ORIGINAL ARTICLE

Assessment of plastic waste disposal practices and its association with dengue outbreaks: A comparative study between low and high dengue incidence areas in Chengalpattu district, Tamil Nadu

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Abstract

Background: Indiscriminate use and disposal of plastic products has deleterious effects on ecosystem. Studies suggest discarded plastic waste as potential breeding source for Aedes mosquitoes. *Aim and Objectives:* To compare plastic waste disposal practices in low and high dengue incidence areas and identify possible association between plastic waste disposal practices and dengue outbreaks. *Material and Methods:* This was a descriptive, cross-sectional, comparative study conducted between January and February 2021 in Chengalpattu district, Tamil Nadu, among 100 households each selected from low and high dengue incidence areas, categorized based on previous year statistics. A pre-tested, semi-structured questionnaire and an observational checklist were used to assess household plastic use and waste disposal practices. Value of $p \leqslant 0.05$ was considered statistically significant. *Results*: Low-incidence areas were characterized by higher proportion of respondents with diploma/degree (61.5%), pucca houses (54.5%) and apartments (88.9%). Majority (98%) were aware about law prohibiting single-use plastic. Types of plastic products used and reused were similar among both areas, except, plastic covers, barrels and medicine bottles ($p \leqslant 0.05$). Plastic waste segregation (45%) and safe (64.5%) or moderately safe (54.5%) disposal methods was higher in low-incidence areas. A greater proportion of study units in high-incidence areas had signs of burning waste, open disposal, contamination of water bodies, clogging of drains with plastic waste, used and unused plastic containers within and outside premises, plastic waste with water collections and larval breeding compared to low incidence areas ($p \leqslant 0.05$). *Conclusion:* Our research reveals high plastic products usage and inadequate waste management practices. Despite similar pattern of use, low- and high- dengue incidence areas, showed marked difference in plastic waste disposal practices, pointing to potential relationship between poor plastic waste management and occurrence of dengue.

Keywords: Dengue, Plastic use, Plastic Waste, Plastic Waste Disposal, Single-Use Plastic

Introduction

According to the United Nations Environment Programme (UNEP), global plastic consumption provides an indirect measure of plastic waste produced [1]. An approximate 8.3 billion tonnes of plastic has been produced since 1950s and about 400 million tonnes of plastic waste is generated annually [1-2]. Only 21% of total plastic waste ever produced has been processed, while remaining 79% exists in landfills, dumps or in environment [1].

The world recorded a major shift from production of resilient plastic to single-use plastic since 1950s [3]. Including a range of items such as grocery bags, water bottles, dispensing containers, cutlery,

beverage packs and milk packets, single-use plastics accounted for 42% and 36% of global and industrial plastic produced in 2015 [3]. They have profound impact on humans with their constituent elements such as styrene, benzene and bisphenol-A, considered to be associated with cancers and substantial health effects on nervous, respiratory, renal and reproductive systems with intergenerational consequences [1]. Processing of plastic waste incurs high economic expenditure, while unprocessed, discarded plastic waste can have deleterious effects on eco-system [4].

Apart from above direct effects, improper management of plastic waste indirectly poses a public health challenge by serving as breeding sources for mosquitoes [5-6]. Studies from coastal Kenya and Solomon Islands provide evidence of breeding of *Aedes aegypti*, the primary vector of Dengue, Chikungunya, Zika and Yellow fever in plastic litter [7-8]. Banerjee *et al.* has identified potential link between household plastic waste generation and increased productivity of Aedes mosquitoes in urban and rural Kolkata [9].

A Central Pollution Control Board survey (2015) across 60 major Indian cities placed Chennai second only to Delhi in total plastic waste generation (429 tonnes/day) [10]. Reports from Integrated Disease Surveillance Project identify Tamil Nadu as a high-burden state with more than 14% laboratory samples testing positive for dengue in last quarter of 2018 [11]. With high plastic waste generation and high incidence of periodic dengue outbreaks occurring in same region, it is essential to explore possible association between the same, to help improve waste management practices and thereby minimize further dengue outbreaks.

