Of the three different pollutants, the variations in the EF of $PM_{2.5}$ were the most prominent. There are various reasons behind this apparent inconsistency in the emission data proffered by earlier studies conducted in different countries. They may include fuel composition; design and age of engine; manufacturing company; operating conditions; maintenance pattern; road conditions; traffic conditions; and environmental conditions (such as temperature, pressure, humidity, and altitude) during the measurements.

Influence of vehicle age on EF

The EFs of CO, $PM_{2.5}$ and BC were at their maximum for bus, truck, and pickup, respectively, during idling (Table 2). These three types of vehicle tested were older (more than 15 years) than the other vehicles tested in this study. The new vehicles (such as tippers and buses) had comparatively lower emissions than old trucks and buses. The EFs of $PM_{2.5}$, BC and CO for old trucks were more than fivefold, more than threefold, and one–threefold higher, respectively, than for new tippers. Similarly, the EFs of $PM_{2.5}$, BC and CO for old buses were twofold, one–fivefold, and two–fourfold higher, respectively, than for new buses. The study of heavy diesel vehicles conducted by Chen *et al*. (2007) indicated that in China, the EF of CO for old vehicles was threefold higher than for new vehicles. Another study conducted in Slovenia in 2011 disclosed the EF of BC for old, heavy diesel vehicles (of more than 10 years) to be 41% more than those for new vehicles (of 5–10 years) (Jezek *et al*., 2015). Similarly, in China, PM emissions were higher in the case of old vehicles (China III emission standard) compared to the new ones (China IV emission standard) in 2016 (Wang *et al*., 2018). The possible reason behind the high EF from old vehicles might have to do with poor engine combustion and irregular maintenance (Chen *et al*., 2007; Faiz *et al*., 2006).

Impact of servicing on EF

The average EFs of $PM_{2.5}$ and BC reduced by 66% and 30%, respectively, just after vehicle servicing; however, the EF of CO increased by 2% during idling when averaged across four vehicles (Fig. 4). The EFs for both the conditions, before and after servicing, were higher in the beginning, and later on, decreased and attained a stage of stability (Figs. 5a, 5b and 5c). The EF of $PM_{2.5}$ reduced by 57% and BC by 34% after servicing, particularly in the case of old buses. Similarly, the EFs of $PM_{2.5}$ and BC reduced by 65% and 15%, respectively, after new buses were serviced. One limitation in measurement was that there were no old, heavy cargo diesel vehicles for us to observe the impact of servicing. However, in the case of new tippers, we observed reductions in the EFs of $PM_{2.5}$ and BC by 46% and 1%, respectively, after servicing. In addition, servicing an old, light-duty vehicle (e.g., pickup) resulted in reductions in the EFs of $PM_{2.5}$ and BC by 81% and 34%, respectively. Surprisingly, there was an increase in the EF of CO in both heavy- and light-duty vehicles of any age (old and new) after servicing. A similar case was observed in a previous study conducted for gasoline vehicles (Stockwell *et al.*, 2016). The exact reason for this is still unknown (Stockwell *et al.*, 2016). Further detailed studies with a greater sample size are needed to understand this unusual increase in the EF of CO after servicing. However, the EF of CO decreased by 16% in the case of new tipper. Overall, it can be said that vehicle servicing helps to reduce emissions from different types of vehicles of any age, thereby contributing to the mitigation of diesel emissions in the Kathmandu Valley.

CONCLUSIONS

This is the first study of its kind in Nepal which provides the EFs of $PM_{2.5}$, BC and CO from diesel vehicles, while also exploring the impact of servicing on emissions. It presents roadside observations of diesel vehicles in the Kathmandu Valley, discusses the cost of general servicing, and provides measurements of the EF during idling condition from diesel vehicles. From these roadside observations, we found that only some specific vehicles in the entire diesel vehicle fleet were superemitters. We compared the EF during idling from this study with previous studies and found them to be higher than in other countries. The average total cost of general servicing for all types of vehicle was approximately USD 90–100. General vehicle servicing reduces the EF of $PM_{2.5}$ by 66% and of BC by 30% during idling. However, the study does not report an improvement in the EF of CO after servicing. The EFs presented here do not in themselves represent the entire diesel vehicle fleet of the Kathmandu Valley. However, the data provides a strong foundation for future research in the field of diesel vehicle emissions. Thus, this study helps in providing initial inputs toward the preparation of an emission inventory for diesel vehicles which can be used in quantifying global emissions, and it also provides a base to explore the cost-effectiveness of mandating routine servicing in order to mitigate vehicular pollution in the Kathmandu Valley.

There exists some limitations which we were not able to address in the present study. The roadside observations were not conducted during night-time due to safety issues. Similarly, the emissions from vehicles were not characterized based on speed of vehicles, seasonality of driving pattern as well as observations were not conducted during weekends. The EFs were also not measured during driving on plain or slope, and loading or unloading; further we were not able to carry out follow-up measurements after servicing due to strong resistance from the vehicle owners. Moreover, it was highly difficult to track down the same vehicle and get the owner's consent for undertaking emission measurements. In order to overcome such limitations, it is highly essential that academic, governmental and non-governmental agencies are brought together to organize larger campaigns in order to generate robust data on EFs from diesel vehicles.

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REFERENCES

Adhikari, S., Mahapatra, P.S., Sapkota, V. and Puppala, S.P. (2019). Characterizing emissions from agricultural diesel pumps in the Terai region of Nepal. *Atmosphere* 10: 56.

Ale, B.B. and Nagarkoti, R.K. (2003). Evaluation of Kathmandu Valley inspection and maintenance program on diesel vehicles. *Journal of the Institute of Engineering* 3: 81–87.

Alves, C.A., Lopes, D.J., Calvo, A.I., Evtyugina, M., Rocha, S. and Nunes, T. (2015). Emissions from light-duty diesel and gasoline in-use vehicles measured on chassis dynamometer test cycles. *Aerosol and Air Quality Research* 15: 99–116.

Bajracharya, I. and Bhattarai, N. (2016). Road transportation energy demand and environmental emission: A case of Kathmandu valley. *Hydro Nepal: Journal of Water, Energy and Environment* 18: 30–40.

