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Active and passive transport choice behaviour for school students and their exposure to different transportation modes

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Abstract

Study on the selection of school transports by school students among school going students are important for the policy makers in order to achieve the sustainable urban development. School related trips contribute significantly in urban air pollution and vehicle kilometre travelled (VKT). School students are at higher risk towards air pollution due to their higher breathing rate compared to adolescent. The increased distance between home to school and sprawling of urban increases the demand in motorized/passive school transport (PST). This study reports the selection criteria of school transport for school going students and their exposure towards particulate matter (PM) number concentration under different school transports. Pre-primary and female students have shown their maximum dependency over PST modes whereas, students from senior-secondary classes have opted for active school transport (AST). With the increased vehicle population there is subsequent increase in vehicle congestion and travel duration results into exposure of the commuters (school students). PM number concentration of particles size 0.5-1 µm, 2.5 µm and 2.5-10 µm were recorded maximum for three-wheeler (3W) followed by school bus (SB) and were recorded minimum for two-wheeler (2W) at morning school timings (MT) and afternoon school timings (AT) respectively. Inhalation of particles by students while commuting depends upon recorded PM concentration, breathing rate and residence time. Inhaled particle number (IPN) were calculated maximum for 3W and minimum for 2W while commuting at MT and AT.

Keywords: School transportation mode; Active transport; Passive transport; Particle number; Traffic exposure; Inhalation rate

1. Introduction

Urban air quality represents the risk factor for different cardiovascular and respiratory diseases (Pope and Dockery, 2006). Traffic related vehicular emissions are one of the major for polluting the urban air quality. There are various different transportation dependent sectors like office related trips, school related trips and public vehicle trips makes

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significant contribution in estimating (VKT) and vehicular emissions. Available modes of school transport are categorized into two different groups i.e., AST and PST. Non-motorized school transport (walking and cycling) are AST modes whereas, motorized transport (Private motorized transports (PT), 3W and SB) are PST modes. PT modes are usually have less-occupancy space (2W and passenger car) compared to public transport which have high-occupancy space (3W and SB). Students dependencies over AST and PST modes are change in last couple of decades for example, a study in Australia Ploeg et al., 2008, make his observation for Sydney city that the percentage of children aged between 5 to 9 who travelled by personal or public vehicles are increased from 22.8% in 1971 to 66.6% in 2003, and the corresponding percentage for students who aged in between 10 to 14 years increased from 12.2% to 47.8% for same time period. Using of private vehicle by parents make it easier to drop off their children at school (DiGuiseppi et al., 1998; Bradshaw and Atkins, 1996). For example, in 1994 U.K. travel survey data showed that approximately 87% of students don't have any car in their home like to walk to school compared with 36% for students with two or more private vehicles at their house (Bradshaw and Atkins, 1996). While there are obviously some other factors influencing their choice behavior, e.g. socio-economic status, the variation is quite substantial. The rise in childhood obesity and their less involvement in exercise or physical work has occurred at the same time children have radically change their behavior after get into school. In 1969, 42% of students like AT (walked or biked) for covering distance to school; now 13% do. The share of school trips made by auto has increased from 16% in 1969 to 55% in 2008 (Ren and Tong, 2008). Changes in the school trip are important, because 50% of children's weekday trips during the academic year are for school. A reduction in walking and biking for this trip likely means large drops in the overall number of trips by active modes.

A major contributor for degrading the air quality of an urban are on-road motor vehicles (Anenberg et al., 2017; Kumar et al., 2014). Traffic related air pollutants (TRAP) are generally higher in areas near to road-side (Jeong et al., 2015). As the traffic density increases beyond the carrying capacity of roads, it leads to congestion and decreases average fleet speed during at different type of roads (urban, rural and highway) (Pandian et al., 2009). This congestion results into variation of total traffic emission (Achour et al., 2011), energy consumption and average travel time to 2 to 3 h per day for their work trip (Jain et al., 2014). The level of exposure of school students is mainly influenced by the distance between emitter and receiver. Although proximity to traffic has been confirmed as a major determinant of the level of exposure (Janssen et al., 2001; Van Roosbroeck et al., 2007) and consequently of health effect (Brunekreef et al., 1997), these studies have been used in traffic data as a proxy for exposure rather than pollutant concentrations. Exposure of school students towards traffic pollutants depends upon the mode they opt like school bus has to take maximum travel time in order to cover its route and mainly uses city road where many other vehicles moves simultaneously (as large in size), while other vehicles like bicycle, bike and personal four-wheeler use to take minimum time for covering its journey and uses sub routes or less congested route. Transport associated with school and office are highly linked to have affected the average speed and fuel consumption of existing road networks to the maximum extent.

