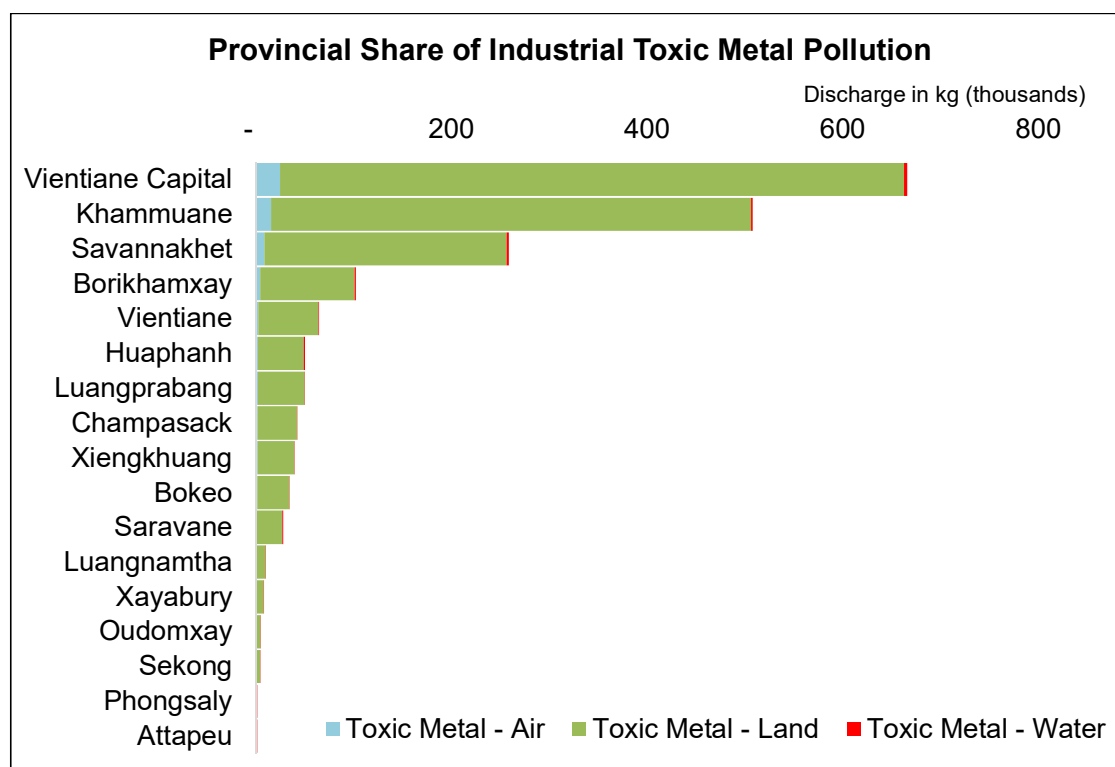


Table 13: Discharges of Toxic Pollutants by Provinces (Red: 3 most important; Yellow: 3 next most important)

Provinces	Total Toxic	Toxic - Air	Toxic - Land	Toxic - Water
Vientiane Capital	3,528,324	1,284,277	2,066,550	177,487
Savannakhet	2,417,202	638,271	1,600,035	178,897
Khammuane	2,104,903	646,657	1,339,666	118,579
Huaphanh	1,341,828	373,110	817,426	151,292
Vientiane	1,025,899	277,927	663,889	84,083
Borikhamxay	871,688	270,978	538,950	61,760
Saravane	785,287	181,611	527,648	76,029
Bokeo	486,364	248,495	203,444	34,425
Champasack	297,661	111,935	174,770	10,956
Luangprabang	282,345	114,895	152,410	15,040
Xayabury	198,523	102,100	84,926	11,497
Xiengkhuang	120,110	54,020	61,416	4,675
Attapeu	62,352	43,642	18,593	117
Luangnamtha	48,601	21,977	24,891	1,734
Oudomxay	44,551	25,215	18,215	1,121
Sekong	40,816	29,398	11,206	212
Phongsaly	6,269	3,686	2,480	103
Grand Total	13,662,723	4,428,193	8,306,514	928,006