Ban-Weiss, G.A., McLaughlin, J.P., Harley, R.A., Lunden, M.M., Kirchstetter, T.W., Kean, A.J., Strawa, A.W., Stevenson, E.D. and Kendall, G.R. (2008). Long-term changes in emissions of nitrogen oxides and particulate matter from on-road gasoline and diesel vehicles. *Atmospheric Environment* 42: 220–232.

Bhandarkar, S. (2013). Vehicular pollution, their effect on human health and mitigation measures. *Vehicle Engineering* 1: 33–40.

Bishop, G.A. and Stedman, D.H. (2008). A decade of on-road emissions measurements. *Environmental Science and Technology* 42: 1651–1656.

Bishop, G.A., Morris, J.A., Stedman, D.H., Cohen, L.H., Countess, R.J., Countess, S.J., Maly, P. and Scherer, S. (2001). The effects of altitude on heavy-duty diesel truck on-road emissions. *Environmental Science and Technology* 35: 1574–1578.

Bond, T.C. and Sun, H. (2005). Can reducing black carbon emissions counteract global warming? *Environmental Science and Technology* 39: 5921–5926.

Bond, T.C., Streets, D.G., Yarber, K.F., Nelson, S.M., Woo, J.-H. and Klimont, Z. (2004). A technology-based global inventory of black and organic carbon emissions from combustion. *Journal of Geophysical Research: Atmospheres* 109: D14203 (1-43).

Burgard, D.A., Bishop, G.A., Stedman, D.H., Gessner, V.H. and Daeschlein, C. (2006). Remote sensing of in-use heavy-duty diesel trucks. *Environmental Science and Technology* 40: 6938–6942.

Chen, C., Huang, C., Jing, Q., Wang, H., Pan, H., Li, L., Zhao, J., Dai, Y., Huang, H., Schipper, L. and Streets, D.G. (2007). On-road emission characteristics of heavy-duty diesel vehicles in Shanghai. *Atmospheric Environment* 41: 5334–5344.

Colbeck, I., Nasir, Z.A. and Ali, Z. (2010). The state of ambient air quality in Pakistan—A review. *Environmental Science and Pollution Research* 17: 49–63.

Deng, W., Hu, Q., Liu, T., Wang, X., Zhang, Y., Song, W., Sun, Y., Bi, X., Yu, J., Yang, W., Huang, X., Zhang, Z., Huang, Z., He, Q., Mellouki, A. and George, C. (2017). Primary particulate emissions and secondary organic aerosol (SOA) formation from idling diesel vehicle exhaust in China. *Science of the Total Environment* 593: 462–469.

Department of Environment. (2017). Air Quality Management Action Plan for Kathmandu Valley, http://www.indiaenvironmentportal.org.in/files/file/Report%20on%20AQM%20Action%20Plan%202017.pdf, Last Access: 7 March 2019.

Department of Transport Management. Details of Registration of Transport up to Fiscal Year 2046/47-072/73, https://www.dotm.gov.np/en/vehicle-registration-record/, Last Access: 7 March 2019.

Edgerton, S.A., Bian, X., Doran, J.C., Fast, J.D., Hubbe, J.M., Malone, E.L., Shaw, W.J., Whiteman, C.D., Zhong, S., Arriaga, J.L., Ortiz, E., Ruiz, M., Sosa, G., Vega, E., Limon, T., Guzman, F., Archuleta, J., Bossert, J.E., Elliot, S.M., Lee, J.T., McNair, L.A., Chow, J.C., Watson, J.G., Coulter, R.L., Doskey, P.V., Gaffney, J.S., Marley, N.A., Neff, W. and Petty, R. (1999). Particulate air pollution in Mexico City: A collaborative research project. *Journal of the Air and Waste Management Association* 49: 1221–1229.

Faiz, A., Ale, B.B. and Nagarkoti, R.K. (2006). The role of inspection and maintenance in controlling vehicular emissions in Kathmandu Valley, Nepal. *Atmospheric Environment* 40: 5967–5975.

Fu, M., Ge, Y., Tan, J., Zeng, T. and Liang, B. (2012). Characteristics of typical non-road machinery emissions in China by using portable emission measurement system. *Science of the Total Environment* 437: 255–261.

Gautam, C. (2006). *Final Report on Action Program on Air Quality Management of Kathmandu Valley*, Ministry of Science, Environment and Technology, Government of Nepal, Kathmandu.

Ghimire, K.P. and Shrestha, S.R. (2014). Estimating vehicular emission in Kathmandu Valley, Nepal. *International Journal of Environment* 3: 133–146.

Government of Nepal. (1993). Motor Vehicles and Transport Management Act, 1993, http://www.ccwb.gov.np/uploads/Resource/Lawpolicies/Act/motor-vehicles-and-transport-management-act.pdf, Last Access: 7 March 2019.

Gurung, P. Challenges of Curbing Vehicle Emissions, https://myrepublica.nagariknetwork.com/news/4064/, Last Access: 7 March 2019.

Hand, J.L. and Malm, W.C. (2007). Review of aerosol mass scattering efficiencies from ground-based measurements since 1990. *Journal of Geophysical Research: Atmospheres* 112.

Huo, H., Yao, Z., Zhang, Y., Shen, X., Zhang, Q. and He, K. (2012). On-board measurements of emissions from diesel trucks in five cities in China. *Atmospheric Environment* 54: 159–167.

Jayarathne, T., Stockwell, C.E., Bhave, P.V., Praveen, P.S., Rathnayake, C.M., Islam, M.R., Panday, A.K., Adhikari, S., Maharjan, R., Goetz, J.D., DeCarlo, P.F., Saikawa, E., Yokelson, R.J. and Stone, E.A. (2018). Nepal Ambient Monitoring and Source Testing Experiment (NAMaSTE): Emissions of particulate matter from wood- and dung-fueled cooking fires, garbage and crop residue burning, brick kilns, and other sources. *Atmospheric Chemistry and Physics* 18: 2259–2286.

Jezek, I., Katrasnik, T., Westerdahl, D. and Mocnik, G. (2015). Black carbon, particle number concentration and nitrogen oxide emission factors of random in-use vehicles measured with the on-road chasing method. *Atmospheric Chemistry and Physics* 15: 11011–11026.

Jha, P.K. (2001). *Transport Sector Technical Inspection System in Nepal*. Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, p. 13.

