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ASSESSMENT OF SOLID WASTE GENERATION AND MANAGEMENT IN SELECTED SCHOOL CAMPUSES IN PUDUCHERRY REGION, INDIA

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Abstract

Among all the prominent contributors of municipal solid waste (MSW), schools have been chosen for the study since the rate of solid waste generation and its respective composition has not been reported or rather has been underestimated in the schools of Puducherry region. Hence, the present paper is an attempt to fill up this gap in our knowledge. The existing waste management system in selected schools was unsystematic and relatively scarce to meet the waste management objectives in precise manner as specified in Municipal Solid Waste Management Rules 2016, India. During the study it was found that the average per capita waste generation rate in the selected schools was 0.092 (±0.025) kg/capita/day varying from a high of 0.117 (±0.021) kg/capita/day in higher secondary schools to a low of 0.059 (±0.020) kg/capita/day in primary schools. The mean composition of school waste was made up of 39% food waste; 33% paper; 11% silt, soil and mud (combined); 8% plastic; 2% wood, glass, metal and textile (combine); 2% clinical and sanitary wastes; 1% E-waste; 4% other wastes. Approximately, 70 - 80% of generated solid waste was burnt or dumped openly in the premises, 10 - 15% collected by municipal authorities and the remaining 6 - 8% recovered through informal recycling and composting facilities. On the basis of the findings, recommendations for developing practices for preventing the wastes generation and efficient management of the generated wastes were suggested. Establishing "waste avoidance, handling and recovery" policies and programs for food, paper, plastic and soil wastes could significantly influence the success of sustainable solid waste management system at the institute level.

Key words: environmental education, recycling, resource recovery, solid waste audit, waste characterization

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1. Introduction

Puducherry, erstwhile Pondicherry, is an amalgam of French enclaves along the East coast of India constituted into a Union Territory (UT) after being integrated into Indian Republic in 1954. It has an area of 480 km^2 and population of 1244464 as of 2011, accounting for 0.10% of India's population (Census of India, 2011). The population density in Puducherry (2598) is third highest in the country after Delhi (11297) and Chandigarh (9252) and literacy rate is 85.55%, which is 30.5% above the national average. Through smaller in area, the UT enjoys status and all facilities equivalent to any Indian State. As a consequence, the quality of living standards and development is far higher than the neigbourhood regions; immigration from other states also is high due to enhanced job and livelihood opportunities. Decadal population growth rate in the UT has increased from 20.62% in 1991-2001 to 28% in 2001-2011. Puducherry has become a regional hub for education; medical care; cultural, historical, and spiritual tourism (Puducherry Developmental Report 2010). However, the speed and scale of urbanization and economic

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growth challenges the capacity of the Puducherry Government to adequately meet the solid waste management needs of the growing number of urban/peri-urban dwellers.

Solid waste disposal and unavailability of landfill sites are the common problems faced by developing countries of Asia (Kumar, 2016). Puducherry generates an estimated 370 tons of municipal solid waste (MSW) per day and the average per capita waste generation is 0.59 g (Pattnaik and Reddy, 2010). Inadequate infrastructure, operational inefficiency, shortage of skilled professionals, lack of political concern and low community participation influenced quality of municipal services at all levels of MSW management in Puducherry region which poses serious risk to human health and degrades the environmental resources (Rajamanikam et al., 2014). MSW in Puducherry region is generated by diverse sectors, such as residential, commercial, institutional, industrial, agricultural and domestic, which may need different approaches of waste management. Educational sector is not yet considered as a major sector generating MSW and attention towards this direction is often lacking among officials, policy makers in India. Schools are high density places where the volume of solid waste has not been reported or is underestimated and collection facilities are practically non-existent. According to Ana (2011), inappropriate solid waste management practices in the schools of the urban areas is one of the key factors leading towards decline of environmental health conditions in their neighborhoods.

Setting up a waste management system in schools not only provide a clean and healthy environment for students, but also cultivates a deeper understanding of sustainable practices that have a carry-over effect into their later life where they would live and be employed (Chapman and Sharma, 2001; Kayihan, 2012). Environmental projects and involvement in programs associated with education for sustainable development or education for environemtal protection is suggested to encourage interest of the students towards environmental problems (Alexandar and Poyyamoli, 2011; Otto and Pensini, 2017). Working with schools also has the advantage of educating the students about waste related issues and best management practices. In addition, the educational institutions can pioneer sustainability practices in the society (Iojă CI et al., 2012).

A total of about 2,55248 students were enrolled in both Private and Government schools in Puducherry, which represents 21% of total population of Puducherry (Dept. of Education, Puducherry 2011). Considering the demographic fact, the urgent need for collecting information related to solid waste generation rate and waste stream composition at schools cannot be ignored. At present, data on solid waste generation and disposal practices at schools of Puducherry are undocumented. There is no accurate data available regarding the sources of waste and quality of waste generated. Nevertheless, there is ambiguity regarding the devolution of roles and responsibilities for school waste management among the stake holders which has resulted in the lack of proper guidelines for management of solid waste at the schools situated in Puducherry. The aim of the study was to generate baseline information on the rates of solid waste generation; its quantity and composition at selected schools of Puducherry region and to, review the existing campus waste management practices along with appropriate recommendations. Thereby, the most appropriate and viable alternatives can come out which would recognize precise and locally pertinent opportunities for the reduction of waste, reuse and recycling, representing an important step towards green and healthy school campuses.

2. Material and methods

2.1. Study location

The Union Territory (UT) of Puducherry is an agglomerate of four geographically separated coastal regions viz. Karaikal, Mahe, Yanam and Puducherry. Puducherry is the capital city of Puducherry UT, which is located on the east coast (Coromandel Coast) of South India, 162 km south to Chennai city. It consists of 12 scattered areas lying in between 11o 42' 12o 30' N and between 76o 36' and 79o 53' E. Puducherry district is divided into two Municipalities and five Commune Panchayats for administrative convenience.