Figure 17: Provincial Share of Industrial Toxic Pollution

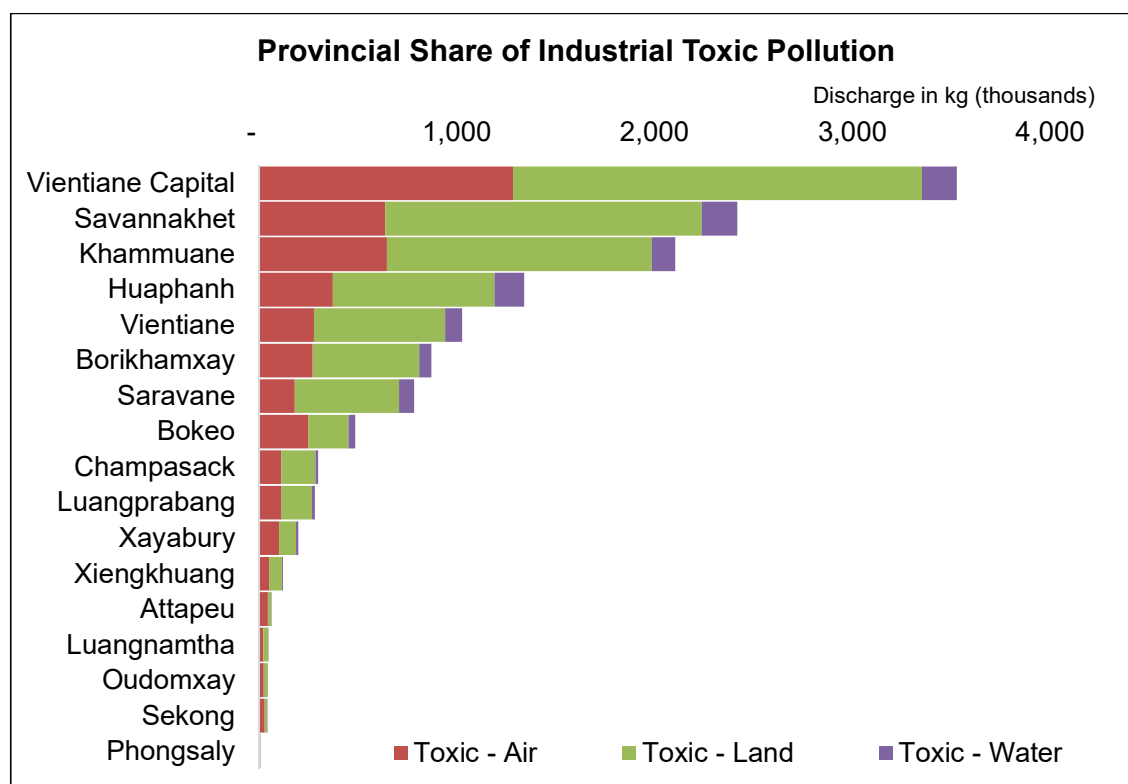


Table 14: Discharges of Water Pollutants by Provinces (Red: 3 most important; Yellow: 3 next most important)

Provinces	Total	BOD	TSS
Vientiane Capital	20,144,615	1,113,979	19,030,636
Savannakhet	5,939,850	542,424	5,397,426
Khammuane	4,290,519	388,940	3,901,579
Borikhamxay	4,103,007	91,575	4,011,432
Huaphanh	2,417,045	615,785	1,801,260
Vientiane	1,493,193	184,920	1,308,273
Bokeo	1,429,571	296,852	1,132,718
Xiengkhuang	1,211,257	69,969	1,141,288
Champasack	906,300	168,803	737,497
Xayabury	679,362	236,774	442,588
Luangprabang	616,885	49,958	566,927
Luangnamtha	430,710	17,349	413,361
Saravane	360,395	119,633	240,761
Attapeu	282,896	113,512	169,384
Sekong	84,239	47,948	36,291
Phongsaly	21,462	9,542	11,920
Oudomxay	15,757	4,031	11,726
Grand Total	44,427,062	4,071,995	40,355,067