Kean, A.J., Harley, R.A. and Kendall, G.R. (2003). Effects of vehicle speed and engine load on motor vehicle emissions. *Environmental Science and Technology* 37: 3739–3746.

Kim, B.M., Park, J.-S., Kim, S.-W., Kim, H., Jeon, H., Cho, C., Kim, J.-H., Hong, S., Rupakheti, M., Panday, A.K., Park, R.J., Hong, J. and Yoon, S.-C. (2015). Source apportionment of PM10 mass and particulate carbon in the Kathmandu Valley, Nepal. *Atmospheric Environment* 123: 190–199.

Kirchstetter, T.W., Harley, R.A., Kreisberg, N.M., Stolzenburg, M.R. and Hering, S.V. (1999). On-road measurement of fine particle and nitrogen oxide emissions from light- and heavy-duty motor vehicles. *Atmospheric Environment* 33: 2955–2968.

Larssen, S., Gram, F., Haugsbakk, I., Jansen, H., Olsthoorn, X., Giri, A. S., Shah, R., Shrestha, M. L., Shrestha, B., Shah, J. J. and Nagpal, T. (1997). *Urban Air Quality Management Strategy in Asia: Kathmandu Valley*, The World Bank, Washington D. C., p. 174.

Latimer, R.N.C. and Martin, R.V. (2019). Interpretation of measured aerosol mass scattering efficiency over North America using a chemical transport model. *Atmospheric Chemistry and Physics* 19: 2635–2653.

Liu, H., He, K., Lents, J.M., Wang, Q. and Tolvett, S. (2009). Characteristics of diesel truck emission in China based on portable emissions measurement systems. *Environmental Science and Technology* 43: 9507–9511.

Mahapatra, P.S., Puppala, S.P., Adhikary, B., Shrestha, K.L., Dawadi, D.P., Paudel, S.P. and Panday, A.K. (2019). Air quality trends of the Kathmandu Valley: A satellite, observation and modeling perspective. *Atmospheric Environment* 201: 334–347.

Maji, S., Ahmed, S. and Siddiqui, W.A. (2015). Air quality assessment and its relation to potential health impacts in Delhi, India. *Current Science* 109: 902–909.

Manufacturers of Emission Controls Association. (2014). Emission Control of Two- and Three-wheel Vehicles, http://www.meca.org/resources/Motorcycle_whitepaper_update_0914.pdf, Last Access: 7 March 2019.

McCormick, R.L., Graboski, M.S., Alleman, T.L., Alvarez, J.R. and Duleep, K.G. (2003). Quantifying the emission benefits of opacity testing and repair of heavy-duty diesel vehicles. *Environmental Science and Technology* 37: 630–637.

McCormick, R.L., Graboski, M.S., Alleman, T.L. and Yanowitz, J. (2000). Idle emissions from heavy-duty diesel and natural gas vehicles at high altitude. *Journal of the Air and Waste Management Association* 50: 1992–1998.

Molina, M.J. and Molina, L.T. (2004). Megacities and atmospheric pollution. *Journal of the Air and Waste Management Association* 54: 644–680.

Moosmuller, H., Mazzoleni, C., Barber, P.W., Kuhns, H.D., Keislar, R.E. and Watson, J.G. (2003). On-road measurement of automotive particle emissions by ultraviolet lidar and transmissometer: Instrument. *Environmental Science and Technology* 37: 4971–4978.

Mountain Air Engineering. (2016). Ratnoze1 User Guide, http://www.mtnaireng.com/Ratnoze1_User_Guide_v8.pdf, Last Access: 7 March 2019.

Mues, A., Lauer, A., Lupascu, A., Rupakheti, M., Kuik, F. and Lawrence, M.G. (2018). WRF and WRF-Chem v3. 5.1 simulations of meteorology and black carbon concentrations in the Kathmandu Valley. *Geoscientific Model Development* 11: 2067–2091.

Njoku, K.L., Rumide, T.J., Akinola, M.O., Adesuyi, A.A. and Jolaoso, A.O. (2016). Ambient air quality monitoring in metropolitan city of Lagos, Nigeria. *Journal of Applied Sciences and Environmental Management* 20: 178–185.

Parajuly, K. (2016). Pollution: Clean up the air in Kathmandu. *Nature* 533: 321.

Park, S.S., Kozawa, K., Fruin, S., Mara, S., Hsu, Y.-K., Jakober, C., Winer, A. and Herner, J. (2011). Emission factors for high-emitting vehicles based on on-road measurements of individual vehicle exhaust with a mobile measurement platform. *Journal of the Air and Waste Management Association* 61: 1046–1056.

Petkova, E.P., Jack, D.W., Volavka-Close, N.H. and Kinney, P.L. (2013). Particulate matter pollution in African cities. *Air Quality, Atmosphere and Health* 6: 603–614.

Sahu, S.K. and Kota, S.H. (2017). Significance of PM2.5 air quality at the Indian capital. *Aerosol and Air Quality Research* 17: 588–597.

Sarkar, C., Sinha, V., Sinha, B., Panday, A.K., Rupakheti, M. and Lawrence, M.G. (2017). Source apportionment of NMVOCs in the Kathmandu Valley during the SusKat-ABC international field campaign using positive matrix factorization. *Atmospheric Chemistry and Physics* 17: 8129–8156.

Schneider, J., Kirchner, U., Borrmann, S., Vogt, R. and Scheer, V. (2008). In situ measurements of particle number concentration, chemically resolved size distributions and black carbon content of traffic-related emissions on German motorways, rural roads and in city traffic. *Atmospheric Environment* 42: 4257–4268.

Shakya, K.M., Rupakheti, M., Shahi, A., Maskey, R., Pradhan, B., Panday, A., Puppala, S.P., Lawrence, M. and Peltier, R.E. (2017). Near-road sampling of PM2.5, BC, and fine-particle chemical components in Kathmandu Valley, Nepal. *Atmospheric Chemistry and Physics* 17: 6503–6516.

Sharma, R.K., Bhattarai, B.K., Sapkota, B.K., Gewali, M.B. and Kjeldstad, B. (2012). Black carbon aerosols variation in Kathmandu Valley, Nepal. *Atmospheric Environment* 63: 282–288.