In addition, COVID pandemic in 2020 and 2021 with ensuing lockdowns caused significant impact on plastic waste management system such as disruptions in informal scrap system, dry waste disposal and recycling systems; surge in commercial and domestic consumption of single-use plastic; and increase in health care waste such as masks, gloves and personal protective equipment and their disposal along with general waste without scientific treatment mechanisms [6, 12].

Against this background, this study was planned to assess and compare plastic waste disposal practices in low and high dengue incidence areas of Chengalpattu district, Tamil Nadu and identify any possible association between plastic waste disposal practices and dengue outbreaks.

Material and Methods

A descriptive, cross-sectional study was conducted between January and February 2021, in the villages of Chengalpattu district covered under the field practice areas of our Institution. Based on proportion of people who dispose plastic waste in open in Kancheepuram district (Kanagabala *et al*.), as p (13.1%) with d as an absolute error of 5%, the sample size was calculated using the formula, $4\ pq/d^2$ [13]. The estimated sample size of 195 obtained after 10% correction for non-response was approximated to 200; 100 households each were sampled from low and high dengue incidence areas.

Our Institution directly caters to an immediate population of about 2 lakhs from surrounding areas. In addition, the urban and rural field practice areas cover approximate populations of 50000 and 18000 respectively. The details of

families covered under field practice areas are maintained under family registers.

A multi-stage sampling method was adopted. As a first step, villages covered under the field practice areas of our Institution were enlisted. The information about persons diagnosed or admitted with dengue in the previous one year was identified from family registers maintained at rural and urban health and training centres and our hospital records. This information was used to categorise villages under our field practice areas as low and high incidence areas.

In the next step, 5 villages each were randomly selected from low and high incidence areas; 20 households were randomly chosen from each village, based on a line-listing prepared from family folder registration numbers, to arrive at the required sample size of 100 in both low and high incidence areas.

A pre-tested, semi-structured questionnaire consisting of following sections was prepared- sociodemographic details; knowledge of plastic waste disposal; nature and purpose of plastic products used in households; plastic waste disposal practices; availability of plastic waste disposal options and knowledge of dengue outbreaks in the area. An observational checklist was added to the questionnaire and consisted of details on water stagnation; plastic waste management in the area which was observed and filled by the investigator. The items of checklist were scored as 0 or 1. Higher total scores implied increasing inadequacy of plastic waste disposal practices.

Institutional Ethics Committee approval was obtained. The questionnaire was administered to the male or female head of the family after obtaining informed written consent for the study. If the selected household was unwilling or unavailable for participation, the adjacent house was selected for participation in the study. After completion of questionnaire, the environment was evaluated using the observational checklist.

The collected data were entered in Microsoft Excel 2007 and statistical analysis was performed using Statistical Package for Social Sciences (SPSS) v23.0. Categorical variables were expressed as frequencies and percentages and quantitative variables were summarised as mean and Standard Deviation (SD). Chi-square test and student t-test for difference of means were used for statistical analysis of categorical and quantitative variables respectively. A value of $p \leqslant 0.05$ was considered statistically significant.

Operational definitions

For the purpose of our study, the following operational definitions were used,

Low incidence area: areas where $\leqslant$ 1 patient reported with dengue in the previous year, based on our hospital records and urban and rural health and training centre records

High incidence area: areas where 2 or more patients reported with dengue in the previous year, based on our hospital records and urban and rural health and training centre records

Type of plastic waste disposal

Safe: households who predominantly returned plastic waste to Government waste collection system, or had exclusive bins for plastic waste, recycled or reused plastic waste such as shopping bags were considered to practise safe disposal

Moderately safe: households who primarily disposed plastic waste in general waste bin or sold to plastic waste dealers were considered to have moderately safe disposal practices

Unsafe: households who generally disposed plastic waste in open grounds or anywhere else or usually burnt the waste were considered to have unsafe disposal practices

Results

The mean age of the respondents was 40.8 ± 16.5 years and their mean duration of stay in the study areas was 16.7 ± 14.4 years.

Table 1 compares the distribution of baseline characteristics in low and high dengue incidence areas.