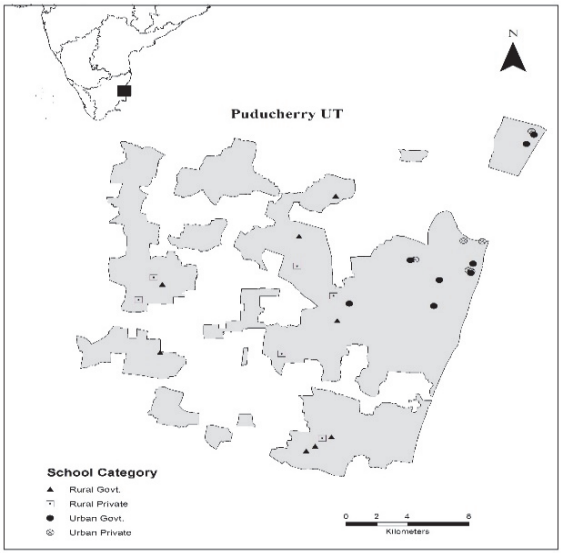

Fig. 1. Geographical Locations of Selected School

2.2. Profile of school education system in the union Territory of Puducherry and sampling procedure

There are 718 schools in the Union Territory of Puducherry with a total enrollment of 255248 students that represents the 20.55% of the total population (Department of Education, Puducherry- 2011). Of the total 718 schools, 487 schools are located in Puducherry district, 60% of the schools are Government run and 40% privately managed. Most of

the Government schools use the local language *i.e.,* Tamil as the medium of instruction, while private schools generally opt for English. As of 2011, 76% of the total population and 75% of school students in the Union territory belong to the Puducherry region. The concentration of schools /higher number of students in Puducherry region made this an ideal site for the present study. Table 1 provides details about the student's enrolment by classes in Puducherry schools as of 2011.

There are 487 schools in Puducherry district of which 283 are run by State Government and 201 by private organizations or individuals (3 schools run by Central Government were not considered for the study as they form the minority). For this study, the schools were divided into four strata *viz.*, Rural Government schools, Rural Private schools, Urban Government schools and Urban Private schools and samples were drawn in a convenient manner based on the school's self-interest and co-operation of the school staff and availability of different age groups in the school. 28 schools were selected for the study, following a 5% sampling regime, drawn from all seven administrative divisions in Puducherry region (Municipality and commune panchayats). (Fig 1). The study also intended to determine the difference in waste generation and composition across different age-groups within these strata.

There are broadly four stages/levels of school education in India, namely primary school (age group 5-10; classes – 1st to 5th standards), middle school (age group 10-13: classes – 6th -8th standards), high school (age group 13-15; classes 9th – 10th standards) and higher secondary (age group 15 – 17; classes 11th – 12th standards). In Puducherry, most of the Government schools are having either one or a combination of different levels of education (belonging to different age groups) and correspondingly named based on the highest level available in school such as primary (1st- 3rd, 1st- 5th standards), middle (1st- 8th), high (1st – 10th or 6th - 10th) and higher secondary schools (1st to 12th; 6th to 12th or 9th to 12th). However, most of the private schools in Puducherry region are "composite schools" having classes starting from 1st standard to highest level as the name of the school suggest, like 1st to 5th (primary school), 1st to 10th standards (high school) or 1st to 12th standards (higher secondary school). It was a challenging to select equal proportion of Government and Private schools having similar age group distribution, since most of the private higher secondary schools had 1st to 12th standards (primary school included) and Government higher secondary schools had no primary school level in higher secondary school. Hence samples were drawn in such a way that the primary school is proportionately represented by drawing additional samples from both Government school strata to match the private composite schools having all age groups from 1st to 12th standards.

2.3. Waste generation and characterization

The available literature indicated that classification and quantification of solid waste streams is essential and a reliable data is required to design any sustainable soild management system (Adeniran et al., 2017; Gallardo et al., 2016; Zotesso et al., 2016). The pilot scale studies had shown that the amount of waste generated by building construction and campus greening activities complicated the estimation of the exact quantity of waste generated by students. Therefore, solid waste generated in any selected school was classified into campus and student wastes. Campus waste is generated by the school gardening and construction activities. Student waste composed of materials discarded from classrooms, corridor, conference hall, library, administration and office rooms, food service area, open field, laboratory, rest room and health center.

The waste stream was analyzed through physical collection of solid waste from all functional sectors of the school campus. Collected wastes were then sorted, weighed, characterized and analyzed. During the waste audit, the sources of waste generation were determined and labelled and the net weight of collected waste was calculated. The waste was sorted into ten categories outlined by the Center for Science and Environment (2011) Manual, such as paper, plastic, soil/ mud, food waste, horticultural waste, wood, glass, metal, e-waste and hazardous wastes; additionally, the category "others" was added to include those waste which will not fit into these categories. The waste audit was conducted during the six-month period between November 2011 and February 2012 and August 2014 and November 2014.

Table 1. Student Enrolment in Puducherry Schools - 2011 (Source: Puducherry Education Department)

	Student Enrolment in Numbers				
Category	***Puducherry Region***	***Karaikal***	***Mahe***	***Yanam***	***Total No. of Students***
Primary school	82.466 (76%)	17572 (16%)	4617 (4%)	4865 (4%)	109520 (100%)
Middle School	53907 (76%)	11140 (16%)	2673 (4%)	3224 (4%)	70944 (100%)
High School	34929 (76%)	7343 (16%)	1857 (4%)	1847 (4%)	45976 (100%)
Higher Secondary	22354 (77%)	4203 (15%)	1162 (4%)	1089 (4%)	28808 (100%)
Totals Students	**193656**	**40258**	**10309**	**11025**	**255248**
% for Each Category	76%	16%	4%	4%	100%

In each school, samples were collected for a week. Schools were provided different color polythene bags to segregate and collect the waste at the source. Food waste generated from each school was collected and weighed every day in the studied week and dry and garden waste was collected and weighed weekly. The per capita waste generation of each school was calculated by dividing the total waste generated with the total number of campus strength (students + teachers + staff). Essential equipment used during the waste audit included manual weighing machineries both the minimum scale (Postal weighing scale with the capacity of 1 kg x 5 g) and medium scale (Hanging scale having accuracy of 50 g, rated load 100 kg), protective wear (gloves, mask), structured survey sheet and sorting bags. Analysis for Correlation were performed to find a link between quantity of waste generated per day and the strength of the campus community.

2.4. Disposal or treatment practices

Information related to current waste management practices were gathered through intensive field visits, direct observation and interaction with key management staff of the selected schools. To gain a deeper understanding of campus committed practices on waste management, information was also gathered from school principals, science teachers, selected students and all sanitary workers. Structured open ended questionnaires were prepared both in English and the local language *i.e.,* Tamil to to obtain information on solid waste storage, collection, handling and processing practices. After pre-testing, they were finalized and used.

3. Results and discussion

3.1. Waste characterization and quantification

The average rate of waste generation was 0.092 (±0.025) kg/capita/day -varying up to a higher limit of 0.117 (±0.021) kg/capita/day in higher secondary schools to a lower limit of 0.059 (±0.020) kg/capita/day in the primary schools; during festivals, seminars, sports and cultural days, the school campuses attracted more visitors and consequently, waste generation rate was higher (14-20%) than on normal days. Waste stream predominately was composed of four categories (food waste, paper, plastic and soil materials) that together represented 91% of the quantity of the total waste generated by the campus community (Table 2). Table 2 presents the solid waste per capita generation rates of four major categories of schools studied at the Puducherry region.