Shrestha, R.M. and Malla, S. (1996). Air pollution from energy use in a developing country city: The case of Kathmandu Valley, Nepal. *Energy* 21: 785–794.

Shrestha, S.R., Kim Oanh, N.T., Xu, Q., Rupakheti, M. and Lawrence, M.G. (2013). Analysis of the vehicle fleet in the Kathmandu Valley for estimation of environment and climate co-benefits of technology intrusions. *Atmospheric Environment* 81: 579–590.

Stockwell, C.E., Christian, T.J., Goetz, J.D., Jayarathne, T., Bhave, P.V., Praveen, P.S., Adhikari, S., Maharjan, R., DeCarlo, P.F., Stone, E.A., Saikawa, E., Blake, D.R., Simpson, I.J., Yokelson, R.J. and Panday, A.K. (2016). Nepal Ambient Monitoring and Source Testing Experiment (NAMaSTE): Emissions of trace gases and light-absorbing carbon from wood and dung cooking fires, garbage and crop residue burning, brick kilns, and other sources. *Atmospheric Chemistry and Physics* 16: 11043–11081.

Stone, E.A., Schauer, J.J., Pradhan, B.B., Dangol, P.M., Habib, G., Venkataraman, C. and Ramanathan, V. (2010). Characterization of emissions from South Asian biofuels and application to source apportionment of carbonaceous aerosol in the Himalayas. *Journal of Geophysical Research: Atmospheres* 115: D06301 (1–14).

Stone, E.A., Nguyen, T.T., Pradhan, B.B. and Dangol, P.M. (2012). Assessment of biogenic secondary organic aerosol in the Himalayas. *Environmental Chemistry* 9: 263–272.

Subramanian, R., Winijkul, E., Bond, T.C., Thiansathit, W., Oanh, N.T.K., Paw-Armart, I. and Duleep, K.G. (2009). Climate-relevant properties of diesel particulate emissions: Results from a piggyback study in Bangkok, Thailand. *Environmental Science and Technology* 43: 4213–4218.

Wang, H., Ge, Y., Tan, J., Wu, L., Wu, P., Hao, L., Peng, Z., Zhang, C., Wang, X., Han, Y. and Zhang, M. (2018). The real-world emissions from urban freight trucks in Beijing. *Aerosol and Air Quality Research* 18: 1448–1456.

Wang, J.-F., Hu, M.-G., Xu, C.-D., Christakos, G. and Zhao, Y. (2013). Estimation of citywide air pollution in Beijing. *PLOS ONE* 8: e53400 (1–6).

Wang, X., Westerdahl, D., Wu, Y., Pan, X. and Zhang, K.M. (2011). On-road emission factor distributions of individual diesel vehicles in and around Beijing, China. *Atmospheric Environment* 45: 503–513.

Weingartner, E., Keller, C., Stahel, W.A., Burtscher, H. and Baltensperger, U. (1997). Aerosol emission in a road tunnel. *Atmospheric Environment* 31: 451–462.

Zhang, Y., Stedman, D.H., Bishop, G.A., Guenther, P.L. and Beaton, S.P. (1995). Worldwide on-road vehicle exhaust emissions study by remote sensing. *Environmental Science and Technology* 29: 2286–2294.

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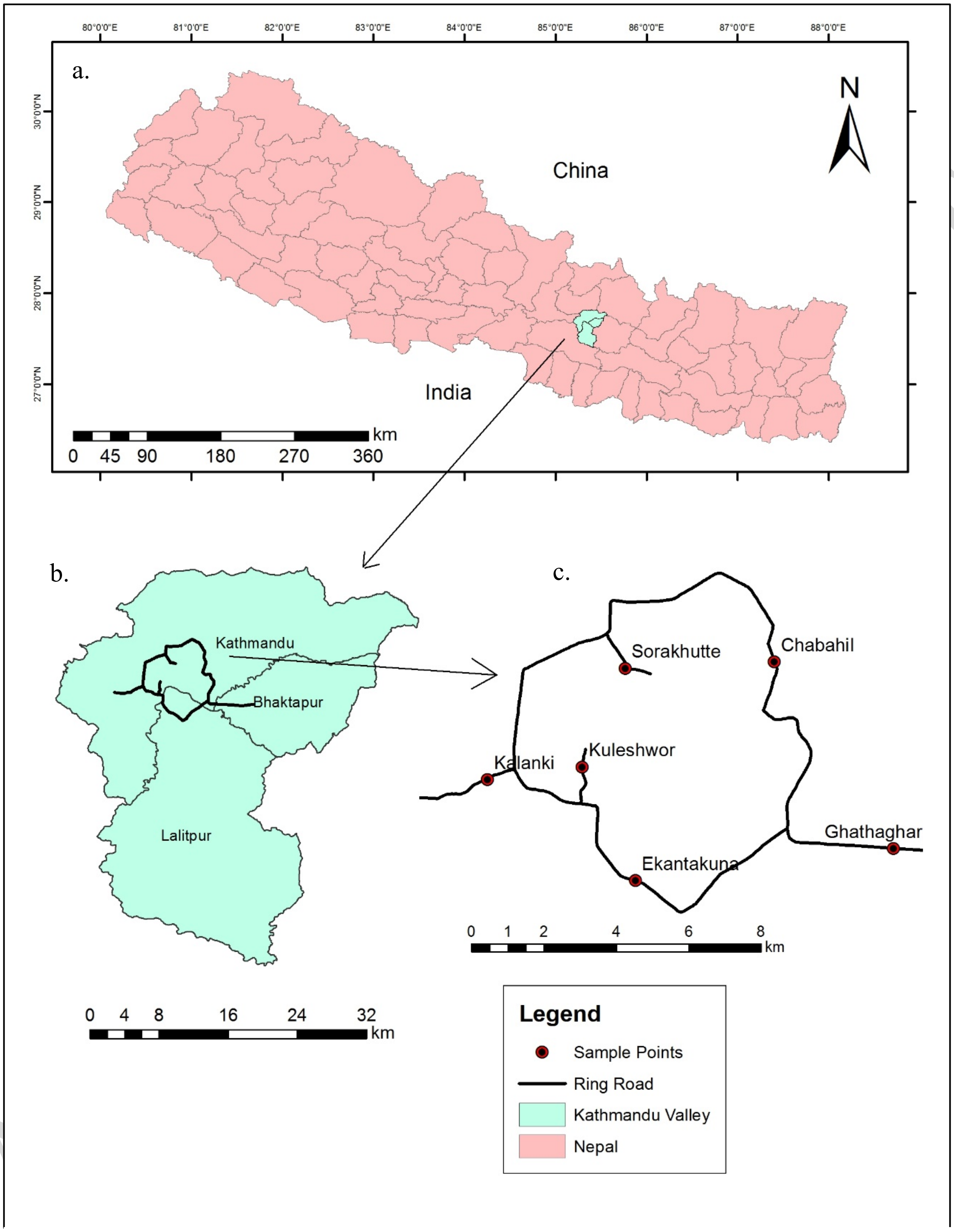