Figure 18: Provincial Share of Industrial Water Pollution

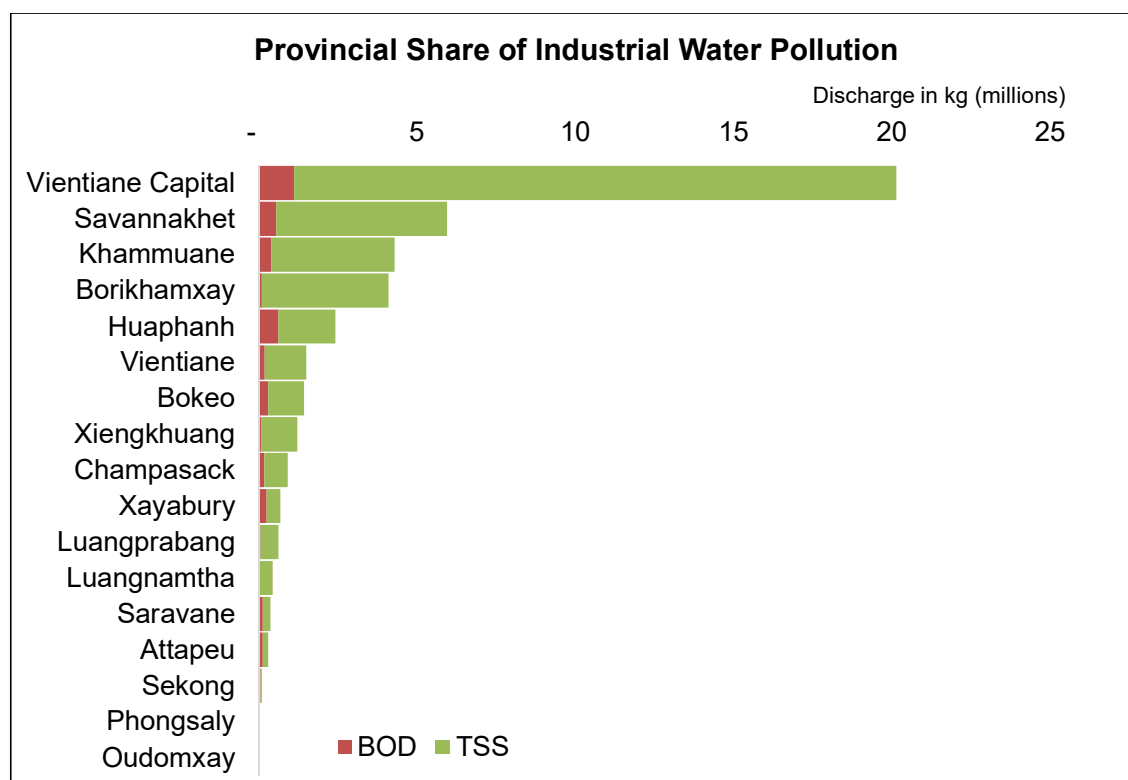


Figure 19: Map Distribution of Industrial Air Pollution by Province