This study examines the percentage choice variation of school students in between different available school transport modes and calculates the inheld particle number concentration while commuting through different school motorized transport modes at different school timings (morning school timing (MT) and afternoon school timing (AT) separately).

2. Methods

2.1. Site description

Dhanbad city of Jharkhand also known as coal capital of India is classified as one of the critical polluted cities by CPCB in 2009. A local school located near to central market area of Dhanabd city is selected for this study. This CBSE affiliated school has more than 6000 students studying from pre-primary to higher secondary classes. School has co-ed education system up to class II and after that they run have different shifts for boy's and girl's students. School has its own school bus facility whereas, other private and public transportation facility were also available for school students. These vehicles cover different road routes (main and local street roads) depending upon the location of student house and available routes option (shown in fig. 1).

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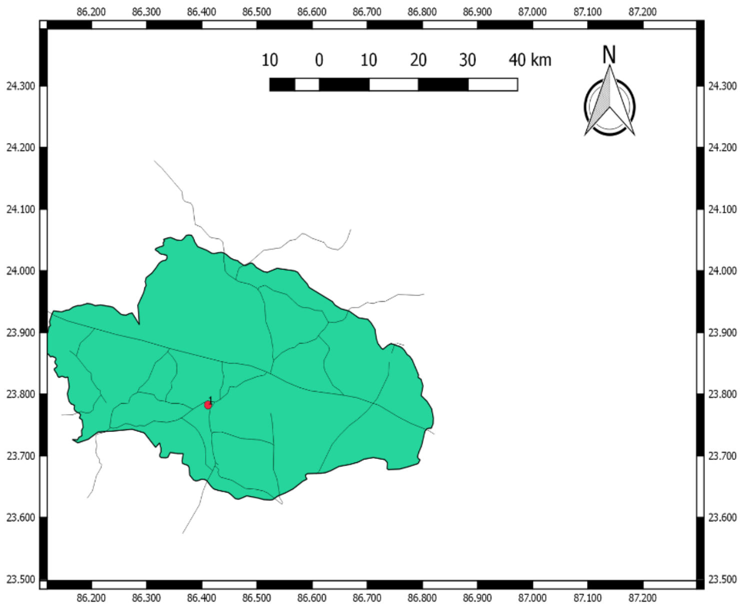


Fig. 1: Location of school in Dhanbad region.

2.2. Questionnaire survey

Questionnaire survey were conducted inside the school premises in order to collect detailed information related with students like opted mode of transport, home location and travel duration. Approximately 5385 respondents are participated in this study out of which 4727 response are found to be suitable for this study and remaining are rejected due to lack of valuable information. Self-administered survey is adopted for this study. Distance and route between school to home are calculated with the help of map software in different stages. AT first, student home and school locations were marked on the map after that all the possible routes are marked and at last with the assumptions that personal vehicle cover shortest distance whereas, public vehicle have their fix route direction we calculate the travel distance for each type of vehicles.

2.3. Monitoring and Instrumentation

Students opted for PST modes have daily travel duration of approximately 45 minutes to 1 hours while going to school and returning from school. While commuting they cover major portion of main-road and likely get exposed to different air pollutants like PM. Concentration of PM pollutants of different sizes varies depending upon the ongoing activities like vehicle rush, congestion and road width. PM numbers concentration of size PM0.5 µm, PM1 µm, PM2.5 µm and PM10 µm were recorded by Metone instrument model GT-526s at an equal interval of 5 second with holding time of 2 second. Later these recorded values were averaged for per minute to reduce the error and calculated in the PM sized bin of PM0.5-1 µm, PM2.5 µm and PM2.5-10 µm for different school transports. Exposure towards TRAP depend upon various factors like openings (windows, doors and cracks), cabin volume, travelling speed, on-road traffic volume and age of vehicle. At the time of monitoring there was no attachments are used to control its emission and also no instruction given to driver and any of the student. All the measurements are recorded under realistic driving condition with no special arrangement.