Fig. 1. (a) Map of Nepal indicating the study area (Kathmandu Valley); (b) Map of study area showing the ring road encircling Kathmandu and Lalitpur; (c) Sample points on the ring road, inside the ring road, and the arterial highways.

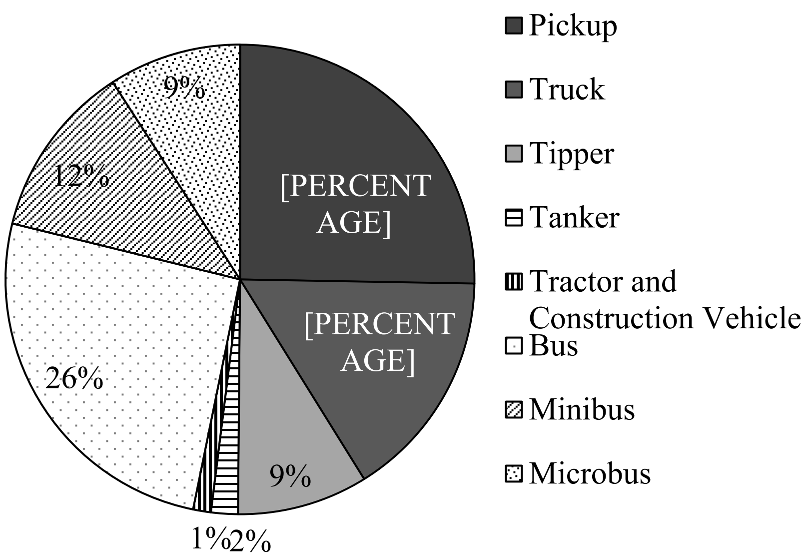


Fig. 2. (a) Composition of all vehicles from roadside observations. The first five vehicle types represent cargo diesel vehicles; the remaining three types represent passenger diesel vehicles.

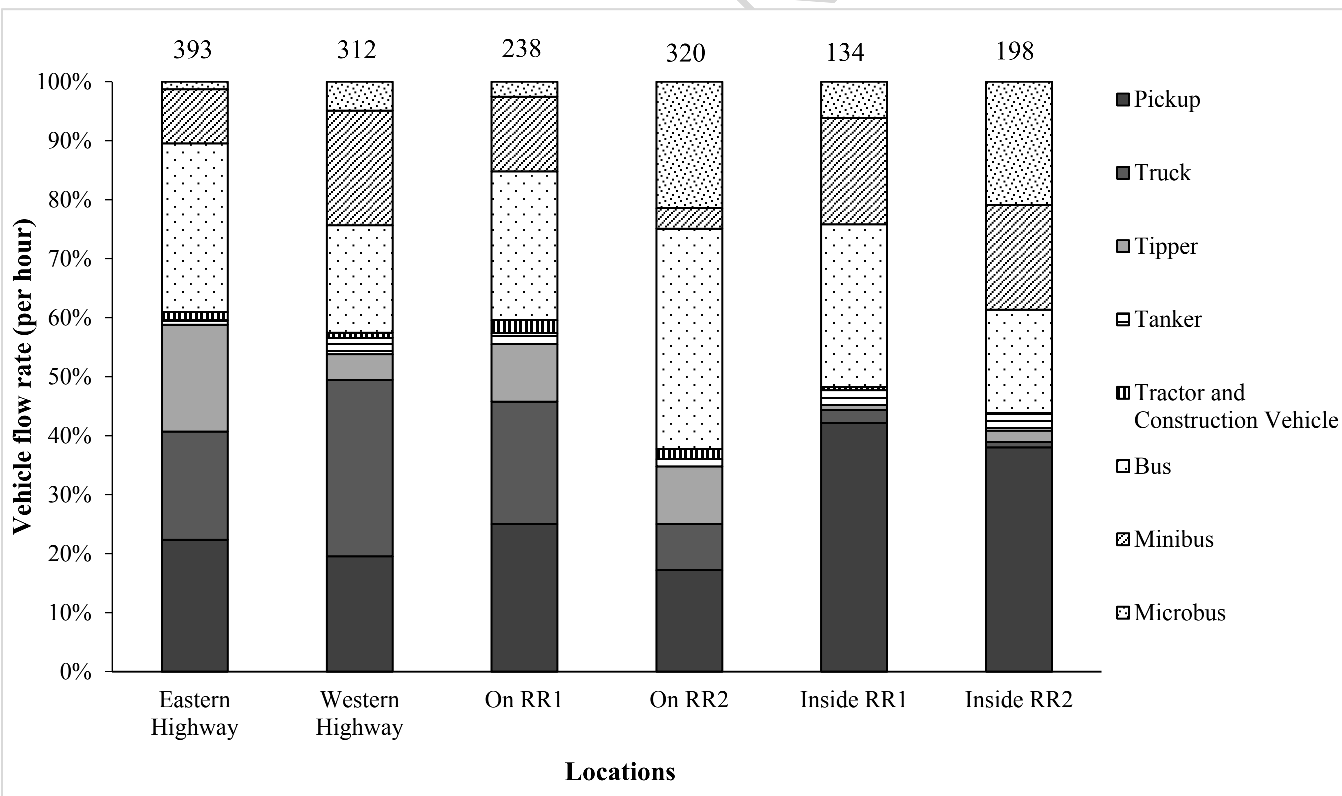


Fig. 2. (b) Vehicle flow rate (h^{-1}) at each survey location listed above each bar for all diesel vehicles. Each data set is further subdivided into eight vehicle types (indicated by shading). The numbers above each bar represent the total number of vehicles observed at the particular location.