Table 2 showcases the distribution of knowledge related to plastic use and its disposal among respondents.

Improving awareness (1.5%) and proper collection and monitoring use (1%) were also suggested as possible ways to reduce plastic waste. Among the respondents, 196 (98%) were aware about law prohibiting use of single-use plastic products.

Figure 1 and Table 3 compared plastic usage practices and Table 4 compares waste management practices among households in low and high incidence areas.

The frequency of buying plastic-packed products was similar between low and high incidence areas (P> 0.05). There was a statistically significant difference in the frequency of disposal of plastic waste between low and high Dengue incidence areas (P=0.002).

The proportion of households who practiced pre-disposal segregation of plastic waste was three-fold higher in low-incidence areas (45%) compared to high-incidence areas (14%). The reasons for non-segregation are compared in Figure 2.

Table 5 presents the distribution of environmental observations in low and high incidence areas.

The mean score for observational checklist was (6.07 ± 2.9). High incidence areas had a higher mean score (7.7 ± 2.56) compared to low incidence areas (4.44 ± 2.11) ($p<0.001$).

Table 1: Distribution of baseline characteristics among low and high incidence areas (N=200)

Variable	N=200 (%)	Low incidence areas (n=100)	High incidence areas (n=100)	*p*
Gender of respondent				
Male	107 (53.5)	58 (54.2)	49 (45.8)	0.202
Female	93 (46.5)	42 (45.2)	51 (54.8)	
Educational status of head of family				
Upto high school	96 (48)	36 (37.5)	60 (62.5)	**<0.001***
Diploma/ Degree	104 (52)	64 (61.5)	40 (38.5)	
Type of house				
Kutcha or semi-pucca	24 (12)	4 (16.7)	20 (83.3)	**<0.001***
Pucca	176 (88)	96 (54.5)	80 (45.5)	
Type of arrangement of houses				
Apartments	9 (4.5)	8 (88.9)	1 (11.1)	**<0.001***
Individual houses	174 (87)	91 (52.3)	83 (47.7)	
Detached/ stand-alone houses#	17 (8.5)	1 (5.9)	16 (94.1)	
Ownership of house				
Own	137 (68.5)	56 (40.9)	81 (59.1)	**<0.001***
Rented	63 (31.5)	44 (69.8)	19 (30.2)	
Type of family				
Nuclear	172 (86)	88 (51.2)	84 (48.8)	0.415
Joint	28 (14)	12 (42.9)	16 (57.1)	

**P<0.05; statistically significant; #houses with no demarcated fences commonly seen in villages*

Table 2: Distribution of knowledge related to plastic use and disposal among participants (N=200)

Variable	Frequency	Percentage (%)
Ill-effects of plastic waste disposal*		
Does not decay	187	93.5
Affects human health	44	22
Affects animal health	24	12
Affects water bodies	40	20
Other environmental issues	71	35.5
Ways to reduce plastic product waste*		
Reduce usage	26	13
Recycle plastic	9	4.5
Use alternatives	166	83
Ban plastic	14	7
Decrease production	35	17.5
Alternatives for plastic*		
Jute bags	156	78
Paper bags	30	15
Cloth bags	183	91.5
Wire bags	9	4.5