2.4. Inhaled particle number calculation

Commuting from congested traffic zones or at peak hours has maximum exposure of commuters towards traffic pollutants and result into different disease like respiratory allergy, bronchitis and asthma (Gauderman et al., 2007; Gehring et al., 2010). Inhaled doses of PM vary with the rate of inhalation which in turn differs according to their respiration volume and rate depending upon their activity (standing up, walking, running, etc.). Inhalation rate also varies with the vehicle type as walking, cycling and running increases breathing rate as compared to commuting through 2W, SB and 3W these activity needs very less or no physical rigorous involvement. The equation used for calculating inhaled PM number per minute (IPN) are shown in equation 1:

$$IPN\ (N/min) = PNC\ (N/m3) \times IR\ (L/min) \quad 1$$

Where, PNC is particle number concentration in numbers/m3, IR is inhalation rate in L/min (IR of an adult are 12 L/min during light intensity activity like standing up and 26 L/min during moderate intensity activity like walking (EPA, 2011)). In this calculation PNC used for calculation are average number concentration recorded while commuting via particular mode of transportation.

3. Results

3.1. Simple survey data categorization

Table 1 lists the number of students and their sharing percentage with opted mode of transportation from different class groups. Individual grouping is done for pre-primary, primary, secondary and senior-secondary class students with their opted mode of transport i.e., AST, PT, 3W and SB. Maximum students participated in this questionnaire were from secondary class i.e., from class VI to X. SB are most preferred mode of transport opted by the school students except for the senior-students as there most opted mode of transport are either AST or PT . Pre-primary class students prefer to use private vehicle whereas, male students more like to use public transport. Share percentage of students (female and male) with their opted mode of transport are shown in fig. 2. Passive school transport (PST) modes are most preferred by pre-primary and female student i.e., 94.7% (93.2% female and 95.5% male) and 82% respectively whereas, overall 65.3% of male student have opted for PST modes and remaining 29.7% opts for AST travel mode. Female students have shown their dependency over private transport modes whereas, male students have shown their dependency on public school transport or AST.

Table 1. Number of students with their opted mode of transportation and their sharing percentage.

Gender	Class		AST	PT	3W	SB
Girls	Pre-primary	Kindergarten	5 (6.8)	33 (44.6)	14 (18.9)	22 (29.7)
	Primary	Class I to V	71 (12.5)	227 (40.0)	139 (24.5)	131(23.1)
	Secondary	Class VI to X	179 (20.9)	368 (43.0)	159 (18.2)	159 (17.8)
	Senior-secondary	Class XI & XII	118 (23.0)	207 (40.4	74 (14.5)	113 (22.1)
Boys	Pre-primary	Kindergarten	6 (4.4)	33 (24.4)	40 (29.6)	56 (41.5)
	Primary	Class I to V	159 (18.3)	214 (24.6)	198 (22.8)	299 (34.4)
	Secondary	Class VI to X	323 (28.7)	238 (43.0)	215 (19.1)	350 (31.1)
	Senior-secondary	Class XI & XII	325 (55.4)	75 (40.4)	70 (11.9)	117 (19.9)

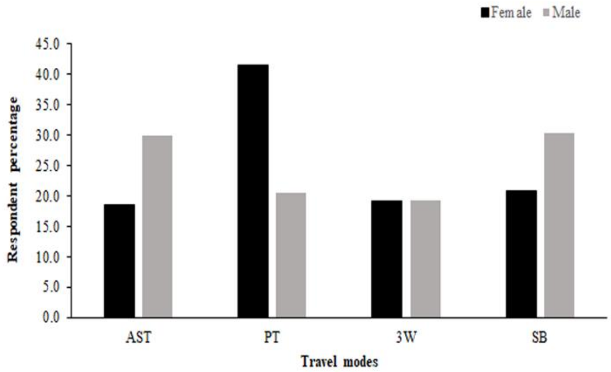


Fig. 2: Student gender aspect of travel mode choice for school related trips.

