

The Impact of the Transport Sector on PM Levels in Hyderabad, India

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Résumé

Avec près de 7 millions d'habitants, Hyderabad est la cinquième plus large agglomération d'Inde et l'une des plus polluées de sa région. Afin d'améliorer la qualité de l'air et d'encourager le développement d'une gestion locale de cette problématique, plusieurs séries de mesures de PM₁₀ et PM_{2.5} ainsi que des études de répartition des sources ont été réalisées en novembre/décembre 2005, mai/juin 2006, et octobre/novembre 2006. Au cours de ce programme, des filtres ont entre autres été prélevés toutes les 24 heures pour l'analyse du PM₁₀ et PM_{2.5} sur trois sites permettant de retracer les niveaux de fond, l'impact des sources mobiles et l'exposition dans les zones résidentielles. La masse, le contenu ionique, les métaux traces, le carbone élémentaire et organique ont été analysés dans les échantillons collectés. Un modèle de bilan de masse chimique (CMB – chemical mass balance) a ensuite permis d'estimer la nature et l'importance des sources responsables des niveaux élevés de PM. En moyenne, les émissions directes par les véhicules ont représenté approximativement 50% des masses de PM₁₀ et PM_{2.5} observées. Des contributions significatives des sols (principalement des routes où les poussières sont remobilisées par la circulation), des feux agricoles où de biomasses, des polluants secondaires (sulfate d'ammonium ou nitrate) ont également été identifiées. Ces résultats de répartition des sources sont enfin accompagnés par des propositions visant à diminuer l'impact négatif du secteur des transports sur la qualité de l'air.

Mots-clefs : *répartition des sources, suivi de la qualité de l'air, gestion de la qualité de l'air*

1. Introduction

Hyderabad is the state capital of Andhra Pradesh, India, on the Deccan Plateau covering ~625 Sq. km, at 541 meters above sea level. It is the fifth largest city in India, with a population nearing 7 million and is the fastest growing city in India (9 percent growth per year). Hyderabad has a population density of ~17,000 persons per sq. km and is a major high-tech center that is undergoing a rapid rate of urbanization coupled with increased economic activity. This boom has encouraged immigration on a massive scale, which has led to an increase of personal, public, and para (3 and 6 seater) transit vehicles (~600 new vehicles added to the fleet per day), and an increasing burden on the city's infrastructure. The increase in motorization and industrial emissions has resulted in declining ambient air quality and a growing incidence of morbidity and mortality attributable to air pollution (HEI, 2004, APPCB, 2006, and IES, 2007).

In light of these air quality impacts, in August 2003, the Supreme Court of India directed various state governments including Andhra Pradesh in which Hyderabad is located to prepare action plans for lowering the levels of air pollution in their cities and submit the plans before the Environmental Pollution (Prevention and Control) Authority. One of the action points of the directive was to conduct particulate pollution source apportionment studies. In Hyderabad, the Andhra Pradesh Pollution Control Board (APPCB) sponsored and conducted a source apportionment study for a period of one year, coupled with an estimation of primary emissions and their impacts on human health to support the action plan submitted to the Government of India. In this paper we present the results of the source apportionment study for PM₁₀ and PM_{2.5}. We also present a number of recommended options that can be implemented to improve air quality in Hyderabad.

2. Air Quality in Hyderabad

The APCCB operates 20 monitoring stations in Hyderabad oriented in a circular grid with Punjagutta station as the center (Figure 1). Since 2004, the average urban PM₁₀ has increased 25 percent, from 92 to 116 $\mu\text{g}/\text{m}^3$, with hot spots around transport and industrial junctions as high as 200 $\mu\text{g}/\text{m}^3$. The large increase in the observed concentrations is attributed to growing vehicular activity in the city. The in-use vehicular population grew from 1.45 million vehicles in 2001 to 2.0 million vehicles in 2007. The divide between the petrol and diesel based vehicles is closing, with diesel fueled vehicles increasing at double the growth rate of petrol fueled vehicles. A lack of infrastructure to manage this increase is leading to congestion problems and consequently lesser fuel efficiency and higher emissions – directly from vehicles and indirectly due to the resuspension of fugitive dust on roads.

