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Bio-medical waste management: situational analysis & predictors of performances in 25 districts across 20 Indian States

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***Background & objectives*: A legislative framework for bio-medical waste management (BMWM) was established in the country more than a decade ago. Though some studies have identified gaps at local levels, no systematic effort was done to collect data from different parts of the country. The objective of this nationwide study was to document existing resources, infrastructure and practices related to BMWM across the study districts.**

***Methods*: The study was conducted in 25 districts spread over 20 States of India including urban and rural areas. Primary (n=388), secondary (n=25) and tertiary care (n=24) health facilities from public (n=238) and private (n=199) sector were assessed and scored for the state of BMWM through 9 items representing system capacity, availability of resources and processes in place. Health facilities were assigned into one of the three categories (Red, Yellow and Green) based on the cumulative median scores.**

***Results*: Around 82 per cent of primary, 60 per cent of secondary and 54 per cent of tertiary care health facilities were in the 'RED' category. Multivariate analysis indicated that charts at the point of waste generation, availability of designated person, appropriate containers and bags, availability of functional needle destroyers, availability of personal protective gears, segregation of waste at point of generation and log book maintenance were independently (OR-between 1.2-1.55; *P*<0.03 or less) associated with better BMWM system in the health facilities. This was true for both rural-urban and public or private health facilities.**

***Interpretation & conclusions*: The study highlighted the urgent need for greater commitments at policy and programme levels for capacity building, and resource investments in BMWM.**

Key words Bio-medical waste management system - BMWM Scoring System - Governance - Micro and macro level BMWM systems - Predictors of good BMW scores

Expansion of health care facilities as well as the recent trend of using disposables has led to an unprecedented burden of health care related waste. Since the last three decades, unregulated handling of biomedical waste is emerging as a serious threat to human health and safety, and many researchers have documented this as a priority area[1,2]. The concern over HIV/AIDS and other blood borne infections has led to an increased professional and environmental activism towards this issue.

At the global level, 18 to 64 per cent of healthcare institutions are reported to have unsatisfactory Bio-Medical Waste Management (BMWM) facilities; predictors include lack of awareness, insufficient resources and poor disposal mechanisms[3]. Many countries lack documented government rules related to BMWM. India was one of the first countries to implement BMWM rules[4]. The Ministry of Environment and Forests notified the "Bio-medical Waste Management and Handling Rules", in July

1998 (later amended in 2003 and 2011) under the Environment Protection Act, 1986[5]. Even after a decade of its implementation, most Indian hospitals are yet to achieve the desired standards for BMWM practices[6,7]. Though some Indian studies have identified gaps at local levels, there is no systematic effort to collect data from different parts of the country[8,9]. The hepatitis outbreak in Modassa, Gujarat (India) 2009, pointed towards the core issue of poor biomedical waste management in the country[10].

During 2002-2004, INCLEN (International Clinical Epidemiology Network) Program Evaluation Network (IPEN)[11] conducted a comprehensive study on the assessment of injection practices in India that included mapping the status of biomedical waste management. The study indicated the existence of inappropriate and hazardous BMWM practices across the country especially in rural areas. Recognizing the urgent need for a nationwide situational analysis to generate evidence for gaps in BMWM and identify appropriate measures, an assessment of biomedical waste management was taken up by the IPEN study group in 2009, in 25 project districts located in 20 States. The primary objective was to document existing resources, infrastructure and practices related to biomedical waste management in primary, secondary and tertiary care health facilities across the study districts. The study design was cross-sectional, expected to identify gaps in the BMWM practices and to recommend appropriate interventions at public and private health care facilities, in rural and urban settings.

Material & Methods

Study site: Data collection was done during March - June 2009 as part of an ongoing IPEN project on Model Injection Centers (MICs) at 25 Partner Medical Colleges (PMC). The country was divided, for the purpose of the study, into five geographical zones with five PMCs in each zone. A total of 25 districts where PMCs are located, were included for assessment of BMWM (Fig. 1).