3.2. PM number concentration under different transport modes

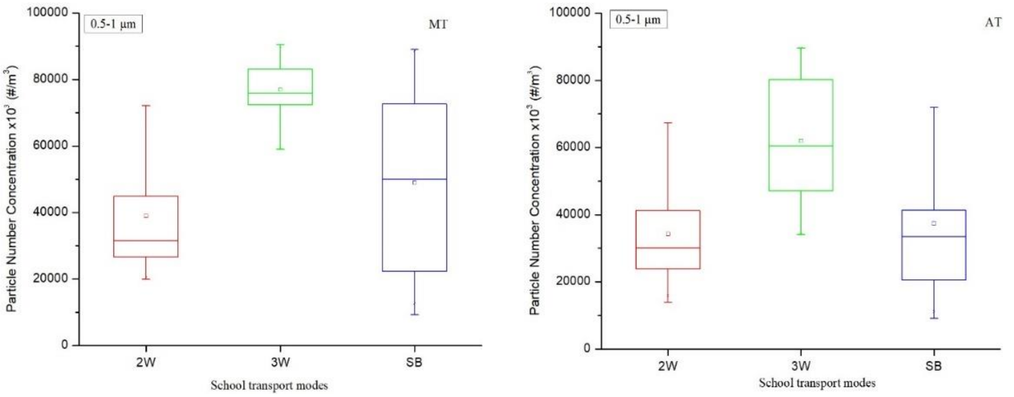
In this study, PM number concentration were measured from different motorized modes at morning school timings (MT) and afternoon school timings (AT) separately. PM number concentration depends upon the vehicle average speed, vehicle openings, age of vehicle, in-cabin volume and road-side activities. Table 2 list the mean, standard deviation (SD), maximum and minimum PM number concentration measured from 2W, 3W and SB recorded separately at MT and AT. Average number concentration of fine particulates (i.e., PM0.5-1 µm) for school transports are maximum during MT compared to AT for all vehicle groups. Among the available school vehicles, PM number concentration were recorded maximum from 3W for all PM groups i.e., PM0.5-1, PM2.5 and PM2.5-10 in AT and MT followed by SB and were recorded minimum for 2W.

Table 2. Particle number concentration for different transport modes at morning and evening school timings.

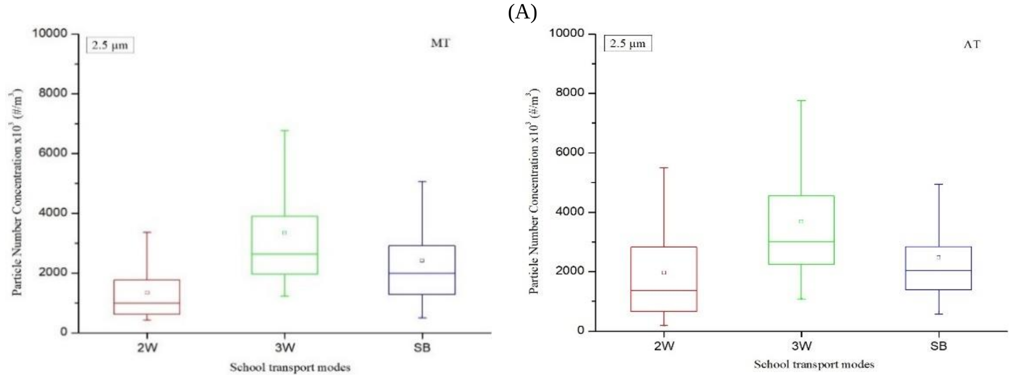
Transport modes		MT (10^3 particles/m^3)			AT (10^3 particles/m^3)		
		0.5-1 µm	2.5 µm	2.5-10 µm	0.5-1 µm	2.5 µm	2.5-10 µm
2W	Mean	38921.96	1342.82	1067.62	34212.31	1962.032	1168.2899
	SD	17391.39	956.01	778.28	15661.36	1752.03	1168.45
	Max	82842.81	5548.10	4880.73	90872.37	11700.81	9648.887
	Min	19881.78	426.70	426.70	13883.53	174.143	174.143
3W	Mean	76956.91	3342.62	3046.56	61935.01	3686.06	3239.32
	SD	6999.99	2266.56	1917.19	16588.36	2108.69	1813.21
	Max	90546.33	17951.25	12386.08	89562.70	9501.94	8234.72
	Min	58958.85	1224.83	1224.83	34108.09	1076.65	1076.65
SB	Mean	48898.37	2416.85	2368.14	37395.45	2479.91	1983.84
	SD	25870.85	1820.46	6310.12	21826.36	1907.27	1472.98
	Max	89000.82	11953.98	89075.12	88937.71	15238.67	11627.58
	Min	9208.52	494.05	250.09	9057.81	563.76	474.74