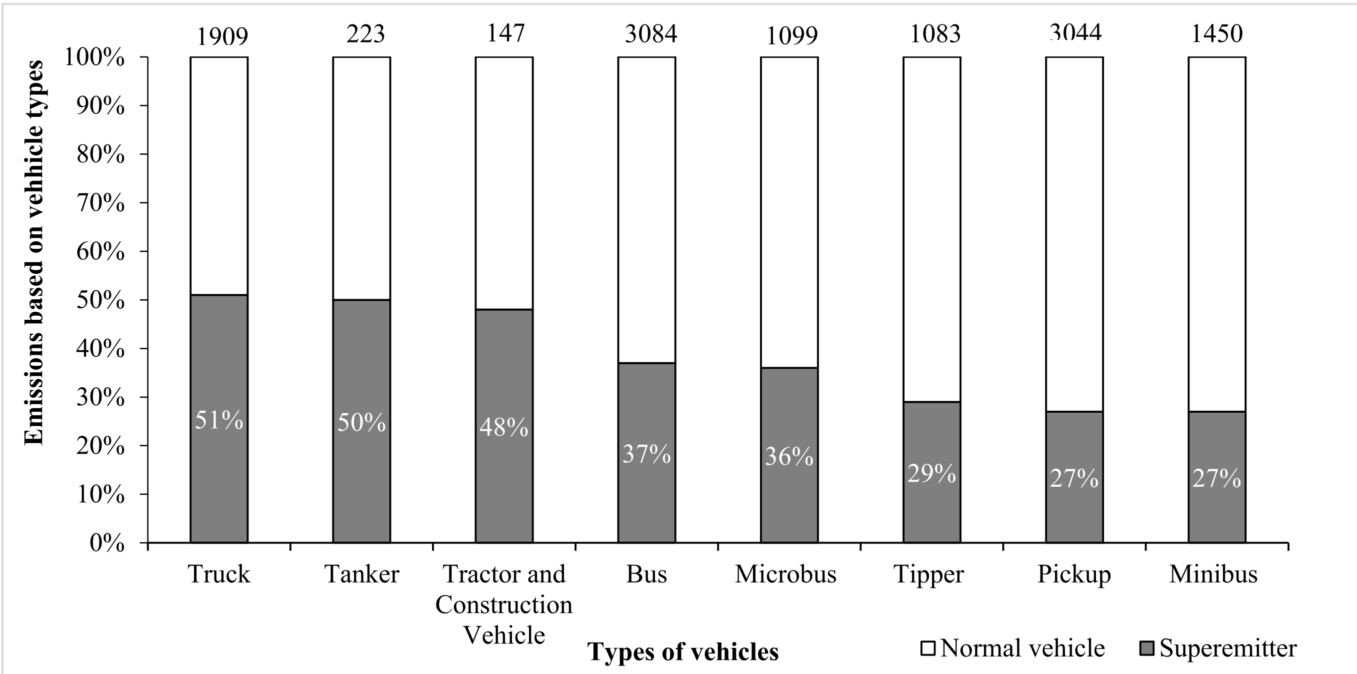


Fig. 3. (a) Composition of superemitter vehicles based on vehicle types. The numbers above each bar represent the total number of individual vehicle types that were observed.

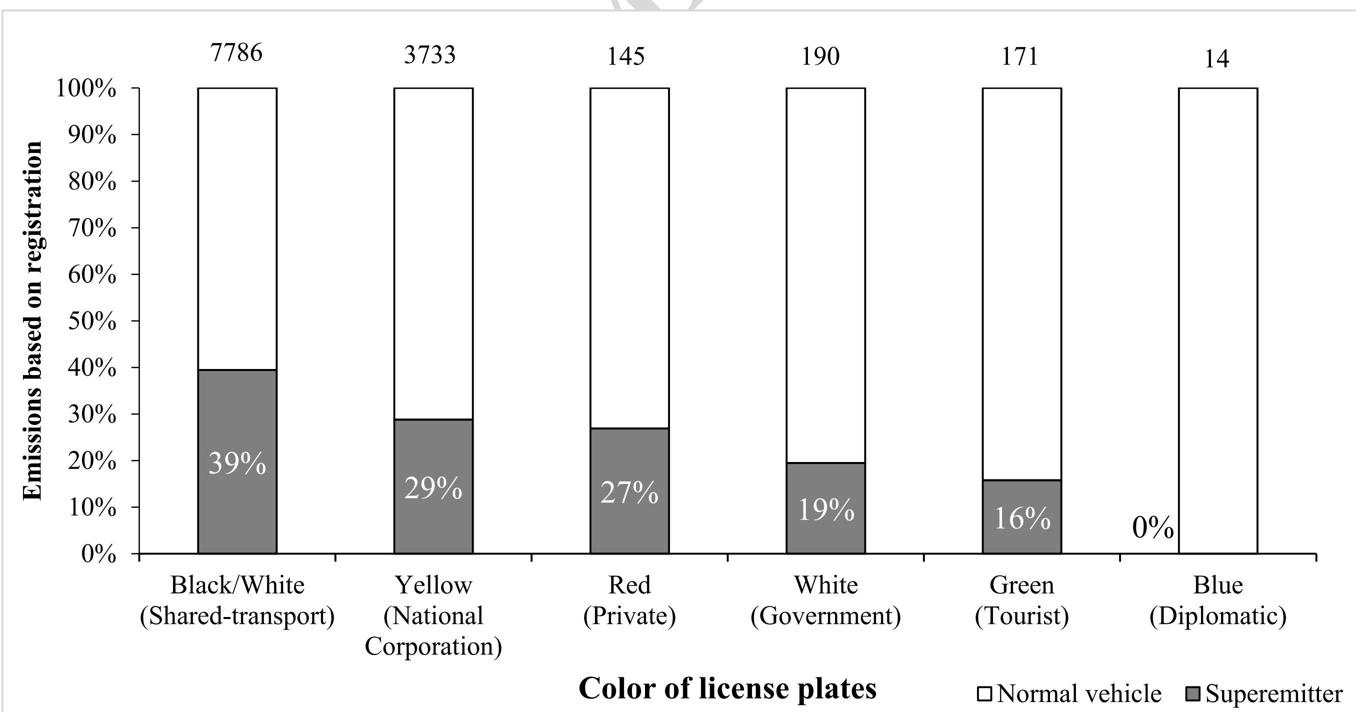
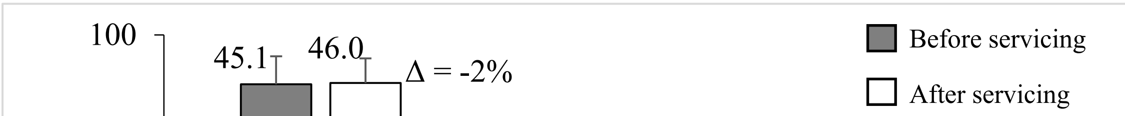