The waste category "others" included pencil shavings, crayon, foam, thermocol, chalk pieces and other unidentified materials, constituted 4% of total waste stream. Metals, glass, wood, rubber and textile wastes (combined) and clinical/sanitary wastes each contributed 2% to the waste stream while E-waste is the least representing waste, amounting only 1% of the waste stream (Table 2). The wood component of campus solid waste came mainly from furniture, but this component will diminish as schools have recently started to use metal furniture instead of wooden. This trend may lead to less re-use because damaged wood items are repaired or used for other purposes while damaged metal furniture is resold. Glass waste came mainly from broken laboratory wares and broken window panes. The main source of rubber in campus solid waste is footwear, eraser, cycle and automobile tyres. Classrooms and offices are the major contributors of paper waste. Paper waste consisting of mixed and notebook paper and other categories that includes materials, such as colored printed paper, officer paper, news paper, and cardboard.

In private schools, news papers and office papers formed the dominant fraction on paper waste; the newspaper being generated from the compulsory student subscription to daily newspaper at school. In Government schools, the notebook paper, book wraps and hard cover formed the major portion of paper waste.

Table 2. Average per capita solid waste generation rates at different categories of schools

	Primary school (1 to 5 std)		***Middle school (6 to 8 std)***		***High school (9 to 10std)***		***Higher sec. student (11 to 12 std)***		***Mean - waste generation rate***	
Waste category	***kg/capita /day***	***(%)***	***kg/capita /day***	***(%)***	***kg/capita /day***	***(%)***	***kg/capita /day***	***(%)***	***kg/capita /day***	***(%)***
Food	0.028	47	0.042	43	0.044	40	0.034	29	0.036	39
Paper	0.013	22	0.030	31	0.035	32	0.048	41	0.030	33
Plastic	0.005	8	0.007	7	0.008	7	0.010	8	0.007	8
Soil & mud	0.007	12	0.011	12	0.015	13	0.011	10	0.010	11
Wood, glass metal & others	0.001	2	0.002	2	0.002	2	0.004	4	0.002	2
E-waste	0.001	1	0.001	1	0.002	1	0.003	2	0.001	1
Clinical/ sanitary	0.000	0	0.001	1	0.003	3	0.004	4	0.001	2
Others	0.005	8	0.003	3	0.002	2	0.002	2	0.003	4
Total per capita generation (kg)	0.059 (±0.020)		0.096 (±0.019)		0.110 (±0.036)		0.117 (±0.021)		0.092 (±0.025) *	

*Numeric values provided in the Table 1 represents quantitative rate (weighed mean) of student waste (kg/capita/ day) generated at different schools categorized, (±) represents Standard deviation, (%) Percentage; * statistical variation*

Analysis of variance was performed to test whether there is any variation in the amount of waste generated among different level of schools, corresponding to student age groups. ANOVA has revealed that the mean per capita waste generation rate is significantly different (*p- value* < 0.001) across different major age groups (Primary, middle, high and higher secondary) (Table 3). The mean per capita waste generation rate gradually increased from primary to higher secondary schools (Table. 2) due to the factors associated with age of the students, academic activities, type of schools; teaching and study materials used at different classes.

Higher secondary schools showed the highest SW generation rate (0.117 kg/capita/day) by having maximum paper waste generation as a result of more paper consumption and usage at class rooms (Table. 2). Food waste accounted for 29%, and silt, soil, mud (combined) contributed 10% followed by the paper wastes. Higher secondary schools also had generated the highest (0.004 kg/capita/day) quantity of wood, glass, metal and textile wastes (combined) than the other category of schools. The E- waste was more significantly produced at 3% at high schools than the 1% uniformly found in primary and middle schools. While clinical and sanitary wastes were not encountered at primary level, higher secondary students produced considerable amount (0.004 kg/capita/day) which mainly consisted of sanitary pads and paper tissues. This indicates the importance on implementing segregation programs, installing the scientific incinerator or adapting other relevant scientific disposal practices at higher secondary schools.

The high school student waste was made up of 40% food waste, 32% paper, 13% soil, 7% plastic, 3% clinical and sanitary wastes, 2% wood and other category wastes and 1% E-waste (Table. 2). The waste stream for middle school ranged from 43% food wastes to 1% E-waste and clinical wastes respectively. The remaining waste was composed of paper (31%), soil (12%), plastic (7%), others (3%) and wood, glass, metal (combine) 2 % of total waste stream (Table. 2). Middle and high school level students produced higher amount of food waste -0.042 kg/capita/day, 0.044 kg/capita/day, respectively than the other groups. The food waste was lesser (0.028 kg/capita/day) at primary schools because food servings at this level was managed and monitored well by the concerned staff and authorities. In the case of plastic wastes, the highest amount (0.010 kg/capita/day) was found in the higher secondary schools and the lowest amount (0.005 kg/capita/day) in the primary student waste stream. Highest amount (0.019 kg/capita/day) of silt, soil and mud (combined) waste was produced at high school level. Primary school generated the least amount of SW on a per capita basis at 0.059 kg/capita/day. The category "others" was higher (0.005kg/capita/day) at primary schools because at primary level students use more pencil, crayon and chalk pieces. Thus, the student age, stages of school education and educational materials used at different levels of education has directly affected the quantity of SW generated at different category of schools.

Two-tailed t-test was performed to test the level of variation among different age groups of students in generation of different categories of waste. Two tailed t-test revealed that generation of food waste (*p* value <0.001) and paper materials (*p* value < 0.05) significantly varied between government and private schools at each stratum (Table. 4). Among all age groups, Government schools generated more amount of food waste than the private schools (Government school mean per capita value is 0.072 kg against 0.013 kg at private schools). In Government schools, the value increased steadily with the age of students, the highest per capita generation being 0.091 kg/capita/day by Government high school; except in higher secondary level which showed slightly lower value. Interestingly, the food waste per capita generation value remained almost the same across different age groups in Private schools (Table 2). Such major variation between government and private schools can be due to the difference in policy followed by them regarding food waste. Government schools were not having any policy on food waste reduction. Students in Government schools were provided with free lunch and snacks; a portion of food received was wasted due to difference in individual preferences, taste, quality and requirement. Students often took more food than they can eat and decided not to take it after tasting it, if it is not palatable.

The leftover food is dumped in the campus itself. On the other hand, the students in Private schools were restricted from dumping the leftover food in school campus since the schools had employed part-time sweepers who were scheduled to work in the forenoon hours, and hence had to take their food waste back home. Results suggested that food waste reduction initiatives must be effectively implemented at Government schools. In private schools, the paper waste stream was predominantly composed of newspaper, whitepaper, notebook paper and office paper while in Government schools, the paper waste stream composed of notebook wraps, parcel wraps and notebook paper.