3.3. Average PM number concentration measured from different vehicle types

Fig. 3 shows the PM number concentration measured from different PST modes at school opening and school leaving hours. Box plot indicates the maximum, minimum and standard deviation value of PM number concentration whereas, solid line (inside box) indicates the median values. Average PM number concentration are maximum for 3W i.e., 76956.90 thousand particles/m3 at MT whereas, average PM concentration were recorded minimum with 2W i.e., 34212.31 thousand particles/m3 during AT. Vehicle size and average speed are the probable reason for difference in PM number concentration as 2W has high average speed with less frontal size compared to 3W lowers the residence time. PM number concentration recorded while commuting through 3W are approximately double compared to number concentration recorded while commuting through 2W. Average number concentration recorded while commuting through SB are 48898.39 and 37395.45 thousand particles/m3 at MT and AT respectively.



(A)



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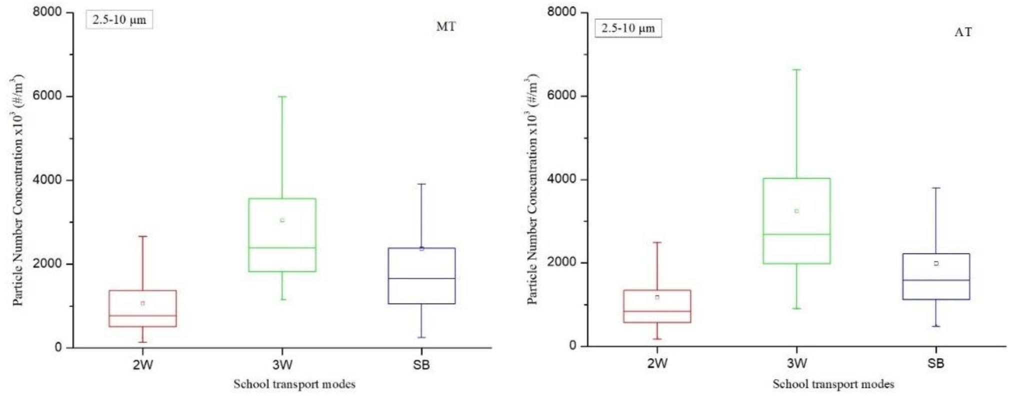

(C)

Fig. 3. PM number concentrations measured from different school motorized transport: (A) 0.5-1 μm; (B) 2.5 μm; (C) 2.5-10 μm.

3.4. Exposure of school students

Inhalation of PM number depends upon the number concentration, breathing rate and travel duration. Table 3 shows inhalation rate (IR) of school students while commuting through different school transport with average PM number concentration and calculated inheld particle number (IPN) concentration. Generally, IR depends upon the activity anyone involved with while commuting all the students are seating at their respective positions and no movement are recorded by any of the students. IR value for less or no activity are assumed in this study i.e., 12 L/min for all the PST modes. PM particle number inheld by students while commuting from different PST modes (2W, 3W and SB) are estimated in thousand particles/min of air. From fig. 4 it is clear that the maximum inhaled PM number concentration for 3W are 923.4, 40.1 and 36.5 thousand particles at MT of PM size 0.5-1 µm, 2.5 µm and 2.5-10 µm respectively and were calculated minimum for 2W as 467.06, 16.1 and 12.8 thousand particles/min respectively. Students opted for SB inhale less PM number compared to 3W and the probable reasons are high number of openings (increases cross air flow), large in-cabin volume and height of openings. 3W. Among all the motorized modes, students commuting by 3W inhales maximum PM particles followed by SB and minimum inhalation of PM particles are while commuting through 2W.

Table 3. Average particles inhaled by school students for different school transport modes at morning and evening school timings.