In 1999, an ordinance was passed to replace petrol based 3-wheelers with liquefied petroleum fuel (LPG), which resulted in a significant reduction in the PM pollution over the period of four years, decreasing from 128 $\mu\text{g}/\text{m}^3$ in 1999 to 83 $\mu\text{g}/\text{m}^3$ in 2002. However, recently a much higher growth rate in the passenger cars (petrol and diesel) has nullified the impact of this conversion. Currently, 40 percent of the 3-wheeler fleet is LPG based and city authorities expect 100 percent LPG conversion by 2010.

3. Methodology

In order to determine the sources of elevated PM in Hyderabad, a one year source apportionment study was conducted and covered three seasons between November 2005 and December 2006. Phase 1 (November 12th 2005 to December 1st 2005) was classified as the winter season, Phase 2 (May 9th to June 9th 2006) as the summer season, and Phase 3 (October 27th to November 18th 2006) as the rainy season. Sampling locations, methodologies, and receptor modeling results are briefly presented in the sections that follow. Additional details are contained in IES (2007).

3.1. Sampling Sites

Three sampling sites presented in Figure 1 were selected for this study.

- **Punjagutta (PG)** is an urban residential/commercial/transport site. This location is also a major transit point in the center of the city to major residential areas and industrial development areas in the north.
- **Chikkadpally (CKP)** is an urban residential/commercial site with significant traffic to the east. Sampling site is close to the road and is lined on either side with shops and commercial enterprises, small scale industries using coal and oil, and constant traffic because of its proximity to twenty cinemas.
- **Hyderabad Central University (HCU)** is a background upwind sampling location, 20 km from the city center and on the old Hyderabad-Mumbai highway. It stretches over 2300 acres of land, with a sprawling, scenic and serene campus.

3.2. Sampling and Analytical Methods

Aerosol samples were collected using twelve Airmetrics MiniVolTM portable air samplers operating at 5 liters per minute for 24 hour sampling periods. Pairs of Teflon/quartz fiber filters were used to collect aerosol samples for PM₁₀ and PM_{2.5} (total four samples per site) every two days.

Samples were subjected to mass measurements using a gravimetric method, ion chromatography for chloride, nitrate, and sulfate ions, colorimetry for ammonium, atomic absorption for Na, K, Ca, and Mg metals, X-ray fluorescence for the rest of the metals, and thermal optical reflectance for organic and elemental carbon.

Receptor Modeling Methodology

Chemical analysis of the samples was followed by receptor modeling using the Chemical Mass Balance (CMB) model version 8.2 (Watson et al., 1997 and Coulter, 2004). The CMB 8.2 model is a Windows-based and includes menu-driven operation, requires speciated profiles of potentially

contributing sources and the corresponding ambient data from analyzed samples collected at a single receptor site. In Hyderabad, no sampling was conducted for developing local specific source profiles. In the absence of local source profiles, profiles from the DRI profile library were selected. Although several profiles for each source type were modeled, only those that provided reasonable statistics for all three sites and both size fractions were retained.

4. Results and Discussion

4.1. Mass

The mass concentrations of PM from the three sampling periods are summarized in Table 1. Punjagutta had the highest average for PM₁₀ (160 µg/m³) as well as PM_{2.5} (86 µg/m³). The PM₁₀ concentrations exceeded the Indian ambient air quality standards prescribed for commercial and residential areas (100 µg/m³) during most intensive measurement periods. HCU also exceeded the standards prescribed for sensitive locations (60 µg/m³). The higher PM concentrations are generally attributed to vehicles and resuspended dust, especially for the traffic junctions of Punjagutta and Chikkadpally.