Fig. 3. (b) Composition of superemitter vehicles based on registration. "Shared-transport" represents both the vehicles having black plates and white figures, and those with white plates and black figures. The numbers above each bar represent the total number of observed vehicles with particular color of license



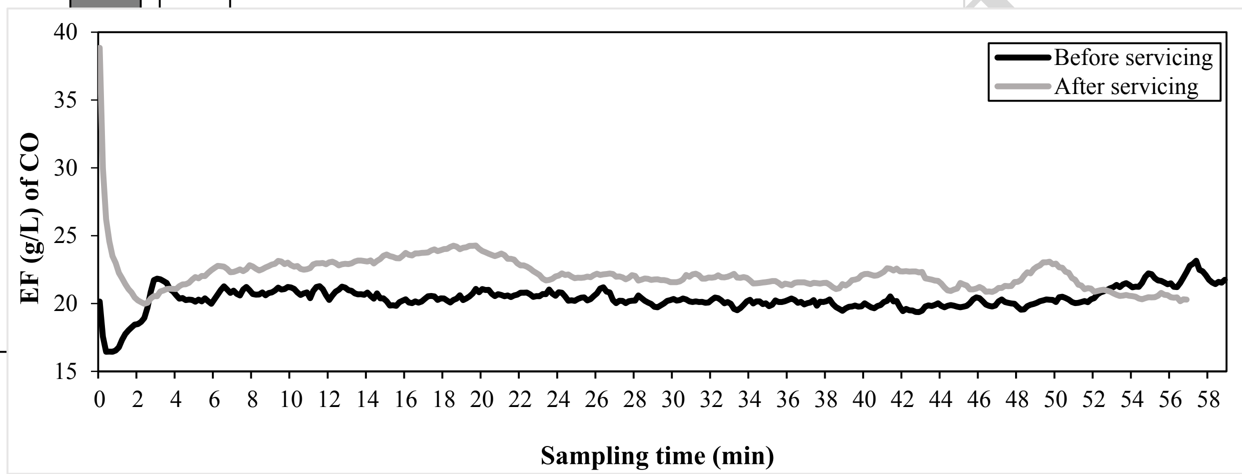


Fig. 5. (a). Real-time EFs of CO for pick-up before and after servicing.

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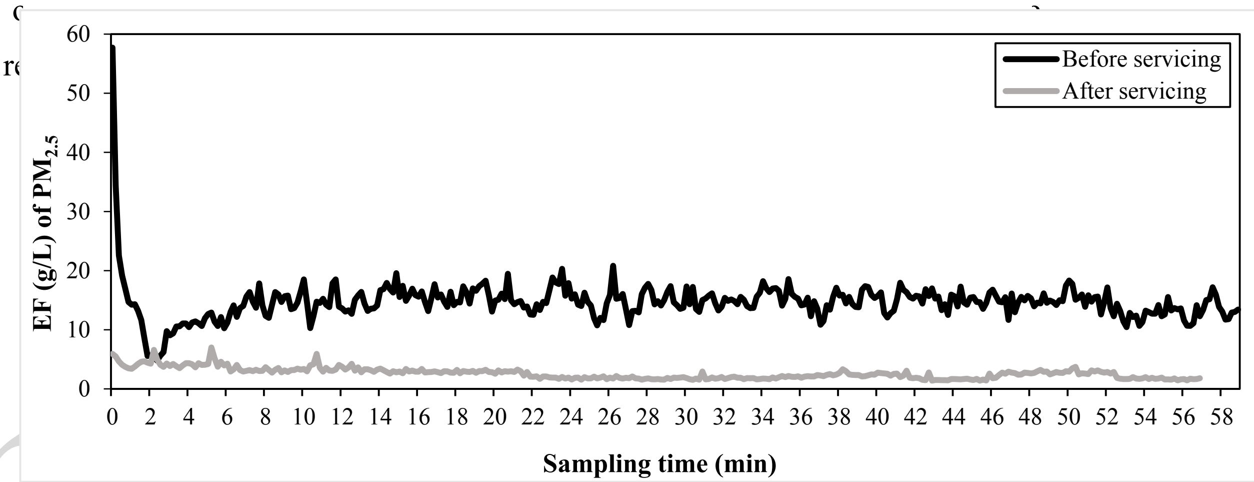

Fig. 5. (b). Real-time EFs of $PM_{2.5}$ for pick-up before and after servicing.