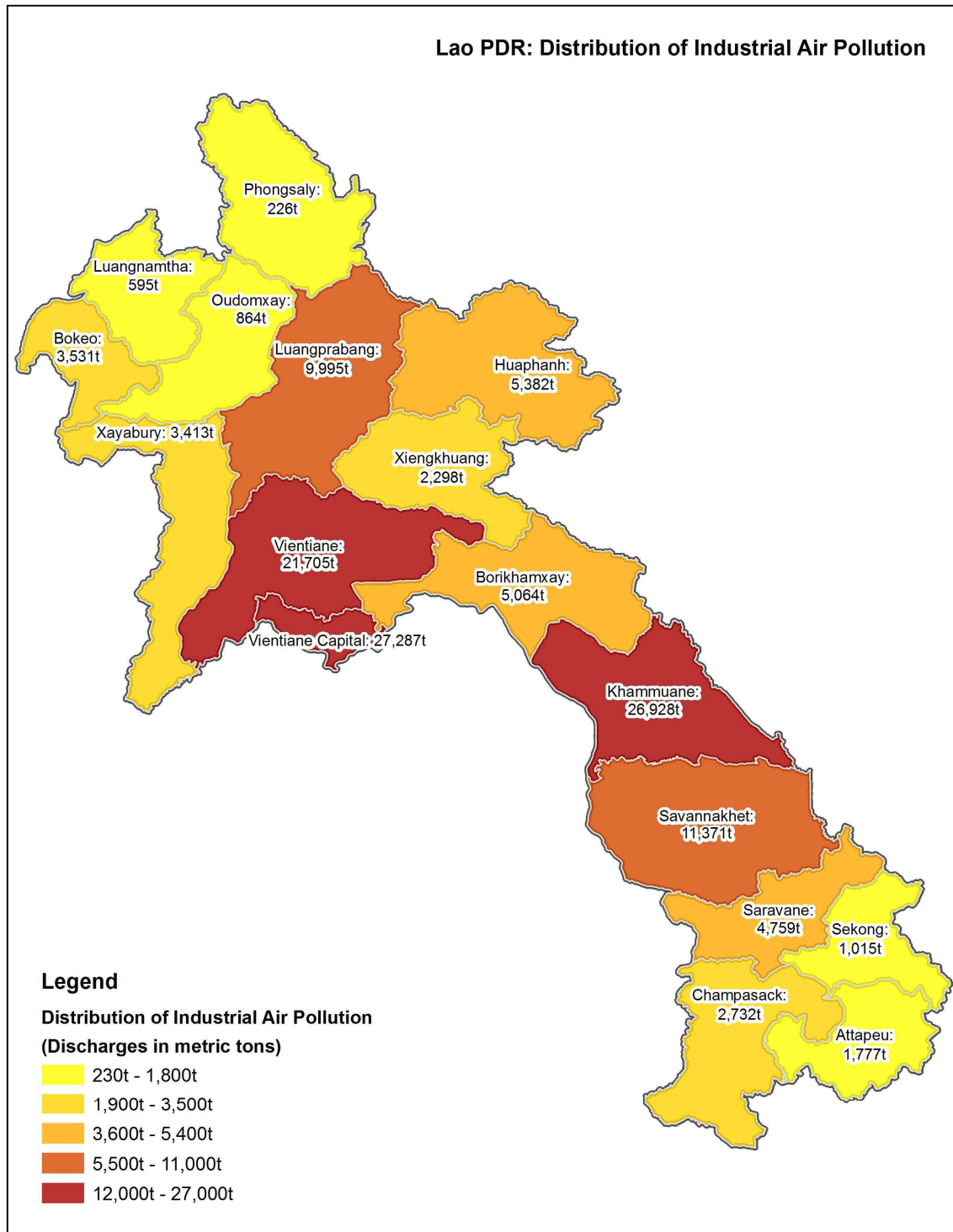


Figure 20: Map Distribution of Industrial Toxic Metal Pollution by Province

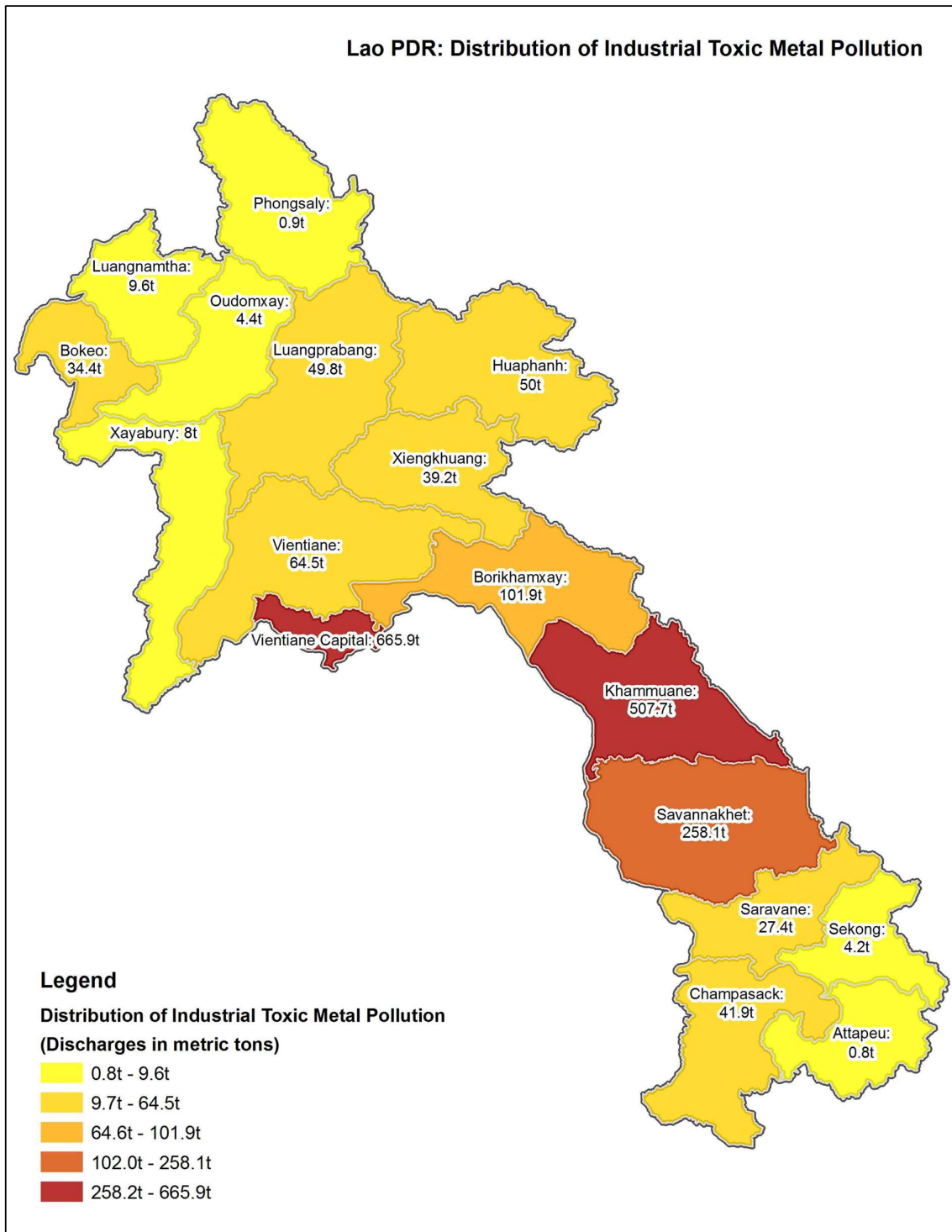