The mass concentrations were higher in the winter and the summer seasons. The concentrations in the summer season were initially high followed by a sudden drop at the end of the sampling period due to an early onset of monsoon rains. In the rainy season, there is a progressive increase of the ambient concentrations at the end of the sampling period, attributed to the gradual change in season from rainy to winter. The ratio of PM_{2.5}/PM₁₀ is high at 50 percent in winter compared to 40 percent in the summer and rainy seasons. Poor dispersion in the winter season followed by inversions and photochemical smog are the primary reasons for the increase in fine fractions in winter season.

4.2. Source Apportionment

The sources of the sampled PM were determined using the CMB model following the analysis of the collected filter samples. A summary of the CMB results is presented in Table 2 for PM₁₀ and PM_{2.5}. The results indicate that, on average, more than half of all the observed PM in Hyderabad can be attributed to vehicular activity (vehicles + road dust).

The results presented in Table 2 are an average of the three stations, along with an average for all sampling sites. Complete results are contained in IES (2007). The most important source measured throughout the sampling campaign was mobile sources, varying from 38 percent to 58 percent for PM₁₀, and 38 percent to 68 percent for PM_{2.5}. The fugitive dust (included soil dust, wear and tear from tires, and construction dust) is the second largest source of PM₁₀, varying between 19 percent and 44 percent, and between 5 percent and 26 percent in PM_{2.5}. Biomass burning and ammonium sulfate also contributed significantly at the three sites, with ammonium nitrate always present at approximately 2 to 5 percent. Coal combustion varied between 0 percent and 36 percent, showing large uncertainties and incidences of long range transport of industrial sources outside the city center. This is also attributed to local coal combustion sources such as cooking at Chikkadpally and Punjagutta. Note, this source is minimal at HCU. PM_{2.5}.

Figure 2 presents the seasonal results for one site, Chikkadpally. The largest contributor to the observed PM₁₀ was mobile sources, with contributions ranging from 41 to 49%. Road dust was also a major source, comprising 29 to 41% of the PM₁₀. It is interesting to note that road dust made up 35% of the total during the rainy season, this result in terms of absolute mass was the lowest for all periods. In terms of PM_{2.5}, vehicles remained the largest contributor, with a reduced contribution from road dust. The summer season exhibited a large increase in the contribution from coal combustion, indicative of long range transport of industrial emissions.

The three sites had similar trends in the variability of the source apportionment results. Results of the winter PM₁₀ apportionments for the three sites are shown in Figure 3. As with the averages presented in Table 2, vehicles were the largest contributor (49 to 58%), followed by road dust (19 to 30%). The contribution from coal combustion did not appear for HCU during the winter. As seen in Figure 1, this site is not near the major local industrial areas, which would minimize the impact from

this source. For PM_{2.5}, mobile sources are still the dominant contributor; however, the impact of coal combustion and secondary species, along with the decrease in the contribution from road dust is observed.

5. Recommendations

Based on the results of the source apportionment study, the majority of both PM₁₀ and PM_{2.5} is due to mobile source activity (tailpipe emissions + resuspended road dust). Thus in order to improve ambient air quality, most of the efforts need to be directed at controlling vehicular emissions. Recommended strategies include:

- Conversion of buses and auto rickshaws from diesel to alternate fuels (natural gas, biodiesel). Currently ~45% of the auto rickshaws have been converted to natural gas.
- Increase public transport use from 40% to 60%. This would require a 30% increase in the number of buses plus the implementation of a light rail system.
- Introduce new emissions standards for cars.
- Vehicle inspection and registration program to facilitate compliance with emissions standards.
- Phasing out old vehicles (>15 yrs.), particularly heavy goods carriers.
- Improve road maintenance and traffic management. This would include street sweeping, making sure all lanes are available for traffic, improving traffic flow, and building more flyovers to reduce congestion at intersections.