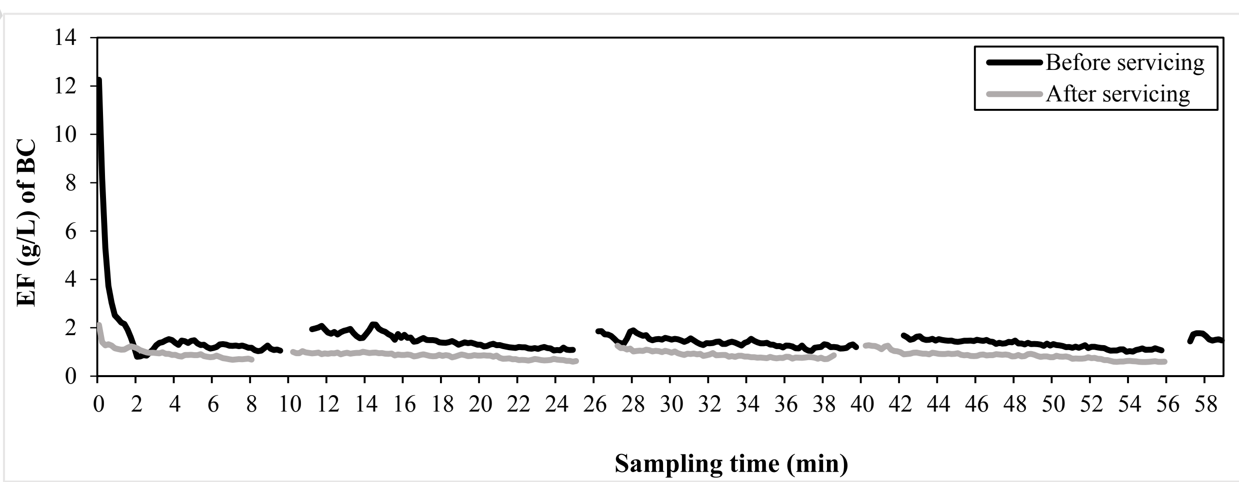

Fig. 5. (c). Real-time EFs of BC for pick-up before and after servicing.

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Table 1. Roadside survey locations with composition of superemitter vehicles

S.N.	Locations	GPS coordinates		Direction	Slope (%)	Number of observed traffic lanes	Date	Local time		Diesel vehicle count	Superemitter vehicle (%)
		Latitude	Longitude					Start	Stop		
1.	Eastern Highway (Ghathaghar)	27.67367°N	85.37587°E	South West	1.7	2	19 March 2017	7:00	17:30	3176	28
2.	Western Highway (Kalanki)	27.69083°N	85.27496°E	South West [a]	6.6	1	16 March 2017	7:00	17:30	2513	40
3.	On RR1 (Ekantakuna)	27.66574°N	85.31175°E	South East [a]	2.7	1	27 February 2017	6:30	17:30	1919	43
4.	On RR2 (Chabahil)	27.72009°N	85.34626°E	South East [a]	5.1	1	17 March 2017	7:00	13:30	1762	46
5.	Inside RR2 (Sorakhutte)	27.71850°N	85.30922°E	North East	7.1	2	27 April 2017	7:00	17:30	1581	27
6.	Inside RR1 (Kuleshwor)	27.69398°N	85.29850°E	South	1.6	2	13 March 2017	6:45	17:30	1088	29
	Total									**12,039**	

S.N. represents serial number.
[a] represents presence of speed breaker to the direction of flowing vehicles.
RR represents ring road.

Table 2. Emission factors (g L^{-1}) of diesel vehicles tested during idling

S.N.	Vehicle ID	Servicing status	Vehicle types	Model year (age of engine)	Emission factor (g L^{-1})			
					$PM_{2.5}$	BC	CO	CO_2
1.	V1	B	Truck	2002	30.80	1.067	46.2	2580
2.	V2	A	Truck	2008	05.82 [a]	0.396 [a]	22.1 [a]	2619 [a]
3.	V3	B	Bus	1998	15.50	1.358	81.3	2524
4.	V3	A	Bus	1998	06.64	0.899	81.4	2525
5.	V4	B	Bus	2012	07.29	0.460	20.4	2621
6.	V5	B	Bus	2013	10.10	0.949	28.6	2608
7.	V6	B	Bus	2016	07.88	0.253	46.4	2581
8.	V7	B	Bus	2016	08.56	0.248	40.8	2590
9.	V7	A	Bus	2016	03.03	0.211	48.6	2577
10.	V8	B	Tipper	2016	04.97	0.285	37.8	2594
11.	V8	A	Tipper	2016	02.67	0.282	31.9	2604
12.	V9	B	Tipper	2009	06.52	0.404	17.3	2626
13.	V10	B	Pickup	1999	14.60	1.494	20.3	2620
14.	V10	A	Pickup	1999	02.71	0.993	22.2	2618

Note: B, EF before vehicle servicing; A, EF after vehicle servicing (changing engine oil, and oil, diesel and air filters).
[a] represents only changing diesel filter; unable to obtain data before servicing.

Table 3. Comparison of EF (g kg^{-1}) with other EF studies

References	Study type	Country	Year	Vehicle type	CO_2	CO	$PM_{2.5}$	BC
This study	Idling	Nepal	2017	Pickup (LDDV)	3,149	24	17.64	1.796
				Tipper (HDDV)	3,137	33	6.91	0.413
				Truck (HDDV)	3,101	56	37.09	1.282
				Bus (HDDV)	3,107	52	11.87	0.786
				Average (HDDV)	3,115	47	18.62	0.827
Park *et al*., 2011	Idling (different driving conditions)	USA	2007	HDDT	N/A	75	0.37	0.220
Subramanian *et al*., 2009	Dynamometer	Thailand	ca 2008	LDDT & HDDT	N/A	N/A	8.40	N/A
Deng *et al*., 2017	Idling	China	ca 2014	HDDT	N/A	N/A	N/A	0.160
Liu *et al*., 2009	On-board (driving)	China	2007 and 2008	LDDT	N/A	N/A	0.60	N/A
Huo *et al*., 2012	On-board (driving)	China	2007 and 2011	LDDT	N/A	32	1.86	N/A
				HDDT	N/A	29	1.37	N/A
Wang *et al*., 2011	On-board (driving)	China	2009	HDDT	N/A	42	2.35[a]	2.200
Kirchstetter *et al*., 1999	Tunnel (driving)	USA	1997	HDDV	N/A	N/A	2.50	1.300
Bishop *et al*., 2001	Remote sensing (driving)	USA	1997 to 1999	HDDT	N/A	31	N/A	N/A
Burgard *et al*., 2006	Remote sensing (driving)	USA	2005	HDDT	N/A	32	N/A	N/A
Ban-Weiss *et al*., 2008	Tunnel (driving)	USA	2006	HDDT	N/A	N/A	1.40	0.920
Weingartner *et al*., 1997	Tunnel (driving)	Switzerland	1993	LDDV	N/A	N/A	N/A	0.020
				HDDV	N/A	N/A	N/A	0.300
Schneider *et al*., 2008	On-board (driving)	Germany	2005	HDDT	3190	N/A	N/A	0.220

[a] represents $PM_{0.5}$

LDDV represents light-duty diesel vehicle
HDDV represents heavy-duty diesel vehicle
LDDT represents light-duty diesel truck
HDDT represents heavy-duty diesel truck