Table 3. Analysis of variance – testing the variation of the mean per capita waste generation among the major categories of schools

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	0.038794983	3	0.012931661	11.23838163	3.93	2.731807
Within Groups	0.082848191	72	0.001150669			
Total	0.121643174	75				

Table 4. Comparison of mean per capita waste generation values between Government and Private schools

Waste category	*Primary school*	*Middle school*	*High school*	*Higher Sec. school*
	Govt. – Private (kg/capita/ day)	*Govt. - Private (kg/capita/ day)*	*Govt. - Private (kg/capita/ day)*	*Govt. - Private (kg/capita/ day)*
Food	0.050 – 0.013**	0.084 – 0.013**	0.091 – 0.012**	0.064 – 0.013**
Paper	0.010 – 0.015*	0.037 – 0.024*	0.027 – 0.040**	0.040 – 0.051*
Plastic	0.004 – 0.005	0.007 – 0.006	0.006 – 0.008	0.008 – 0.008
Soil & mud	0.010 – 0.004**	0.010 – 0.008**	0.019 – 0.011*	0.012 – 0.010
Wood, glass, metal& others	0.001 – 0.001	0.002 – 0.001	0.001 – 0.002*	0.003 – 0.004*
E-waste	0.000 – 0.000	0.000 – 0.001*	0.001 – 0.002**	0.002 – 0.003*
Clinical/ sanitary	0.000 – 0.000	0.000 – 0.000	0.003 – 0.003	0.003 – 0.004
Others	0.004 – 0.005*	0.002 – 0.004**	0.001 – 0.002*	0.001 – 0.002*
Total	0.080 – 0.044**	0.142 – 0.058**	0.152 – 0.081**	0.140 – 0.100**

** values with asterix indicate categories showing statistically significant variation*

** p value < 0.05; ** p value < 0.001*

The mean per capita paper waste generation also significantly varied across all categories (p<0.05) among Private and Government schools, and in high school category this variation was significantly higher (p<0.001). While the average per capita paper waste generation was 0.027kg/capita/day in Government high school, the average per capita paper waste generation in private schools was 0.040 kg/capita/day. The increased production of paper waste in private schools was found to be due to compulsory individual subscription to newspaper middle school onwards; frequent assignments and class tests; print outs and photocopies; paper craftworks. Wood, glass and metal waste generation pattern varied only slightly between Government and private schools, but the generation rate was higher in high and higher secondary schools. This can be due to increased glass waste generated in these age groups from broken laboratory wares. There was no variation in the per capita generation of plastic wastes and sanitary wastes between any category of Government and Private schools. The composition of plastic wastes was also similar in both Government and private schools, being composed of chocolates and snacks wrappers, food parcels and book wraps. This is an interesting observation since majority of them being unavoidable along with purchases of food items. The waste streams of both primary and middle schools have not produced clinical and sanitary wastes; the absence of sanitary waste is due to the age of students and absence of clinical waste reflects lack of first aid and primary health care facilities at the selected schools. Prominence of sanitary pads in the sanitary waste stream in higher age groups point out the lack of attention paid towards the proper disposal of sanitary wastes in both Government and private schools. E-waste generation can be seen as being slightly higher in private middle and higher schools and significantly high in private high schools. This was because computer education becomes part of curriculum in these levels and private schools used computer for office administration as well, unlike Government schools. The 'others' waste stream had similar composition in both private and Government schools, of crayons, pencil shreds, chalk pieces, decorative materials etc.

The generation of category 'others was also found to vary significantly between all categories of Government and Private schools; the rate of per capita waste generation was 0.001 – 0.002 kg/capita/day in the higher secondary government/ private schools and government/ private high schools. The categories of soil wastes and others significantly varied between and among the different groups of schools studied. Unpaved or poorly constructed campus contributed to significant amount of silt and soil waste from sweeping activity in Government schools.

The per capita waste generation rate and its composition in high and higher secondary schools in both urban and rural areas were similar. There is no significant variation observed across different age groups of rural and urban schools in generation of different categories of wastes. The waste generation in urban middle school and rural middle school significantly varied in four categories of wastes. *viz.*, paper ($p < 0.001$), plastic ($p < 0.001$), E-waste ($p < 0.05$) and clinical/sanitary wastes ($p < 0.05$). The data shows that the per capita waste generation rate for the above categories is higher in urban middle school when compared with rural middle school. While the category paper waste constituted the highest fraction of waste produced in High (0.035 kg/capita/ day) and higher secondary (0.045 kg/capita/ day) schools, its generation rate varied significantly among urban and rural schools while the remaining fractions (food, plastic, soil, wood, sanitary waste and others) were generated almost in equal amount (Table 5). The urban primary schools were found to generate more waste category 'others' than its rural counterpart and the generation rate was found to vary significantly (p<0.05) between rural and urban primary schools. Based on these findings, it is suggested that a separate waste management policy for urban and rural schools is unnecessary. Also, the major variation in waste generation pattern between Government and Private schools indicated that separate waste reduction and management policies should be framed for Government and Private schools, according to the major waste fractions and respective generation rates. It is also suggested that establishing "waste avoidance, handling and recovery" policies and programs for

food, paper, plastic and soil wastes at each school along with appropriate motivational and communication strategies could significantly influence the success of sustainable solid waste management system in the schools. The primary factors affecting waste generation/management at school level appeared to be waste management policy, purchasing strategies, waste management knowledge, awareness and infrastructure facilities.

Table 6 presents the recoverable components from solid waste and their percentage share on per capita basis. Among all the selected schools, biodegradable fraction accounted for the major component 0.047 kg/capita/day (50%) of the total waste stream that consisted of food and silt, soil and mud wastes. Hence, by adopting composting, school campuses can significantly reduce waste volume as well as can generate a valuable soil conditioner for horticultural use.

Recyclable portion consisted of paper, plastic, wood, glass, metal and others represented 0.041 kg/capita/day (42%) of total waste stream. Hazardous waste portion made of clinical, sanitary and E-wastes account for 4%. The category "others" are of both partially recyclable and non-hazardous in nature consisted 4% of total school waste. The food waste consists of uneaten and leftover food. Food waste (78%) was a major component in compostable category followed by silt, soil and mud (22%). But not enough attention has been paid by the school authorities towards food waste avoidance and management system. Segregating waste into compostable, recyclable, hazardous wastes and others at source improves recycling and minimizes the quantity of waste ends in the landfills. The garden waste was comprised of dry leaf litter, tree branches and trimming contributed the highest weight amount of campus waste (11 kg/day). The construction waste combined with dirt and concrete materials was the second largest component (5.6 kg/day) of campus waste (Table 7).