**Multiple responses obtained*

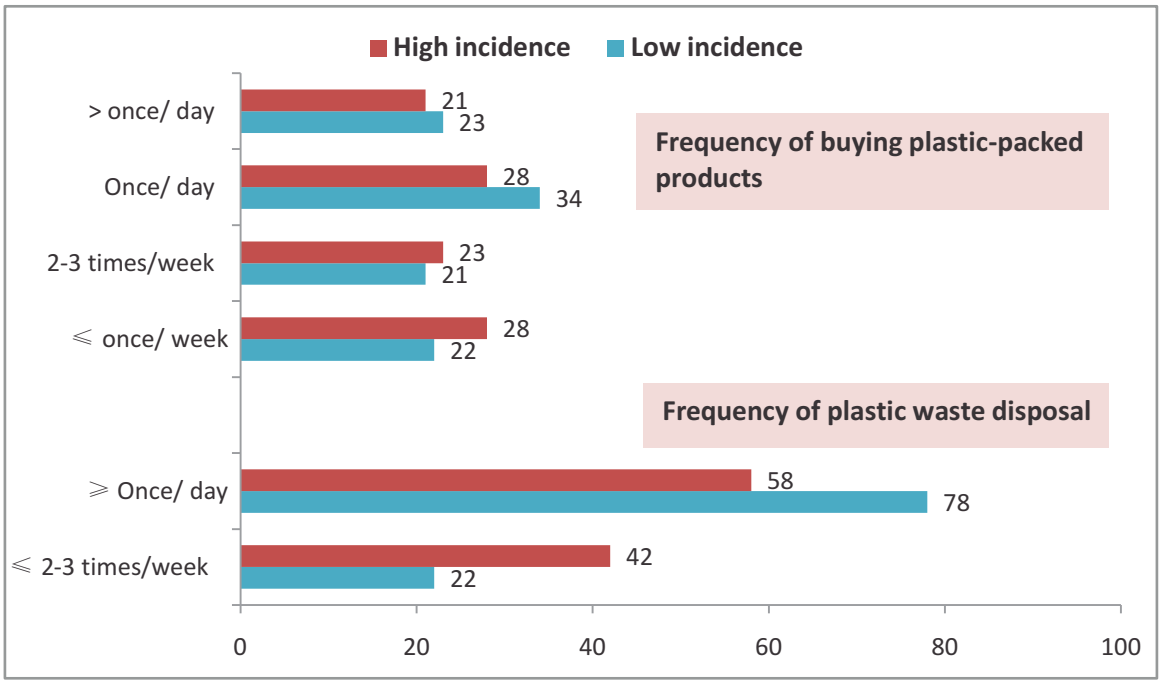

Figure 1: Comparison of frequency of purchase of plastic-packed products and disposal of plastic waste in low and high incidence areas (N=200)

Table 3: Comparison of frequency of purchase of plastic-packed products and disposal of plastic waste in low and high incidence areas (N=200)

Variable	N=200 (%)	Low incidence (n=100)	High incidence (n=100)	*p*
What are the common plastic items used in your household?				
Plastic containers	148 (74)	70	78	1.197
Water bottles	116 (58)	60	56	0.567
Plastic bags/ covers	142 (71)	68	84	**0.008***
Plastic barrels	99 (49.5)	37	62	**<0.001***
Food packages	195 (97.5)	96	99	0.365
Tiffin box	30 (15)	20	10	0.048
Toys	19 (9.5)	7	12	0.228
Medicine bottles	79 (39.5)	31	48	**0.014***
Plastic cups	24 (12)	11	13	0.663
What are the common plastic waste products generated or disposed at your household?				
Plastic containers	64 (32)	33	31	0.762
Water bottles	54 (27)	25	29	0.524
Plastic bags/ covers	139 (69.5)	70	69	0.878
Food packages	193 (96.5)	97	96	1.000
Medicine bottles	63 (31.5)	30	33	0.648
Plastic cups	11 (5.5)	4	7	0.535
What are the plastic products commonly reused in your household?				
Water bottle	78 (39)	43	35	0.246
Oil can	74 (37)	35	39	0.558
Food packages	22 (11)	11	11	1.000

**P<0.05; statistically significant*

Table 4: Distribution of plastic waste management practices in low and high incidence areas (N=200)

Variable	N=200 (%)	Low incidence (n=100)	High incidence (n=100)	*p*
How do you dispose these plastics after use?				
Dump on open ground	84 (42)	27	57	**<0.001***
Burning	51 (25.5)	15	36	**<0.05***
Government waste collector	123 (61.5)	75	48	**<0.001***
General waste bin	30 (15)	14	16	0.692
Dump anywhere nearby	16 (8)	5	11	0.118
Exclusive plastic waste bin	1 (0.5)	1	0	1.000
Recycling	1 (0.5)	1	0	1.000
Reuse as shopping bags	2 (1)	2	0	0.477
Sell to waste dealers	5 (2.5)	3	2	1.000
Disposal in pits	3 (1.5)	3	0	0.245
Do you segregate plastic waste before disposal?				
Yes	59 (29.5)	45	14	**<0.001***
Do you have separate disposal facility or Government collection facility for plastic waste in your area?				
Yes	144 (72)	81	63	**0.005***
Type of plastic waste disposal				
Safe	93 (46.5)	60 (64.5)	33 (35.5)	**<0.001***
Moderately safe	33 (16.5)	18 (54.5)	15 (45.5)	
Unsafe	74 (37)	22 (29.7)	52 (70.3)	