6. Conclusion

In order to address the issue of elevated pollutant levels in Hyderabad, India, a series of intensive monitoring campaigns were undertaken over a one year period in 2005-2006 at three locations (residential/commercial, mobile source dominated and upwind/background). PM₁₀ and PM_{2.5} filter samples were collected using low-volume samplers on a 24-hour basis. The collected samples were analyzed for mass, ions, trace metals, and organic and elemental carbon and the chemical mass balance (CMB) receptor model was used to determine the nature and magnitude of the sources contributing to the elevated levels of PM. All sampling locations exhibited elevated levels of both PM₁₀ and PM_{2.5}, with a maximum of 160 µg/m³ PM₁₀ and 86 µg/m³ PM_{2.5}, both at Punjagutta. Motor vehicles were the major source of the observed PM, contributing approximately 50% to both PM₁₀ and PM_{2.5}. The next greatest source was resuspended soil. Much of this is likely to originate from re-entrainment of paved and unpaved road dust by motor vehicles. Other major contributors include industrial emissions, biomass and agricultural burning, and secondary pollutants (ammonium sulfate and nitrate). Based on this work, we can find that residents of Hyderabad are exposed to unhealthy levels of PM, with motor vehicles being the major source of the problem.

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Table 1: Measured Mass concentrations of PM₁₀ and PM_{2.5} during the sampling period.

S.No	Station name	PM ₁₀ (µg/m ³)			PM _{2.5} (µg/m ³)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Ph asc 1 (Summer)	Punjagutta	188	127	160	99	69	86
	Chikkadpally	163	110	134	84	57	69
	HCU	123	94	106	71	46	56
Ph asc 2 (Winter)	Punjagutta	218	28	111	87	13	47
	Chikkadpally	261	45	113	111	16	43
	HCU	105	14	64	75	6	26
Ph asc 3 (Rainy)	Punjagutta	193	56	122	136	36	66
	Chikkadpally	130	34	86	121	23	54
	HCU	100	23	59	61	15	40

Table 2: Contribution of various sources by location.

	PM10				PM2.5			
	Punjagutta	Chikkadpally	HCU	Average	Punjagutta	Chikkadpally	HCU	Average
Vehicles	54%	46%	44%	48%	49%	48%	51%	49%
Road Dust	27%	36%	37%	33%	8%	9%	16%	11%
Industries	7%	8%	2%	6%	23%	21%	5%	16%
Biomass Burning	5%	4%	5%	5%	8%	8%	8%	8%
Secondary PM	7%	7%	12%	9%	12%	14%	20%	15%

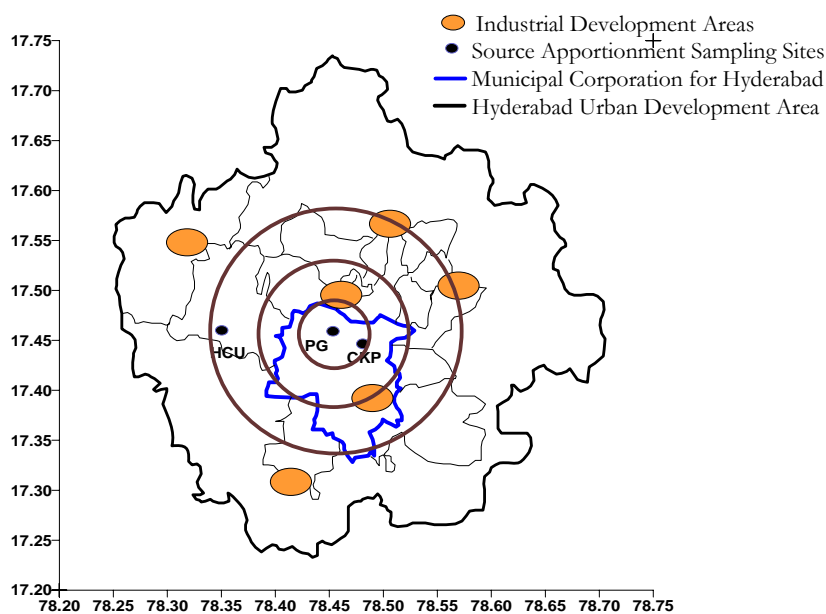


Figure 1: Geographical location of Hyderabad Urban Development Area (HUDA) and major industrial development areas (IDAs). Monitoring sites for the source apportionment study were located at Hyderabad Central University (HCU), Punjagutta (PG), and Chikkadpally (CKP).