Garden waste generation rate was the highest in rural government schools (19 kg/day) and lowest rate was observed in Urban private schools; Urban private schools did not have enough land to support gardening practices while in rural Government schools we observed good tree canopy area.

3.2. Existing waste management practices in selected schools

In Puducherry, MSW is generated by diverse sources, such as residential, institutional, industrial, tourism, commercial and medical sectors were managed in a common platform by the state municipal authority with the partnership of private agency agencies and contractors. These private agencies and contractors were involved in solid waste collection, transportation and disposal services in ways that were inadequate and inappropriate and in violation of most of the MSW management rules. Collection of MSW from schools was given low priority. Around 80% of Rural Government and Urban Government schools did not have proper access to waste collection facilities from the local solid waste management services.

Table 5. Patterns of solid waste quantity and composition of Urban and Rural school

Waste category	***Primary school***	***Middle school***	***High school***	***Higher Sec. school***
	Urban – Rural (kg/capita/ day)	***Urban – Rural (kg/capita/ day)***	***Urban – Rural (kg/capita/ day)***	***Urban – Rural (kg/capita/ day)***
Food	0.030 – 0.025	0.046 – 0.037	0.044 – 0.044	0.033 – 0.035
Paper	0.014 – 0.010	0.037 – 0.021**	0.037 – 0.033	0.050 – 0.041
Plastic	0.004 – 0.004	0.009 – 0.006**	0.007 – 0.008	0.010 – 0.010
Soil & mud	0.005 – 0.008	0.011 – 0.011	0.013 – 0.016	0.011 – 0.012
Wood, glass, metal& others	0.001 – 0.001	0.002 – 0.001	0.003 – 0.003	0.005 – 0.004
E-waste	0.000 – 0.000	0.001 – 0.000*	0.002 – 0.002	0.003 – 0.003
Clinical/ sanitary	0.000 – 0.000	0.001 – 0.000*	0.003 – 0.003	0.004 – 0.004
Others	0.005 – 0.003*	0.003 – 0.004	0.002 – 0.002	0.002 – 0.002
Total	0.062 – 0.054	0.112 – 0.081	0.111 – 0.109	0.117 – 0.117

** values with asterix indicate categories showing statistically significant variation*
** p value < 0.05; ** p value < 0.001*

Table 6. Mean weight/percentage of Compostable, Recyclable, Others and Hazardous wastes of selected schools

	Compostable		***Recyclable***		***Hazardous Waste***		***Others***	
	kg/ capita/ day	***(%)***	***kg/ capita/ day***	***(%)***	***kg/ capita/ day***	***(%)***	***kg/ capita/ day***	***Percentage***
Primary school	0.035	59	0.022	36	0.001	2	0.001	2
Middle School	0.053	55	0.039	41	0.002	2	0.002	2
High school	0.058	52	0.043	39	0.005	4.5	0.005	4.5
Higher secondary school	0.043	37	0.06	51	0.007	6	0.007	6
Mean composition (Kg/capita/day)	0.047	50	0.041	42	0.003	4	0.003	4

Table 7. Mean weight/percentage of Campus solid waste

	Urban Govt. school		*Rural Govt. school*		*Urban Private school*		*Rural Private school*		*Mean waste generation (kg/day)*
	(kg/day)	*(%)*	*(kg/day)*	*(%)*	*(kg/day)*	*(%)*	*(kg/day)*	*(%)*	
Garden waste	9.5	22	19	44	6	14	8	19	11
Construction debris	3.5	15	0	0	11	50	8	35	5.6

However, urban private schools spent money or through political support and effective communication, have organized some support from the municipal services but the system was not adequate to meet the need due to lack of resource recovery practices. Once in a week private contractor collect mixed waste from schools along with other municipal wastes and directly transported them to the waste dump site without recovering recyclable materials.

At present, there has been a limited effort to achieve an appropriate/efficient waste management system in schools of Puducherry region. In general, the campus authorities understand waste management to be complex and expensive. In schools, due to the Government interest on anticipated benefits from waste management, heath and environmental concerns motivated people to initiate waste management program but often they failed to sustain the service due to lack of financial resources, inadequate man power and equipments, technical expertise, onsite processing facilities and poor student participation. 90% of urban and rural government schools did not have proper containers at any of the storage sites; some 20% schools used proper bins only at staff room and administrative wing; some of this schools used cardboard boxes instead of durable plastic bins at classrooms and office areas; in dining area, government schools use second-hand bins without lid which is not ideal for food waste storage. Un-segregated waste at all the government schools was generally dumped within or outside their premises on the street, open land, in drains and other sensitive areas without being treated. Almost any unused ground within the school boundary was used for dumping. This has to be viewed against the backdrop of several earlier reports that pointed out insufficient management of solid waste in majority of the cities in developing countries, that could pose serious problems to human health, environmental and well being (Joshi and Ahmed, 2016; Ziraba et al., 2016; Singh et al., 2018). Around 60% of private urban and private rural schools have installed plastic containers with proper lid in classroom, corridor, lab, office, dining hall, play ground and garden areas; On an average 12- 40 bins varying with 9- 60 litre size were used in private schools based on waste sources and campus population; but only 34% of them used dual bin system to separate waste into organic and inorganic fractions. Surprisingly, none of the selected schools adopted source segregation practices due to lack of awareness, inadequate training, and absence of recycling facilities that made students to think source segregation is a waste of time. Dumping on street corners or burning was the dominant disposal option of the private schools who received inadequate solid waste collection services. It was seen that about, 70 - 80% of the total solid waste generated is either burent od dumped in the campus, out of which only 10 - 15% is collected by municipal authorities and the remaining 6 - 8% is recovered through composting facilities and informal recycling practices. Open burning of garbage- especially plastic causes smoke nuisance and releases toxic fumes (some of them are carcinogenic, such as dioxins and furans) into the environment and damages human health and natural resources (Wiedinmyer et al., 2014; Verma et al., 2016; Wang et al., 2017). Even though proper treatment plants are not in place, majority of rural government schools converted garden waste into compost. Raw garden wastes such as un-shredded tree trimmings, leaf letter and grass mixed with soil materials were decomposed by natural decomposition process; but the compost was not properly utilized, with several heaps left unattended. Leftover food items at rural government schools were fed by livestock and street dogs, recovered in the form of animals feed. Proportion of garden waste recovered through composting practices at Unban government and urban private schools was very low (20 – 30%) due to lack of space and knowledge about appropriate composting practices. Construction debris, bulky wastes (furniture, vehicle parts, and wood branches) and materials that cannot be disposed off without proper permission were accumulated in all parts of both government and private school campuses. Increased land values have made storage area unavailable and concerns of the neighbors about burning and dumping garbage has further complicated the problem and there is more and more of a crisis to solve the waste management issues in schools.