**P<0.05; statistically significant*

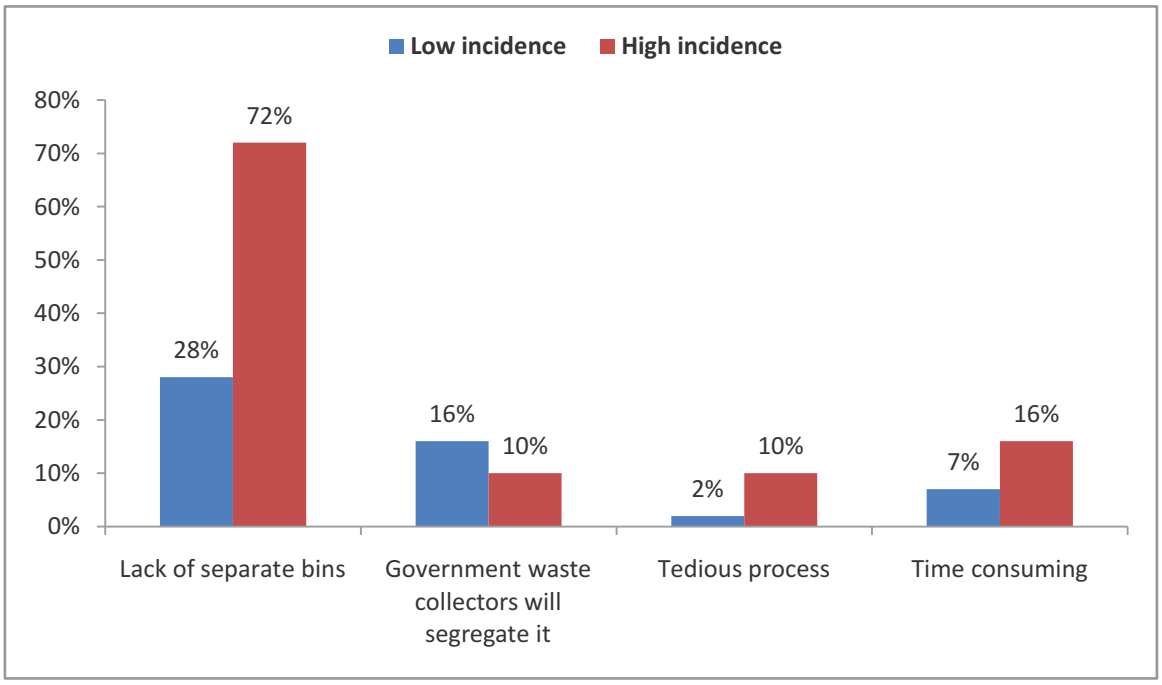

Figure 2: Distribution of reasons for non-segregation of plastic waste among low and high incidence areas (N=59)

Table 5: Distribution of Observational checklist items (N=200)

Observational checklist item	N (200)	Low incidence (n=100)	High incidence (n=100)	*p*
Signs of burning of plastic waste	79	25	54	<0.001*
Clogging of drains with plastic waste	88	23	65	<0.001*
Open disposal of plastic waste on the streets	148	62	86	<0.001*
Contamination of water bodies with plastic waste	110	38	72	<0.001*
Plastic containers in use, inside or outside the premises	195	95	100	0.024*
Unused plastic containers inside or outside the premises	109	34	75	<0.001*
Plastic waste with water collections	105	29	76	<0.001*
Larval breeding within water collections in plastic waste	71	14	57	<0.001*
Exclusive plastic waste disposal or collection facility in the area	147	89	58	<0.001*
Plastic waste recycling system or collection dealers in the area	144	87	57	<0.001*
Prominent sign board banning single-use plastic	0	0	0	