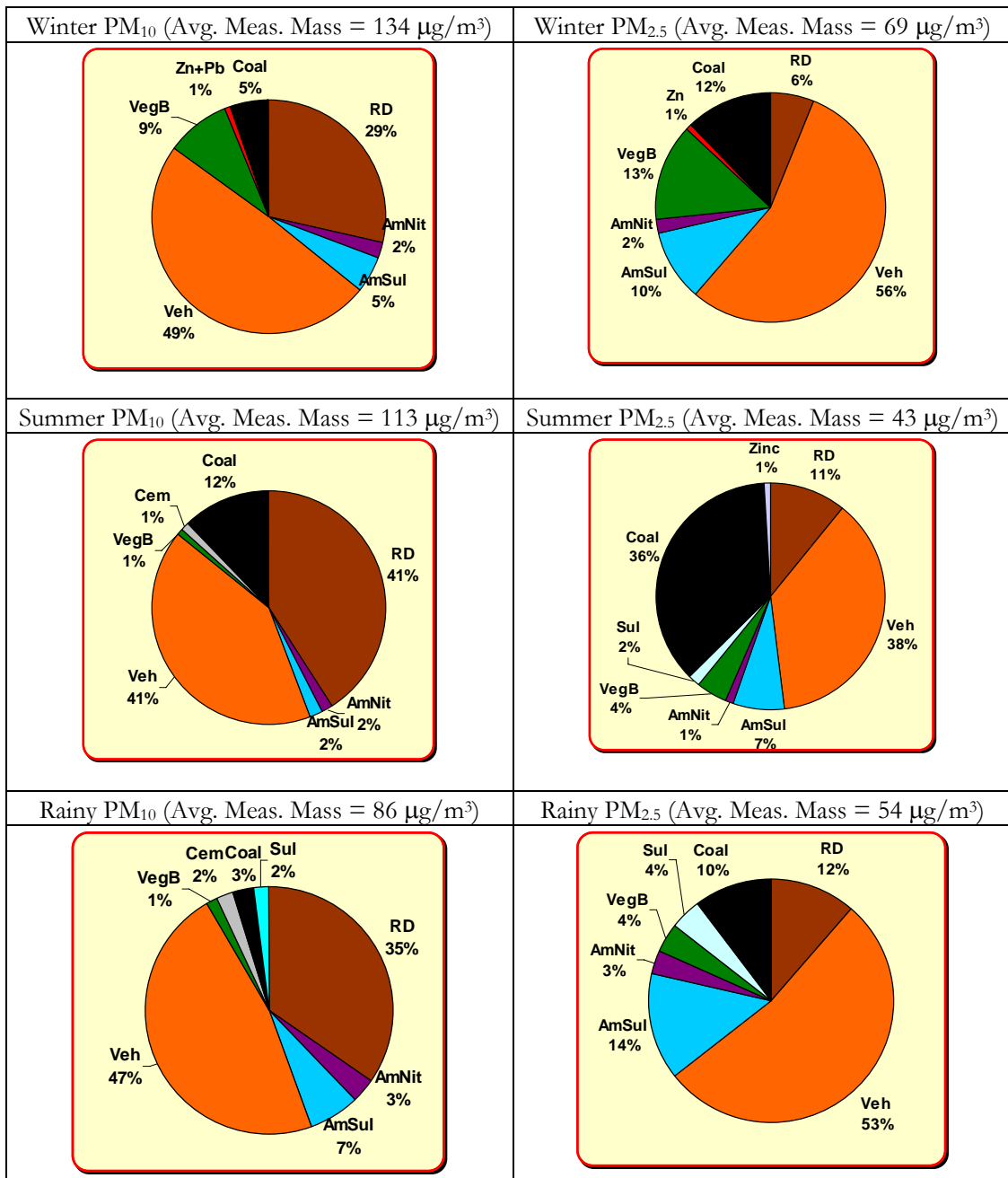


Figure 2: Source apportionment results for three intensive measurement periods at Chikkadpally.