Data collection at the districts was carried out by the site principal investigator and co-investigator of the respective PMC. The study included different

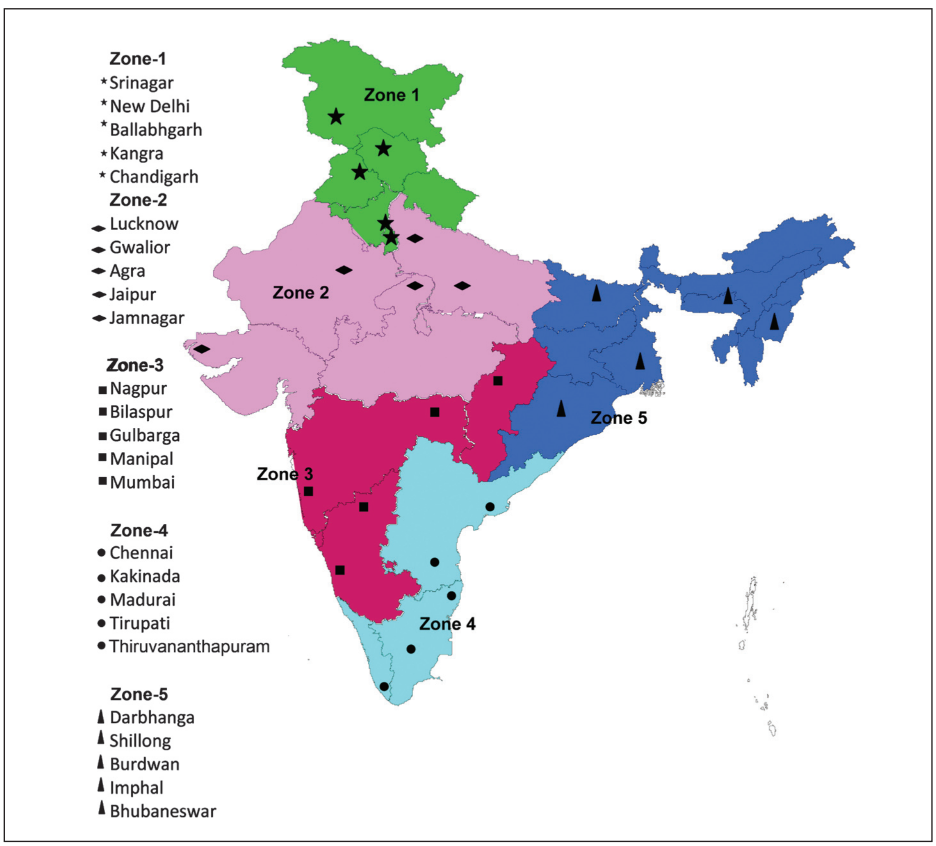

Fig. 1. Districts in which Bio-Medical Waste Management assessment done.

levels of health facilities; in urban and rural areas, and from public and private sector providers (Fig. 2). In every district separate lists for primary care health facilities in urban and rural areas were prepared based on the information available with the district health department, professional associations, local bodies and the district pollution control board's office. For rural areas, the lists for public sector and private sector were separate while in urban areas, only private sector facilities were included in the sampling list. Private sector lists from rural areas also incorporated clinics run by informally trained practitioners (RMPs/ Quacks). The desired number of health facilities were then identified as per the scheme outlined in Fig. 2 through computer generated random numbers. In urban areas, the government district hospital and the partner medical college hospital were recruited to represent secondary and tertiary care facilities, respectively. In Bhubaneswar due to administrative reasons the district hospital could not be recruited and in its place, a 150 bedded private hospital run by a charitable trust was included. Non formal prescribers (small clinics) were 74.7 per cent in rural areas (71 out of 95). Four out of 25 (16%) PMCs were private medical colleges.

Patient care areas for observation were predetermined for each type of health facility (Table I). The sites of observation were decided on the basis of group discussions and experiences of investigators in the hospitals of different settings. The study was a cross-sectional survey with direct observation of BMWM systems at different levels of health care.