Transport modes	Timing	PNC (103 #/m3)			IR	IPN (#/min)		
		0.5-1 µm	2.5 µm	2.5-10 µm		0.5-1 µm	2.5 µm	2.5-10 µm
2W	MT	38921.96	1342.82	1067.62	12	467063.50	16113.80	12811.48
	AT	34212.31	1962.03	1168.29	12	410547.71	23544.39	14019.48
3W	MT	76956.91	3342.62	3046.56	12	923482.88	40111.47	36558.67
	AT	61935.01	3686.06	3239.32	12	743220.17	44232.76	38871.89
SB	MT	48898.37	2416.85	2368.14	12	586780.41	29002.22	28417.65
	AT	37395.45	2479.91	1983.84	12	448745.46	29758.98	23806.13

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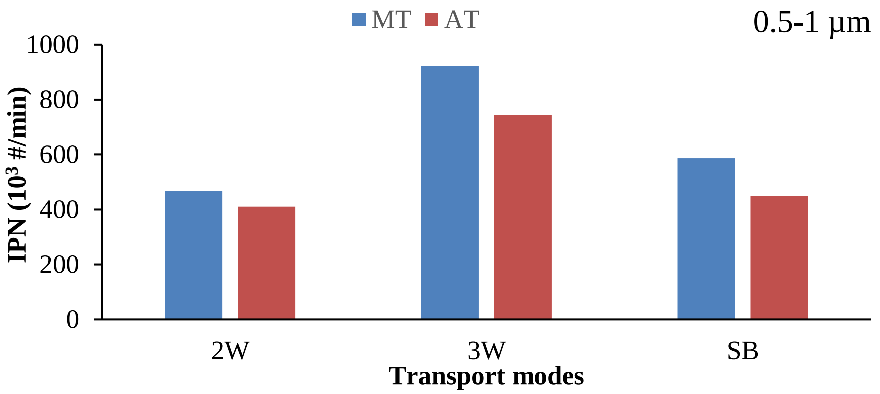
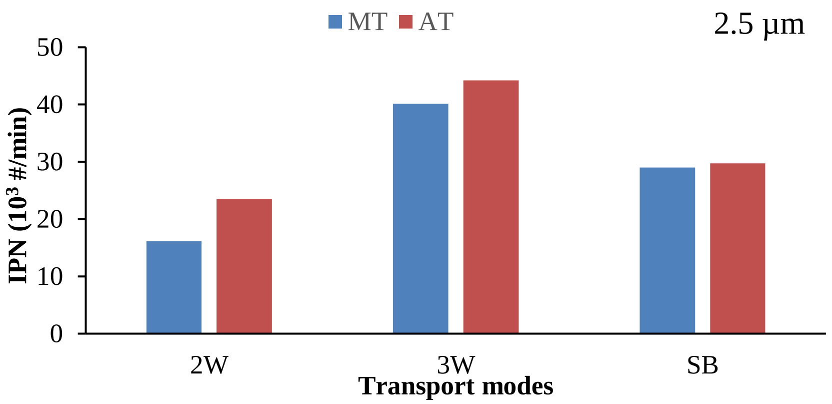


(a)



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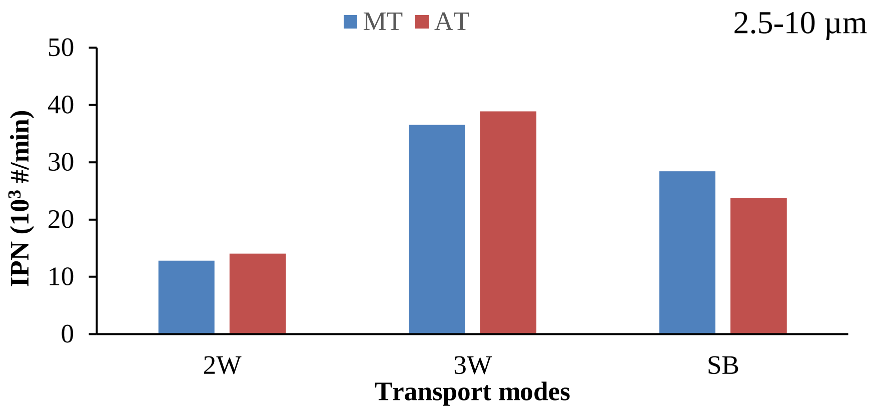

(c)

Fig. 3: Particles inheld by students while commuting through different school transports pf different PM size bin at MT and AT school hours: (a) 0.5-1 µm, (b) 2.5 µm and (c) 2.5-10 µm

4. Discussion

Students choice of school travel (AST and PST) in between the available choice of school transport and their selection behavior compared to class group, gender and age are estimated. Exposure of students towards number concentration of PM particles and their inhalation rate were calculated for different PST modes.