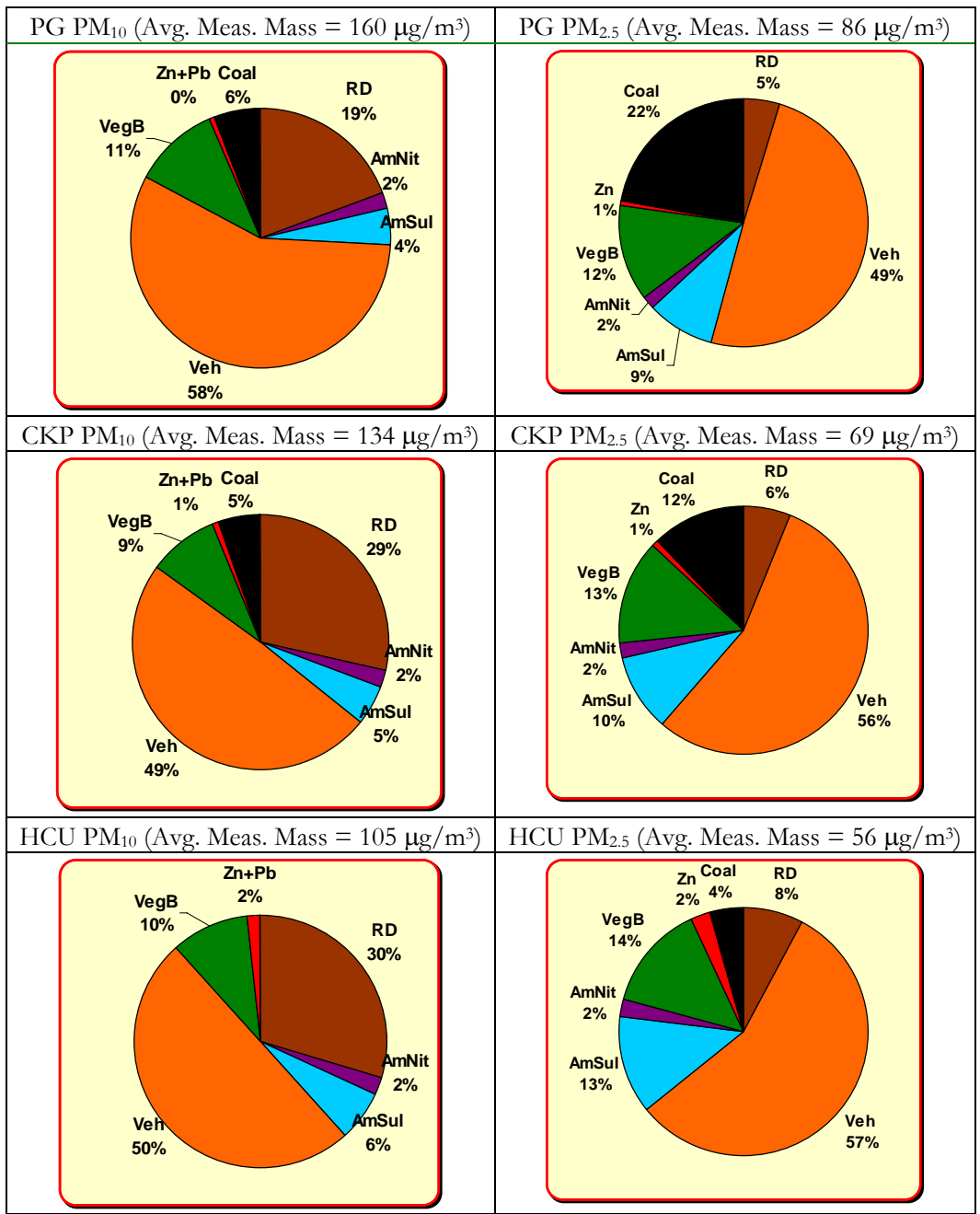


Figure 3: Source apportionment results for the winter intensive measurement periods for the three monitoring locations.