Assessment tool: The WHO tools were adapted to suit the needs of the present study and two instruments were prepared. Assessment tools were common for all types of health facilities across levels, locations and sectors (public and private), on the basis of WHO standards for BMWM[12]. Separate tools were prepared

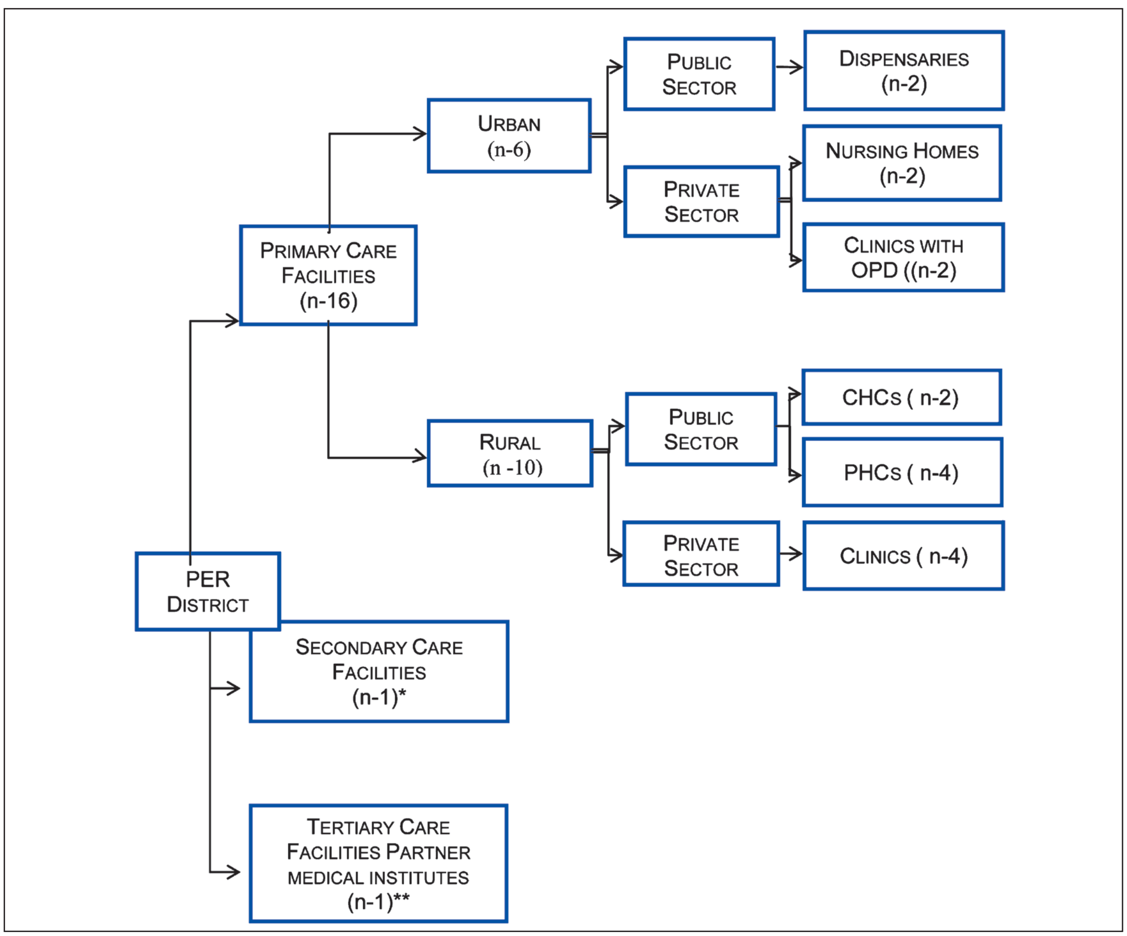

Fig. 2. Scheme of Health Facility identification for assessment for BMWM at district level. *Except a secondary level private hospital in Bhubaneswar other 24 were public sector district hospitals; **Four out of 24 were private medical colleges (Jaipur, Gulbarga, Manipal and Bhubaneswar). CHC, community health centres; PHC, private health centres.

for interviewing pollution control board and municipal authorities (available on *http://www.inclentrust.org/*).

(i) Health facility tool which comprised of

(a) Section 1: Observation checklist based on the National Accreditation Board Standard for Hospitals and healthcare providers (NABH 2007)[13] in India to assess the BMWM system and actual practices through direct observation. Same checklist was used for primary, secondary and tertiary level health facilities. The checklist included issues of system capacity, resources and processes covered under nine domains with related questions[13].