4.1. Factors affecting the school students in making their choice for school transportation

Preliminary study over student selection behavior for school transports predicts that student from pre-primary, primary and secondary class are more like to opt for PST transport. Most of the female students have opted for PST modes compared to male students in class category whereas, most of the male students from senior-secondary classes have opted AST modes. Out of total respondents, 42.5% of them are female students and 57.5% of them are male students. Among the total participated students, 25.1% of total had opted for AST modes whereas, remaining 74.9% of students had opted for PST modes. Among the AST users, 68.5% are male students whereas, 31.5% are female students. From the PT dependent students, 52.9% of them are female students whereas, remaining 47.1% are male students. SB are most preferred by male students i.e., 66.3% of total opted students are male and remaining 33.7% are female students. The selection criteria of school transports are influenced by different parameters like age, gender, studying class and travel distance. Amon PST dependent students, female students are more like to travel by PT whereas, male students are more like to use public transport. Motorized transports are dominantly used by the lower-class students probably due to safety and security concern.

4.2. Factors related to air pollution concentrations and Inhalation rate for students on different vehicle types

Urban traffic fleet are very sensitive and get affected with the increased population of school vehicles (Black et al., 2001). In most of the schools, their timings match with the office timings results as large vehicle population, congestion and heavy rush on-road (Singh and Vasudevan, 2018). Emissions from vehicles are very much influence by driving behavior and road structure (He and Giuliano, 2017). In this study, 180 to 200 minutes PM exposure data are used for the calculation except of 3W afternoon data. PM number concentration measure while commuting 2W are found to be less probably due to less residence time whereas, number concentration is recorded high for 3W and the reason are probably due to low height vehicle and high residence time. Diesel driven vehicles are main source of particulate matter (PM) emission of ultrafine size range (<0.1 µm), which have carcinogen potential by U.S. EPA (2002 a, b) (Hochstetler et al., 2011). Inhalation of PM concentration depends upon their breathing rate, involved activity and particulates concentration. In present study, all the students are seating at one position after boarding whereas, there exposure timings depend upon selected school mode. Students opted for 3W has maximum PM exposure and also inhales maximum particles compared to other school modes.

5. Conclusions

The influencing factors affecting the selection of school transports are age, gender, daily travel distance and available transport facility. AST modes are mostly liked by male student especially from secondary and senior-secondary classes. PST modes are mostly like by pre-primary and female students, probable reason is their parents concern for safety and security. In this study, from public modes, SB were most preferred mode for students whereas, PT modes are mostly used by the female students. Public school modes and AST are mostly liked by male students whereas, PT mode are mostly like by the female students. 3W opted students have maximum exposure towards PM compared to other available school transport at MT and AT. Inheld particle numbers are also maximum for students opted for 3W and minimum for 2W due its less residence time. High number of openings and height of school bus are the probable reason for less particle number concentration inside bus cabin.

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References

Achour, H., Carton, J. G., & Olabi, A. G., 2011. Estimating vehicle emissions from road transport, case study: Dublin City. Applied energy, 88(5), 1957-1964.

Anenberg, S. C., Miller, J., Minjares, R., Du, L., Henze, D. K., Lacey, F., Christopher, S. M., Emberson, L., Franco, V., Klimont, Z., & Heyes, C., 2017. Impacts and mitigation of excess diesel-related NO x emissions in 11 major vehicle markets. Nature, 545(7655), 467.

Black, C., Collins, A., & Snell, M., 2001. Encouraging walking: the case of journey-to-school trips in compact urban areas. Urban studies, 38(7), 1121-1141.

Bradshaw, R., & Atkins, S., 1996. The use of public transport for school journeys in London. In public transport planning and operations. proceedings of seminar f held at the ptrc european transport forum, brunel university, england, 2-6 september 1996. volume p405.