Informal recyclable collection provides the recovery facility for small quantity (2%) of recyclables. Sweepers and peons get a small amount of revenue from the commercially valuable portions, such as metal, newspaper, cardboard and office paper. It is suggested that the re-organization of social, economical and environmental benefits from informal recycling should be examined systematically so that its implications can be well understood (Nzeadibe, 2009). The advantages of recycling not only limits upto saving the landfill space, but also conservation of energy, reduced pollution, conservation of resources and reduction of expenses due to avoided costs. It is estimated that about 6 to 8 per cent of the total waste stream in the selected schools were recycled or composted while 92 to 94 per cent of campus solid waste was disposed off in an inappropriate manner.

In all girls and co-ed schools, mostly there was no proper system for collection and disposal of sanitary wastes. Poorly managed sanitary napkin wastes often ends up in drainage systems where it clogs pipelines resulting in damage to the infrastructure, flooding and breeding of insect and rodent vectors. In some schools, incineration of sanitary wastes has been introduced to ensure proper disposal. They installed low cost simple incinerators near toilets to burn the used pads at high temperature. Due to limited experience with waste incineration, the sustainability and environmental impacts of these practices are yet to be assessed and understood. Executing an awareness drive that will embolden students to initially consume less food initially and get second helpings if still hungry could help to curtail the amount of food being wasted. Similarly, the cooks also may be informed about the need for preparing tasty food, given the financial constraints.

Memnon et. al. (2010) has reported that the reduce, reuse, and recycle (3 R) approach in waste management can tap into potential resource recovery methods along with significant reduction in the health and environmental risks posed by unscientific solid waste disposal. There is no policy about reducing, reusing and recycling practices in most (80%) of the schools in the region. As a consequence, existing systems for recycling and disposal of solid wastes were unsatisfactory from the resource recovery point of view. Some (20%) private schools at the urban and rural areas have established plastic free zone at their campuses where people are not allowed to use plastic materials. Almost all selected schools have organized annual campus cleanup program which involves students and teacher volunteers engaged with service learning.

3.3. Action plan for sustainable campus waste management program

During the study, it was observed that there is no effective solid waste management program practiced at the schools studied. India is not having a separate waste-management policy for schools, the Municipal Solid Waste Management Rules, 2016 is broadly applicable to schools and other institutions as well; and the local self government (Municipality and Commune Panchayat, in Puducherry) is the designated authority for collection, transportation and disposal of MSW. However, Municipal authorities generally ignore the school wastes and let the schools themselves take care of the waste or the school should pay to get these services.

The interactions with the school administrators revealed that even those school authorities who were willing to initiate and adopt solid waste management programs have struggled with lack of guidelines, expertise and infrastructure; and hence were not successful. In this section, a four- step cost effective participatory local waste management plan for schools is proposed which involves design and planning, capacity building and awareness programs, implementation and operation, monitoring and evaluation.

3.3.1. Design and planning

The first phase “design and planning” starts with formation of a school committee committed to waste management. The committee should consist of a volunteer group of students, teachers, non-teaching staff and parents. The students can be drawn from the existing student volunteering programs such as National Service Scheme (NSS), National Cadet Corps (NCC), National Green Corps (NGC) and Nature Clubs. Other students should also be motivated to join the committee from different age levels. Teaching staff headed by Principal should initiate, supervise, assign tasks to the students, set targets and assess the results. The assisting teachers should be selected by the Principal preferably from science and physical education background including the teacher /student coordinators of the above progamme. The non-teaching staff that include sanitary workers, peons, plumbers, gardeners, security personnel and caterers should also be made a part of the committee, selected based on their personal willingness to commit time, energy and effort for the tasks with a passion to serve and lead the green school movement. Parents should be informed and updated on the working plan of the committee and requested to help their children comply with the school policy by assisting them in waste reduction practices. This waste management committee should ‘design’ an appropriate program that would comply with the National Policy and the local waste disposal facility available (A list of adoptable waste minimization policies in schools is given in 4.4).

Primary and long-term targets of the program should be set; and the roles and responsibilities should be determined. This team will also suggest key operational elements (source separation, collection, transportation, processing and disposal aspects), institutional framework, help to form working groups, design equipments and sites, organize capital investments and operational costs, design outreach programs. Students can be divided into teams and assigned different activities such as solid waste audit, campus clean up, reuse of materials, collection, composting, recycling, organizing exhibitions, conducting monthly meetings, cost accounting, preparing flyers, poster and newsletters for awareness creation. This team will also investigate and record solid waste sources, generation rate, composition and its recovery rates under the guidance of a teacher. A monthly meeting can be organized for the non-teaching staff under any supervising teacher to instruct and train them to follow the newly adopted MSW programme in their respective work areas at school. The Committee should identify appropriate funding sources, which can be through exploring Government aid for school sanitation programs as well as charging a justifiable waste management fee from the campus community. In addition, local industries may be approached for support under Corporate

social/Environmental Responsibility. The Committee should work on a quarterly review basis and an annual report would document the various aspects of the program implemented, which can be published in the school magazine.

3.3.2. Capacity building and awareness programmes

Capacity building through regular education, awareness and training programs is the supporting pillar of any participatory waste management program. The efficiency of this step determines the level of success that the program may achieve. It should be an ongoing process that helps to sustain the initial level of enthusiasm and effort being put during the design and implementation phases of the program as new staff and students join in. These programs can be designed in various stages before and throughout implementation of the waste management program. Since the participants belong to different age and education levels, separate programs should be arranged accordingly. Five main issues are needed to be addressed through these programmes adopting green practices at individual level (minimization, diversion, reuse), creating awareness on role and responsibilities of each individual (avoiding unrecyclable materials, proper usage of waste bins), tricking down of guidelines from the administrative level to individual level (effective implementation of policies and programs), and specific instructions for how to practice source separation, recycling and scientific disposal activities. The program can be commenced with an open lecture with a short video and/ or one-day seminar/workshop that introduce basic waste management concepts to the campus community. The training workshops should be organized separately for students belonging to different age groups (primary, middle, high, higher secondary levels) according to their ability to grasp the concepts. The concept and principles of sustainable solid waste management program and its benefits can be incorporated into the curriculum. This curriculum should be developed considering students age and class limits. The capacity building should involve stories and fun games (for primary students), puppet shows, skits, documentary movies, invited talks, training workshops (making of paper bags, crafts from waste, composting etc), field trips to scientific waste management facilities and demonstrations. The students should be encouraged to device innovative waste management models that can be presented in interschool science exhibitions.