There were 31 items spread over system capacity (7); resources (8); and process (16). Thus, differential weight age was given by way of variable number of items under the three major domains. Initially all items were kept with two options (compliance – yes or no). However, after piloting only eight items were left with two options (no compliance and full compliance) and 22 items had three options (no compliance, partial compliance and full compliance). Piloting also helped to define partial compliance. The observations from at least three and maximum five BMW generation points were obtained in secondary and tertiary care hospitals. In primary care facilities, the observations were made only at one point of BMW generation (Table I).

(b) Section 2: Interview schedules for the medical officer, or the officer-in-charge responsible for BMW.

(ii) Interview schedule for officials from local bodies and pollution control boards (District level only).

Quality assurance measures: The instruments were piloted at one site in each of the five zones. Before the launch of the study, a National Protocol Finalization Workshop was organized to bring uniform understanding among all principal investigators. Data collection was closely monitored at central coordinating office in New Delhi and Central Coordinating Team (CCT- multidisciplinary team of investigators; these were different from site investigators) members visited each site to oversee data collection in at least two health facilities.

Data processing: The filled questionnaires from each PMC were entered into Intelligent Character Recognition (ICR) sheets and scanned. Before scanning, 100 per cent ICR sheets were matched with original questionnaires. After scanning, the database was matched with ICR sheets; this reduced the error rates to around 1 to 2 per 1000 data points. The forms were automatically recognized and the data were processed using ABBYY ® Forms Processing software[14]. After verification and validation of the data using the same software, final data was exported to MS excel 2007 spreadsheets. The data were transformed into STATA software[15] and were analyzed after appropriate cleaning procedures. A total of 19 questions in two types of interview schedules for key informants were open-ended. Responses to these questions were analyzed using qualitative methods to identify emerging themes and sub-themes. The answers were then coded and converted into quantitative format[16].

Table I. Patient care areas and departments for observation during Biomedical Waste Management assessment

Type of health facilities	Patient care areas observed	Department
Secondary care & Tertiary care setting	Injection room / immunization room	Paediatrics
	Treatment / Procedure room	Internal Medicine
	Dressing room	General Surgery
	General wards	Obstetrics & Gynaecology
Primary care setting	Injection room/ immunization room	Out-patient Departments

BMW storage and treatment facilities were visited at each hospital, wherever these existed

Framework for analysis

Health facility score: The questions were clustered around three major domains (system capacity, resources and processes) which were further categorized into nine sub-domains or items, each with 1 to 4 questions. These nine sub-domains of BMW management included: one domain for systems capacity; four domains each under resources and processes namely segregation of BMW; management of sharps; in-house transport of BMW and for storage and record keeping, respectively. Systems capacity assessed availability of guidelines, charts, designated official and provision of protection for health providers. Each question was separately assigned scores as full compliance (10 points), partial compliance (5 points) and no compliance or absence of the particular component (0 points) as per NABH standards, 2007. Any health facility or individual domain could thus achieve a minimum score of 0 and a maximum score of 10.

Domain score was calculated as average scores of included questions. The median scores of domains were used to determine the overall score for health facility. Aggregate of individual health facility scores was the basis of computing median score of a particular level of health facility in the specific district/ zone/ overall. As a measure of dispersion of score, along with median scores, 25th and 75th percentiles (quartile range) were also computed.

Grading of BMWM system (Table II): The decision to classify health facilities according to the status of the BMWM system (Red, Yellow & Green) was arrived at the protocol finalization workshop where the site investigators participated along with principal investigators and central coordinating team (CCT). CCT comprised of public health specialists, hospital management professional with expertise in biomedical waste management, paediatricians, physicians, social scientists, biostatisticians and anthropologists. The group decided cut-off median cumulative scores reflecting system capacity, resources and processes to help facility managers to take appropriate actions. Median score < 2.5 was interpreted as no credible BMWM system in place while score ≥ 2.5 to < 5.0 was interpreted as system present but that needed major improvement; both these groups were put under Red category. Median score ≥ 5.0 to 7.5 indicated system required some additional efforts and categorized as Yellow while median score ≥ 7.5 indicated good system in place for BMWM (Green category).

Comparison was made for health facilities (*i.e.*, primary, secondary and tertiary care settings) in urban and rural settings as well as public and private settings. Cumulative scores for health facilities of a particular level at zonal level were also estimated and compared.