Brunekreef, B., Janssen, N. A., de Hartog, J., Harssema, H., Knape, M., & van Vliet, P., 1997. Air pollution from truck traffic and lung function in children living near motorways. Epidemiology, 298-303.

C.A. Pope, D.W. Dockery Health effects of fine particulate air pollution: lines that connect J. Air Waste Manage Assoc., 56 (2006), pp. 709-742.

DiGuiseppi, C., Roberts, I., Li, L., & Allen, D., 1998. Determinants of car travel on daily journeys to school: cross sectional survey of primary school children. Bmj, 316(7142), 1426-1428.

EPA, 2011. Exposure Factors Handbook 2011 Edition (Final). U.S. Environmental Protection Agency, Washington, DC. EPA/600/R-09/052F.

Gauderman, W. J., Vora, H., McConnell, R., Berhane, K., Gilliland, F., Thomas, D., ... & Peters, J. (2007). Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. The Lancet, 369(9561), 571-577.

Gehring, U., Wijga, A. H., Brauer, M., Fischer, P., de Jongste, J. C., Kerkhof, M., Oldenwening, M., Smit, H. A., & Brunekreef, B., 2010. Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life. American journal of respiratory and critical care medicine, 181(6), 596-603.

He, S. Y., & Giuliano, G., 2017. Factors affecting children’s journeys to school: a joint escort-mode choice model. Transportation, 44(1), 199-224.

Hochstetler, H. A., Yermakov, M., Reponen, T., Ryan, P. H., & Grinshpun, S. A., 2011. Aerosol particles generated by diesel-powered school buses at urban schools as a source of children’s exposure. Atmospheric environment, 45(7), 1444-1453.

Jain, S., Aggarwal, P., Kumar, P., Singhal, S., & Sharma, P., 2014. Identifying public preferences using multi-criteria decision making for assessing the shift of urban commuters from private to public transport: A case study of Delhi. Transportation Research Part F: Traffic Psychology and Behaviour, 24, 60-70.

Janssen, N. A., van Vliet, P. H., Aarts, F., Harssema, H., & Brunekreef, B., 2001. Assessment of exposure to traffic related air pollution of children attending schools near motorways. Atmospheric environment, 35(22), 3875-3884.

Jeong, C. H., Evans, G. J., Healy, R. M., Jadidian, P., Wentzell, J., Liggio, J., & Brook, J. R., 2015. Rapid physical and chemical transformation of traffic-related atmospheric particles near a highway. Atmospheric Pollution Research, 6(4), 662-672.

Kumar, P., Morawska, L., Birmili, W., Paasonen, P., Hu, M., Kulmala, M., Harrison, R. M., Norford, L., & Britter, R., 2014. Ultrafine particles in cities. Environment international, 66, 1-10.

Pandian, S., Gokhale, S., & Ghoshal, A. K., 2009. Evaluating effects of traffic and vehicle characteristics on vehicular emissions near traffic intersections. Transportation Research Part D: Transport and Environment, 14(3), 180-196.

Ren, C., & Tong, S., 2008. Health effects of ambient air pollution–recent research development and contemporary methodological challenges. Environmental Health, 7(1), 56.

Singh, N., Vasudevan, V. (2018). Understanding school trip mode choice–The case of Kanpur (India). Journal of Transport Geography, 66, 283-290.

U.S. EPA, 2002a. Health Assessment Document for Diesel Engine Exhaust, National Center for Environmental Assessment. U.S. Environmental Protection Agency, Washington, DC. EPA/600/8-90/057F, Available from: The National Technical Information Service, Springfield, VA, PB2002-107661. http://www.epa.gov/ttn/ atw/dieselfinal.pdf.

U.S. EPA, 2002b. Fact Sheet: Diesel Exhaust in the United States. EPA/420-F-02-048. U.S. Environmental Protection Agency, Washington, DC.

Van Roosbroeck, S., Jacobs, J., Janssen, N. A., Oldenwening, M., Hoek, G., & Brunekreef, B., 2007. Long-term personal exposure to PM2. 5, soot and NOx in children attending schools located near busy roads, a validation study. Atmospheric Environment, 41(16), 3381-3394.