Figure 21: Map Distribution of Industrial Toxic Pollution by Province

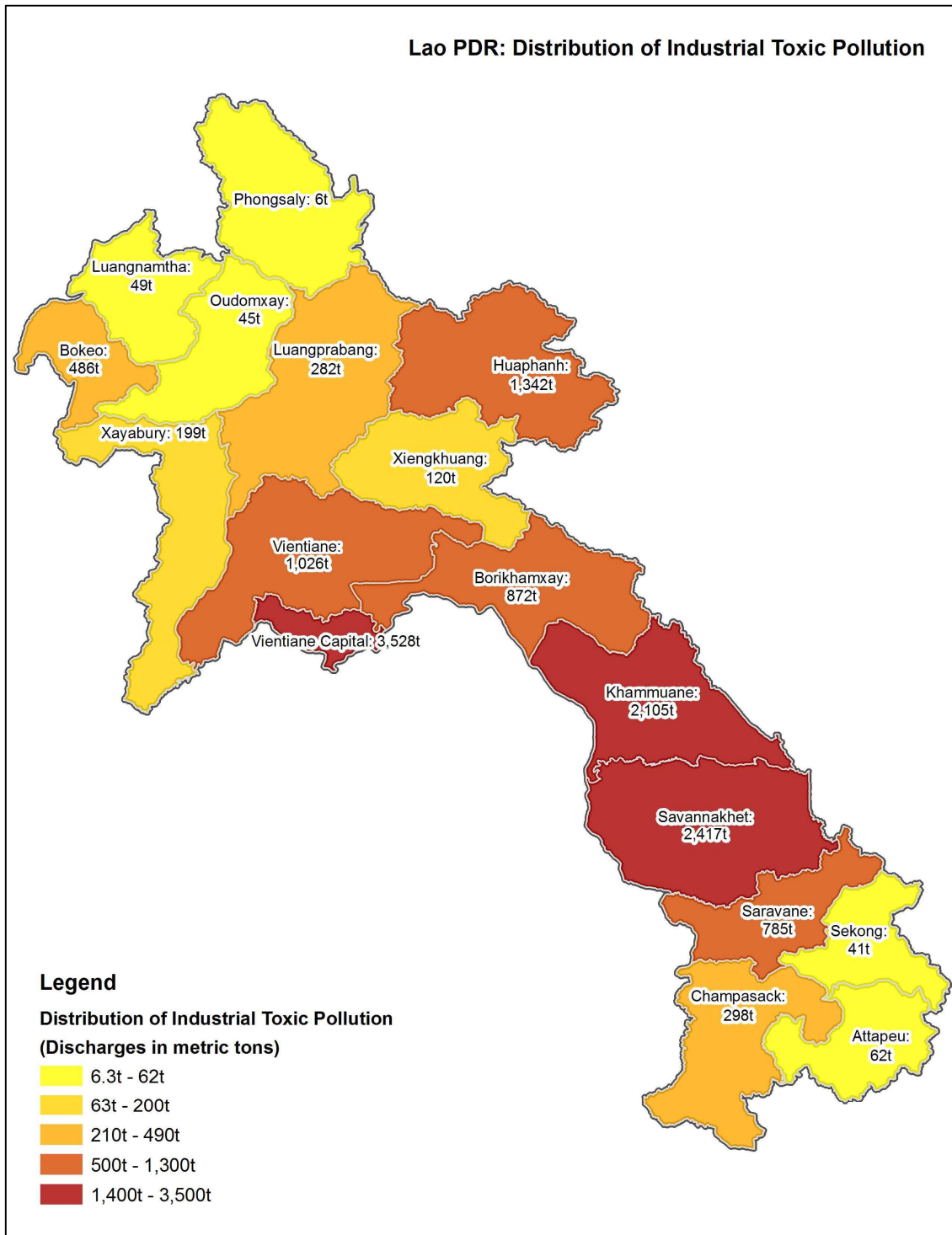


Figure 22: Map Distribution of Industrial Water Pollution by Province