Table II. Median BMWM score categories for health facility & their interpretation

Median BMWM scores	Interpretation	Colour Code
<2.5	No credible BMW management system in place	RED
≥2.5 - <5.0	System present but needs major improvement	
≥5.0 - 7.5	System requires some additional efforts	YELLOW
≥7.5	Good system in place for BMWM	GREEN

Multivariate analysis was done to determine the predictors of grade (red, yellow and green) of health facilities. Two sets of models were generated: first, in which dependent variable was health facilities graded as 'Yellow' and above (score ≥ 5.0) versus all others, and second, in which dependent variable was 'Green' health facilities (score ≥ 7.5) versus all others. Independent variables for both the models were scores of individual items under system capacity, resources and processes.

Results

Data for BMW management were obtained from 24 PMC, 25 district hospitals and 400 primary care health settings. After appropriate data cleaning and validation the information from 24 PMCs, 25 district hospitals and 388 (194 public and 194 private) primary care health facilities were analysed. The number of private health facilities at secondary (n-1) and tertiary level (n-4) in urban areas were very few. The biomedical waste management scenario was analyzed at two levels: type of health facility and public/private sectors (Table III).

The status of BMWM was alarming across the study sites; 82 per cent (318/388) of primary care, 60 per cent (15/25) of secondary and 54.2 per cent (13/24) of tertiary care facilities were in the RED category indicating need for major efforts to improve the BMWM across the country. The median scores for secondary and tertiary care health facilities were 4.34 (25th/75th percentile: 2.16, 6.31) and 4.96 (25th, 75th percentile: 4.05, 7.26), respectively. The state of BMWM at primary care health facilities [median 1.84 (25th, 75th percentile: 0.76, 4.24)] indicated requirements of major inputs for the improvement; the situation was worse in rural areas (median score 1.58) compared to urban facilities (median score 2.74). Public sector providers in rural areas had better BMWM system than their counterparts in urban areas. In contrast, there was almost complete lack of BMWM systems in the private sector in rural areas, generally reflecting on clinics of informal practitioners (Table IV).

Quantity and type of BMW generated (Table V): BMW including plastic wastes generated in secondary and tertiary care health facilities was 3 to 10 times higher every day as compared to that in primary care facilities. Infectious waste comprised of improperly segregated BMW, and mixture of material contained in blue or red and yellow coloured bags. Segregation was particularly poor in primary care facilities (Table V). The proportion of infected waste was 66.7 per cent in

Table III. Status of BMWM: Distribution of median BMWM scores across level of health facilities in private and public sector

Grade of BMWM scores & color category	Health facilities		Median score (25th, 75th percentile) (n)	Total median (25th, 75th percentile) (n)
0 - <5.0 RED	Primary	Public	1.75 (0.77, 2.84) (n-165)	1.36 (0.63,2.79) (n-318)
		Private	1.09 (0.48, 2.44) (n-153)	
	Secondary	Public	2.42 (1.78, 4.18) (n-15)	2.42 (1.78, 4.18) (n-15)
		Private		
	Tertiary	Public	4.04 (3.02, 4.85) (n-12)	4.1 (3.19, 4.89) (n-13)
		Private	4.95 (n-1)	
5.0 - <7.5 YELLOW	Primary	Public	6.07 (5.30, 6.85) (n-17)	6.03 (5.50, 6.63) (n-45)
		Private	5.9 (5.51, 6.61) (n-28)	
	Secondary	Public	6.51 (5.57, 7.01) (n-9)	6.51 (5.57, 7.01) (n-9)
		Private	0	
	Tertiary	Public	6.91 (6.74, 7.10) (n-6)	6.91 (6.74, 7.10) (n-6)
		Private	0	
≥7.5 GREEN	Primary	Public	7.9 (7.66, 9.32) (n-12)	8.16 (7.77, 9.48) (n-25)
		Private	8.51 (7.89, 9.50) (n-13)	
	Secondary	Public	0	9.51 (n-1)
		Private	9.51 (n-1)	
	Tertiary	Public	8.38 (n-2)	8.57 (8.35, 9.37) (n-5)
		Private	9.37 (n-3)	

primary care settings, 79 per cent in secondary and 76 per cent in tertiary care settings.