Regular guest talks and field visits to nearby ongoing waste management sties can develop the staff knowledge. Hence, a series of environmental education campaigns need to be conducted to improve the network linkages among the different groups for bringing desirable changes in their behaviors or habits. A structured newsletter and posters must be made to guide the participants. A dedicated website may be developed by the State Education Department which can facilitate the waste related information on all aspects of solid waste and basic guidelines. Through this website, common issues can be shared across the schools and stakeholders.

3.3.3. Implementation and operation

Implementation and operation is the effort of execution and institutionalization of the design (action plan) which starts with staff mobilization, organizing training and capacity building activities, scheduling working hours, installing facilities, conducting campus cleanup and waste audit, collection, treatment and disposal of solid waste. Parallely, the school should initiate waste reduction programs by incorporating appropriate waste reduction policies. Waste auditing is necessary to determine the quantity and type of major wastes so as to schedule the frequency of waste collection, number and size of bins and adequate processing or disposal of different wastes. After the design is set, campus waste auditing should be undertaken by students under the guidance of a teacher to calculate the waste generation rate, characterize the waste stream, quantify the major categories and determine the resource recovery potential. Based on waste audit result, the solid waste storage and processing facilities should be built. Local NGOs who are undertaking waste processing in local communities can be contacted and made collaborators. This network would provide closer collaboration and combined effort to achieve the target level of service in an integrated manner.

3.3.3.1. Source separation

Source separation and onsite storage facilities are the basic requirements which provides clean waste stream to processing and recovery system and minimizes the landfill waste. The best solution for the municipal waste segregation 'at source' -the waste sorted by the producers (Marcinkowski et al., 2012; Moh, 2017; Wadehra and Mishra 2018). A stabilized source separation practice needs consistent training, clear instructions and motivation among the campus community to achieve the excellent recycling rate. Hence, the program initiatives must share the needed information and closely work with campus community to improve their potential participation. Source separation facility must have a design based on the solid waste sources, available recycling facilities and quality and type of generated waste. Durable closed bins should be used since the frequency of collection is once in a week. Suitable color coded bins must be set - green colored bin can be used for biodegradable waste, blue for plastic, yellow for paper, red for miscellaneous (Glass, cloths, metal) and black for clinical and sanitary wastes as per the mandatory Govt. of India rules (MSW Rules, 2016). Classroom, office, library and places where students take lunch can have two bins for compostable and recyclables. Single bin system is adequate for garden waste. Each building must have the specific /appropriate space for storage space to receive the recyclables. Source segregation of wastes, promoting recycling or reuse of segregated waste materials, lessens the waste quantity thus reducing the burden on

landfills and providing raw materials for manufacturers (Philippe and Culo, 2009).

3.3.3.2. Recycling

Recycling process is a significant element of the sustainable waste management system that in principle reduces the amount of the waste disposed by recovering the useful resources which usually end up in the disposal sites (Hopewell et al., 2009; Othman and Yuhaniz, 2018; Ziadat and Henry, 2005). Schools can develop comprehensive onsite recycling program for paper wastes in their campus and they can investigate the best option for commercial recycling services for the different types of wastes. Frequent recyclable collection can be achieved when the service users adapt the comprehensive waste separation programs. In and around Puducherry, a number of recycling factories recycle almost all types of paper, plastic, glass, metal and rubber items. Small-scale to wholesale scrap dealers are available in any rural and urban areas of India. These scrap dealers could periodically collect the recyclables and distribute to recycling factories. A kilogram of printed white paper sells for between INR 12 to 14 while plastics go for INR 26 depending on the chemical composition and quality. Glass gets INR 2 per kilogram but broken glass gets only INR 1. So, by selling recyclables a school can make additional revenues. The estimated revenue from the school waste was about INR 4000 – 6000 per ton. Recycling the paper wastes into new paper products consumes lesser energy and results into fewer emissions than manufacturing the same quantity of paper from virgin materials (Merrild et al., 2008). Since biogas and energy recovery plants are expensive both in terms of initial investment and throughout their operation, we suggest that the low cost and simple composting facilities could be a viable solution for organic waste, except for larger residential schools. A study by Seo et al. (2004) concluded that composting is a simple and controlled technique of utilizing microorganism to degrade the organic portion of solid waste. Several researchers have reported that the composting process when properly handled provides various advantages such as production of biofertilizer that improves moisture holding capacity and maintains soil fertility, relatively low water and air pollution, low operational cost and income generation (Gautam et al., 2010; Jara-Samaniego et al., 2017; Pedra et al., 2007; Ribas-Agustí et al., 2017; Taiwo, 2011). Composting at source level should be promoted, for it effectively reduces waste right at the source, which is more effective in reducing waste management costs and it saves the energy used for waste transportation to the dump yard (Adhikari, 2010). Uneaten food waste can be recovered if it is used as feed for animals. Inert materials such silt, soil and mud can be reused for landscaping, horticulture or road constructions.

3.3.3.3. Disposal of non-recyclable and special wastes

Leftover non-recyclable wastes of composite nature and special wastes like clinical, sanitary and E-wastes need to be disposed appropriately. Keeping sanitary landfills in exception, mostly all other sites seem to be risky to human health and tend to be a source of environmental pollution. Properly constructed sanitary landfills are preferable alternative for the managing the solid waste (Aljaradin and Persson, 2011; Qasim, 2017; Yousuf and Rahman, 2009). If the school is spacious, as in many rural schools, a deep pit landfill can be constructed for disposing composite dry waste (except special wastes) which can be secured once full.

The best alternative for urban schools is to dispose it in the nearest community bin or to install a push cart-like bin for the purpose that can be outside the school compound where Municipal vehicle can come and collect. The school should install an incineration unit (scientific or constructed) for disposing bandage, soiled cotton, soiled tissues, sanitary pads etc. Schools should design the system for collection of electronic wastes. Since schools generate comparatively small quantity of E- wastes, adaptation of onsite processing facilities often is not possible. Establishing a regional common facility for receiving such wastes from all the schools is essential. Centralized "drop-off or buy back facilities" can be facilitated by appropriate policies to collect the hazardous wastes generated by individual school and ensure the recycling service. Appropriate collection and disposal technologies are fundamental for any hygiene and healthy school campuses.