**P<0.05; statistically significant*

Discussion

Sociodemographic characteristics

The mean age of our participants was 40.8 ± 16.5 years, which was comparable to study by Kanagabala *et al*. (43 ± 15.25) from a similar area [13]. On comparison of baseline characteristics, high-incidence areas had fewer proportions of family heads with diploma/degree (38.5%), increased number of kutcha/semi-pucca houses (82.3%) and detached or stand-alone houses (94.1%) compared to low-incidence areas, which could explain to certain extent the differences in plastic waste and environmental management practices between the areas.

Knowledge about plastic use and its disposal

Majority respondents (93.5%) identified its non-degradable nature as the chief hazard associated with plastic waste. But less than one-third respondents identified the adverse impact of plastics on environment, animal and human health. These figures markedly differ from other studies on assessment of knowledge and practices related to plastic waste management. A higher level of awareness on hazards of plastic waste was reported by Kanagabala *et al*. from Kancheepuram, Chaudhary *et al*. from Meerut, Kakoti from Guwahati and Chin *et al*. from Malaysia [13-16].

In our study, 98% respondents were aware about legislation banning single-use plastics; 83% opined that using alternatives was the best option to reduce plastic waste. Cloth, jute, paper and wire bags were suggested as alternatives in that order. Studies by Kanagabala *et al*. and Joseph *et al*. from rural and urban areas respectively from two different states of India display similar high awareness about the legislation and report comparable order of alternative choices, highlighting adequate dissemination of information and appropriate positive attitudes by the population [13, 17].

Plastic usage practices among households

Food and beverage packages was the commonest (97.5%) form of plastic used by households, followed by plastic bags/covers, water bottles, plastic barrels and medicine bottles. Except for food packages which were reported to be used by 45% respondents, an identical pattern of usage was observed in the study by Kanagabala *et al*. [13]. This difference in use of food packages could be due to the mix of urban and rural population in our study and the predominant availability of smaller food establishments in urban areas. Among these commonly used products, food packages, plastic bags or covers, medicine bottles by virtue of their single-use pattern are more likely to end up as plastic waste. Plastic barrels used to store water can act as effective breeding places for Aedes mosquitoes. On comparison, a greater proportion of households in high-incidence areas used plastic bags/covers, plastic barrels and medicine bottles ($p < 0.05$).

While segregation and disposal with authorised recyclers or Government waste collection system is recognised as the least possible responsible behaviour in plastic waste management, unsafe practices such as open dumping, burning and burying have been reported by authors from geographically diverse studies. Burning and dumping were the commonest disposal practices identified by Kanagabala *et al*. [13]. In study by Kakoti from Guwahati, unsafe practices such as open dumping (62%), burying (22%), burning (56%) and throwing in drain (42%) were reported to a great extent [15]. A study by Pandirajan *et al.* from Kanchipuram district, reported burning (31%) and burying (10%) of plastic waste in a similar population [18]. Few studies have also reported safe and responsible practices such as using alternatives and reuse of used plastics. A study by Joseph *et al*. from Mangalore presents a relatively hopeful picture with many respondents practising disposal in dust bins (78.8%); reusing plastic bags (20%) and use of cloth bags (5.2%) [17]. In study by Halder from Kolkata, safe practices such as disposal in dust bins (56%), reuse

(35%) and return to registered recyclers (10%) were observed [19]. One-third of participants reported segregating plastic waste in study by Chin *et al*. among Malaysian population, which was marginally higher compared to our study (29.5%) [16]. Participants of our study display a combination of safe and unsafe disposal behaviour; such as disposal with Government waste collection system (61.5%), general public waste bin (15%), open dumping (42%) and burning (25.5%).