Performance of BMWM at primary, secondary and tertiary care settings (Table VI): Primary care settings fared poorly for most domains in comparison to secondary and tertiary care settings (Table VI). Lack of resources and poor processes emerged as the key problems across health facilities. There were practically no resources for segregation, in-house transport and for storage and record keeping of BMW in primary care health facilities. It appeared that at higher levels of health settings, more resources were available and efforts were put in for establishing BMWM system resulting in better overall scores. In tertiary and secondary level facilities 82.6 per cent (19/23) and 64 per cent (16/25) were having designated officials for management of BMW while in primary health facilities only 40.8 per cent (149/365) had a designated official. Only 63.3 per cent (216/341) of primary facilities were providing personal protectives for waste handling staffs as compared with 87 per cent (20/23) in secondary and 95.5 per cent (21/22) in tertiary health facilities. Similarly, waste handling staff was not trained in 56.7 per cent (204/360) of primary and 20.8 per cent (5/24) of secondary while all of such personnel in tertiary facilities had received appropriate training. Around 47.2 per cent (101/214) of primary, 81.2 per cent (13/16) of secondary and 92.9 per cent (13/14) of tertiary health facilities were using authorities other than municipalities for handling biomedical waste.

Multivariate analysis for predictors of higher scores: Table VII gives the key items under system capacity, resources and processes that were predicting the scores of 5 and more (*i.e.*, acceptable or good BMWM system) for a health facility. Odds of a health facility entering into yellow or higher category increased significantly with every one increase in the median score of each of these variables. Although in univariate analysis these appeared important, higher scores were not independently predicted by location (urban-rural) or sector (public-private) of the health facility.

Among those health facilities which had score ≥ 5, the possibility of being a green (score ≥ 7.5) health facility for BMWM was associated with factors of system capacity (guidelines/charts displayed at waste generation sites) (OR 1.8; 95% C.I; 1.2, 2.8), resources (availability of personal protective equipment for waste handling staff) (OR 1.6; 95% C.I; 1.2, 2.0), and process (disinfection of plastic waste or sharps) (OR; 1.4; 95% C.I; 1.1, 1.7).

Table IV. Status of BMWM: Distribution of BMWM scores at different levels of health facilities in urban and rural settings

Grade of BMWM Scores	Health facilities	Median score (25^{th}, 75^{th} percentile) (n)	Total median (25^{th}, 75^{th} percentile) (n)
Primary Urban	Public	2.5 (0.83, 4.28) (n-49)	2.74 (1.01, 5.13) (n-148)
	Private	2.97 (1.09, 5.35) (n-99)	
Primary Rural	Public	2.03 (0.98, 3.69) (n-145)	1.58 (0.67, 3.53) (n-240)
	Private	0.99 (0.31, 3.18) (n-95)	
Secondary care	Public	4.26 (2.13, 5.94) (n-24)	4.34 (2.16, 6.31) (n-25)
	Private	9.51 (n-1)	
Tertiary care	Public	4.9 (3.69, 6.91) (n-20)	4.96 (4.05, 7.26) (n-24)
	Private	8.87 (6.65, 9.41) (n-4)	

Perception of key stakeholders about BMWM at their respective health facilities: Officers-in-charge of BMWM at health facilities and nodal district officers at the pollution control boards and municipalities were asked about the different aspects of BMWM in their health facilities/ districts. At primary care facilities, between 34.3 to 48.9 per cent respondents were either not concerned about the problems or denied existence of any problems in BMWM at their health facilities. At tertiary (16.7%) and secondary (28.0%) level hospitals, such apathy was less. Interestingly, 40 per cent (10/25) of municipal authorities and 54 per cent (13/24) of pollution control board officials also responded in a similar manner. There was consistency across stakeholders about the need for building systems capacity (36 to 77.6%) and higher resource allocations (32 to 55%) if BMWM was to improve across health facilities and sectors (Table VIII). It was important that officers looking after BMW in pollution control boards, municipalities and tertiary care hospitals emphasized the critical role of better governance to improve the BMWM system at various levels of health care.