3.3.3.4. Monitoring/Evaluation and Research (MER)

MER is needed to assess the efficiency of the system as well as to ensure long term follow up. Evaluation of implemented process through regular audits help in two ways: to identify the gaps and flaws of the current system and to redesign the system based on current composition and quantity of waste generated. If the audit report after one year of implementation of program suggests less quantity of waste generated and less non-recyclable fraction and special wastes in the waste stream, the waste management facility can be rearranged to assign lesser man power and resources than that of system in place. Schools can use standardized manuals like Green School manual (2008) prepared by Centre for Science and Environment, India which has standard performance benchmarks and a score-based evaluation tool to evaluate the performance of the system directly. Collection efficiency, quantity of waste disposed, quantity of waste avoided, resource recovery rate should be assessed on quarterly basis; Student participation in segregation, satisfaction of the stake holders and revenue from sale of recyclables can be assessed on yearly basis. At the end of the academic year, the best performing volunteering students, teachers and non-teaching staff should be acknowledged and rewarded.

Future research in this area should focus on recent developments in sustainable solid waste management at school level by revisiting national and international best practice case studies. It should cover

issues on social, financial and environmental benefits of the current systems and new advanced technologies for special wastes (Hazardous and medical wastes). To meet the current waste management needs, the overall plan must be made by considering the local resources including political, financial, institutional and technical aspects. A sound waste management policy must clearly define the stakeholder's role and responsibilities towards source reduction, recycling, composition, safety disposal of generated waste.

3.4. Strategies for effective waste reduction and recovery practices

The effective waste management system starts with waste prevention activities. The producers (the school community – the administration, staff, students etc.) should be aware of what activity and operations generate significant portion of unnecessary packaging and toxic materials. Appropriate program and policies, such as the following need to be designed to promote realistic waste reduction efforts for these specific materials:

Waste Avoidance and Minimization: Reducing the generation of waste at source is achievable by imposing policy targets in the form of waste generated per capita. It is probably the most active and efficient way of dealing the problems in the long run (Mazzantia and Zoboli, 2008; Mastro et al., 2017). Our research suggests that certain types of wastes frequently encountered in schools can be avoided or minimized by adopting and implementing appropriate policies at school level. This will include:

- Repair and reuse the damaged furniture and other electronic items rather than replacing it.
- Buy durable products with extended lives than short-term solutions.
- Sensitize the nearby vendors to use recyclable packaging like food wrapping paper and paper bags for home-made food/snacks wherever possible instead of packaging in low density plastics. The schools can permit woman self help groups to open small shops in the school campuses where home-made sweets and snacks are available without plastic wraps, thereby limiting the students from buying products from outside.
- Sensitize student community to prefer food items with less packaging or eco-friendly packaging and to avoid snacks packaged in silver-coated plastics which have no recycling facility in the region.
- Chocolates and sweets produce significant quantity of non-recyclable silver-coated plastics during festive occasions and birthday celebrations, which can be avoided if those occasions can be celebrated with home-made sweets, cakes or fruits. This strategy can sound less practical, but six private schools and one Government school in Puducherry region have already adopted and are practicing it successfully.
- Buy in bulk: government schools offer free milk and biscuits for students-instead of buying several milk and biscuits packets they can buy bulk to avoid small individual packaging which will not add to the amount of landfill waste, milk can be delivered in returnable containers.
- School administrative works generate much paper wastes which can be minimized if office works, letters, official records and orders can be maintained and shared electronically. Making two-sided copies while printing and photocopying can also reduce usage of paper. Students can be motivated to make paper bags out of waste paper and use/distribute them in the school.
- In government schools about 36% of students were found to be using second hand books, which avoided the amount of waste paper entering the waste stream. If schools have such a policy to promote use of secondhand study materials it will minimize the annual paper waste generation.
- Create free store facilities in each school where old, unwanted and reusable items including books, magazines, cloths, stationery materials and office appliances can be dropped and used by anybody. Through these steps, the school can minimize the amount of wastes to be managed and this helps to minimize the cost, staff time and environmental impacts associated with processing and disposal operations.
- Most of the private high and higher secondary schools in Puducherry have mandated the students to purchase individual copies of daily newspaper, even if the student family has a home subscription. This increases daily per capita paper waste generated by the students in private schools, which can be avoided if the class room is made to subscribe not more than 5 copies of news paper for general circulation and additional copies being subscribed to the library.

However, as the suggestions given demand additional work load for the school administration as well as the teacher and student community, we have to ensure that there is a system of recognizing and rewarding those who volunteer to lead and operate the mass movement. Such reward may be in the form of recognition at the regional / state level for the school teachers, students and sanitary workers who are exemplary in their services. While such a certificate for teachers and non-teaching staffs can be considered for their promotions, for others it may be added as an advantage for climbing up the professional ladder. In this context, the proposed innovative initiative under the Swachh ("clean" in hindi language) Bharat ("India" in hindi language) programme: Swachh Vidyalaya, the national movement driving 'Clean India: Clean Schools' supported by Government of India, can be effectively used by the schools and the Education department.

Interestingly, there are innovative alternative models of sustainable waste management such as societal businesses would be an opportunity for the corporates to implement the corporate social/environmental strategy of extended producer accountability more efficiently. In this business model, the producers can contribute more significantly

in the process of social development, promoting value creation, ensuring product stewardship and equity within the society. Additionally, the conceptualized waste management social entrepreneurship model will endorse closed-loop resource flow in the society and will lead to maximizing the resource utilization through recycling, reusing and re-gifting in the circular society (Zaman, 2012).

4. Conclusions

Solid waste composition in the selected schools of Puducherrry region contained high fraction of compostable 0.047 kg/capita/day (50%) and recyclable fractions 0.041 kg/capita/day (42%) of waste. Nearly 92% of the solid waste produced by the school campus community could be potentially reused and recycled through the adoption of effective waste reduction strategies, low cost composting techniques and expanding the recycling facilities. However, the existing practices of managing wastes in the selected schools is unsystematic and insufficient in order to meet the specific waste management objectives as specified in the revised Municipal Solid Waste Management Rules (2016), India. To overcome this issue, a sector-based waste management approach can be implemented to bring about responsible waste management at the school levels. Sector based waste management will play a key role in setting up cost effective and sustainable waste management systems through effective people participation and improved policies.

Effective waste management depends upon the level of campus community involvement. The existing role and responsibilities on waste management issue of the school communities need to be modified. A clear guideline and structured responsibility manual for all the phases from source reduction to disposal of waste can strengthen the idea of waste minimization and recycling efficiency.

A revamping of the curriculum can be facilitated to create the much-needed awareness among students of all age groups and the staff on the importance of solid waste processing and treatment. The objective of the solid waste curriculum is to engage the school students in all levels of waste management activity and encourage/motivate them to inculcate this habit both in school and social environment.

To improve the waste management in schools, a state level expert committee may be appointed to look into all the aspects of MSW management at the school level for each sub- region. This committee will develop the policy and program as well as monitor and suggest appropriate recommendations to improve the prevailing waste managing systems in the schools. Sustaining campus waste management in schools will make a pathway for successful sector based waste management approach at the regional level.

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