Based on their disposal methods, 37% households practised completely unsafe methods of disposal. Comparing both areas, unsafe disposal practices such as burning and dumping were practised by relatively higher number of households in high-incidence areas and safe practices such as use of Government waste collection system and pre-disposal segregation of plastic waste were practised by greater number of households in low-incidence areas ($p < 0.05$).

Observational checklist findings

In our study, open disposal of plastic waste was observed near 74% households; 97.5% households used plastic containers with water collections inside premises. A multi-country study by Arunachalam *et al*. has also observed visible garbage dumps and plastic containers with tap water collections in clusters studied in Chennai [20]. A relatively greater proportion of study units in high-incidence areas had signs of burning waste, open disposal of plastic waste, contamination of water bodies and clogging of drains with plastic waste, used and unused plastic containers within and outside premises, plastic waste with water collections, larval breeding in water collections, compared to low-incidence areas; and the difference in proportions was statistically significant ($p < 0.05$). Availability of exclusive plastic waste disposal or collection facility and informal plastic waste recycling system or collection dealers was comparatively high in low-incidence areas ($p < 0.05$).

The findings of observational checklist provide indirect albeit substantial, objective evidence of possible relationship between plastic waste management and dengue occurrence. Though elimination of single-use plastic and consequent ban was initiated under Solid Waste Management Rules, 2016, it was observed that none of the study areas had sign boards banning single-use plastic at public places or in small or large commercial establishments.

Possible association between plastic waste disposal and dengue outbreaks

Our study reports clear distinction in plastic waste management practices between low and high dengue incidence areas pointing to a potential relationship between inappropriate disposal practices and increased incidence of dengue. Such evidence has also been reported in studies from coastal Kenya and rural and urban areas of Kolkata [7, 9]. Some studies have provided a higher level of evidence through population-based, analytical studies. A positive relationship between dengue occurrence and risky practices such as garbage accumulation around house and low frequency of garbage collection in spatial population-based, case-control study in Sao Paulo, Brazil was reported by Cordeiro *et al*. [21]. A community-based, case-control study on risk factors for dengue by Chen *et al*. in China identified regular removal of trash and stagnant water from

residential areas as one of the most significant protective factors ($p<0.001$) [22]. A multi-country study by Arunachalam *et al*. confirmed the contribution of unused and unprotected containers to high pupal production and efficacy of waste management and environmental vector control measures in eliminating breeding sites [20].

A remarkable finding in our study was that the households in low-incidence areas bought and disposed plastic products at relatively higher frequencies compared to high-incidence areas. Except for plastic bags, covers, barrels and medicine bottles, the pattern and proportion of plastic products used, reused and waste generated or disposed did not differ greatly between households of low and high incidence areas. The major difference between the two types of areas was observed only in the way the plastic waste was managed. Practices of segregation of waste, safer methods of disposal and availability of waste collection systems were reported to be higher in low-incidence areas compared to high-incidence areas. The self-reported practices corroborated with the findings of the observational checklist. This knowledge provides scope for channelizing health education and behaviour change communication activities towards safe plastic waste management methods for prevention and control of future outbreaks of dengue. But the increasing frequency and quantum of use of plastic products in all areas points to potential environmental and public health threat and serves as an alert to immediate action in terms of rigorous plastic waste production and usage policies by countries with involvement of all stakeholders including communities who are end-users.

This study has its limitations. Being a descriptive, observational study, our study does not prove causal association. But it is one of the first studies which compare plastic use and waste management practices in low and high dengue incidence areas in India thus providing indirect evidence of potential relationship between plastic waste mismanagement and vector-borne diseases. In addition the observational checklist helps in supporting and strengthening the evidence by reducing the bias of self-reporting.

Conclusion

Our research reveals high household plastic products usage and inadequate plastic waste management practices despite satisfactory knowledge about its associated ill-effects. Both low- and high- dengue incidence areas showed similar pattern of plastic use, but marked difference in plastic waste disposal practices, pointing to potential relationship between poor plastic waste management and occurrence of dengue. Considering the public health burden associated with dengue, our findings suggest scope for targeted behaviour change communication activities at community level focusing on judicious plastic use and disposal in prevention and control of dengue and other vector-borne diseases.

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