Discussion

BMWM was alarming both at macro and micro levels across different parts of the country; in the 25 study districts 82 per cent of primary care health facilities, 60 per cent of secondary care and 54 per cent of tertiary care health facilities were in the RED category *i.e.* absence of a credible BMW management system in place or ones requiring major improvement. These findings have to be attributed to lack of system capacity, gaps in resources and processes. Resources for segregation and in-house transport of BMW along with resources and processes for storage and record keeping were particularly deficient across all type of health facilities. Interview with key stakeholders in municipality as well as pollution control board in each

Table V. Type and quantity of biomedical waste generated in different levels of health facilities

	Primary health facility (Mean; 95 % C.I) [n]	Secondary health facility (Mean; 95% C.I) [n]	Tertiary health facility (Mean; 95 % C.I) [n]
Total amount of waste generated (kg/day)	7.8 (5.14, 10.5) [211]	23.2 (0.8, 46.58) [15]	87.1 (30.3, 143.9) [17]
Infectious wastes (kg/day)	6.13 (3.1, 9.1) [140]	16.4 (4.1, 28.8) [12]	62.7 (11.6, 113.8) [16]
Median proportion of infectious waste (%)	66.7 (50, 90) [97]	79 (46.3, 100) [10]	76.9 (36, 96.6) [15]

Table VI. Overall performances of BMWM & domain scores at different levels of health facilities

	Domains of BMWM performances	Primary care settings median (25th, 75th percentile) (n-370)	Secondary care settings median (25th, 75th percentile) (n-25)	Tertiary care settings median (25th, 75th percentile) (n-24)
A.	System capacity for optimum BMWM system (Guidelines or charts for BMW, location of charts, appropriateness and readability of contents, specific person or MO with clear roles and responsibilities for BMWM, designated waste routes in hospital, personal protectives for waste handlers, designated person for waste storage areas, weighing machine in storage areas)	1.9 (1.4, 2.5)	5 (3.2, 6.9)	7 (5.4, 8.2)
B.	Resources	1.25 (0, 3.75)	4.27(1.6, 5.83)	5.45 (3.10, 7.19)
	B1 - Resources for segregation of BMW (specific person/ MO/nurse to monitor segregation, appropriate containers with coloured bags)	0 (0, 0)	5.7 (4.2, 8.4)	9.3 (5.9, 10)
	B2 - Resources for management of sharps (functional needle destroyer/hub cutter, white puncture proof translucent containers)	2.5 (1.6, 2.5)	3.3 (2.14, 5)	5 (3.5, 6.5)
	B3 - Resources for in-house transport of BMW (containers, trolleys or equipment for transport, specific route, log book or register at source)	0 (0, 0)	0 (0, 4.7)	0 (0, 6.8)
	B4 - Resources for storage and record keeping (centralized area for storing BMW, log book or register at storage site)	0 (0, 0)	3.8 (3.3, 6.5)	3.5 (3.3, 6.9)
C.	Processes	2.39 (1.25, 4.81)	4.36 (2.5, 6.27)	5.61 (3.52, 7.54)
	C1 - Process for segregation of BMW (segregation at source, bio-hazard labels in equipment, bags removed before 3/4th full, plastic wastes in blue/red bags, disinfection of plastic wastes)	2.6 (2.2, 3)	6.0 (3.7, 7.8)	5.7 (4.9, 8)
	C2 - Process for management of sharps (needles / plungers destroyed after injections, bio-hazard labels for white translucent container, syringe plungers in blue or red bags)	2.5 (1.6, 2.5)	2.9 (1.4, 4.9)	5.5 (3.9, 7.5)
	C3 - Process for in-house transport of BMW (frequency of removal of BMW, separate time for removing infectious wastes, clean and labelled trolleys)	2.5 (2.5, 2.5)	5 (5, 5)	5 (5, 6.7)
	C4 - Process for storage and record keeping (lock & key for waste storage area, colour coded bags stored separately, tied and labelled, general cleanliness)	1 (1, 1.7)	4 (1.1, 7)	6 (2.5, 8)

B1 - B4: Sub-domains of Resources; C1 - C4: Sub-domains of Processes; MO, medical officer

district indicated the need for building system capacity and allocation of additional resources to improve existing BMWM systems. A significant proportion of key stakeholders in the health facilities and district regulatory offices demonstrated apathy towards current status of BMWM in their environment. The study provided evidence for need of major policy shifts towards improving BMWM in primary care settings both at public and private in urban and rural areas. Macro level policies and implications need to penetrate into micro level settings through better governance and improved community awareness.

Improper procedures of medical waste management were reported from many places[17]. The status was worst in primary care settings especially in rural areas; 742.7

Table VII. Multivariate analysis for predictors of better health facilities with cumulative BMWM score above 5 (falling in Yellow & Green categories)

S. No.	Variables for yellow and green category (score > 5)	Classification	Overall (n= 390), Psuedo R^2=0.7335	
			Odds ratio (95% C.I)	*P* value
1	Guidelines/Charts displayed at waste generation sites	System capacity	1.21 (1.0, 1.4)	0.009
2	Specific MO/ nurse/ person for monitoring BMW segregation	Resource	1.21 (1.0, 1.3)	0.005
3	Appropriate containers with appropriate colour bag	Resource	1.37 (1.1, 1.7)	0.004
4	Functional needle destroyer / hub cutter	Resource	1.20 (1.0, 1.4)	0.03
5	Personal protective equipment for waste handling staffs	Resource	1.41 (1.1, 1.7)	0.002
6	Segregation of waste at point of generation	Process	1.55 (1.2, 1.9)	0.000
7	A register or log book to maintain the records of wastes	Process	1.40 (1.2, 1.6)	0.000

MO, medical officer

million Indian people live in rural areas and are served through 147,069 sub centres, 23,673 PHCs and 4535 CHCs[18]. The number of private health facilities within rural primary level settings in India was unknown to the best of our knowledge, but almost all big villages have informally trained medical practitioners providing care in private settings. Many authors described the reasons for poor system in the primary health facilities as lack of sensitivity and awareness, concerning health risks of biomedical waste and economic constraints[19]. Tertiary and secondary level hospitals performed better; perhaps on account of better resources and having responded to the regulations. Radha *et al*[20] highlighted that biomedical facilities in urban settings were marginally better as compared to that in rural areas due to greater investment and focus. A study from Gujarat (India), involving 30 hospitals (including 15 private hospitals) showed that 74 per cent were not following segregation guidelines; and all the private hospitals were defaulting on important steps of BMWM[21]. This indicated the need to have a comprehensive national strategy covering both urban and rural areas including public as well as private sectors.

The providers in primary level health settings had minimal capacity (median score 1.9) for optimal bio-medical waste management; one quarter of the health facilities scored 'zero'. More than half of primary settings had no guidelines or designated person for handling BMWM; staff was poorly trained and without adequate protective equipment. A quarter of health facilities in secondary and tertiary care settings were also in the Red category. More than 50 per cent of all health facilities had problems in resources for segregation, sharps management, in-house transport, storage and record keeping. Colour bags, a basic pre-requisite to initiate proper segregation, were not available at many health facilities. Other studies from India have reported similar situations[22,23]. The lack of adequate supply of resources, leading to mixing of BMW with municipal waste was reported from Chandigarh and Gujarat[24]. Hanumantha Rao *et al*[7] reported non-compliance to BMWM guidelines by smaller hospitals but it was not clear whether the problem came up due to non availability of resources for segregation. Key stakeholders from the municipalities, pollution control boards and different health facilities also emphasized the need for capacity building including training and provision of additional resource investment for BMWM as key strategies for all round improvement.

Similar situation existed in several other developing countries[25,26]. Askarin *et al*[25] reported poor state of collection, transportation, disposal, training and personal protective equipments in Iran. A report from Karachi, Pakistan, highlighted issues of resource constraint leading to shortage of supplies and mixing of BMW with domestic wastes[27]. A study from Senegal[28] indicated the non-availability of infrastructure and lack of awareness as key contributors for poor quality of BMWM systems.

This study adapted a scoring system with traffic colour codes (red, yellow and green) to categorize healthcare facilities and assess the system capacity, resources and processes in BMWM. The strategy helped to compare status of BMW across health settings in different geographical areas, public,

Table VIII. Perception of key stakeholders to improve BMWM at their respective Health Facilities

Domains	Officer looking after BMWM (%)		Health Facility Officer looking after BMWM (%)					
	Municipality (n-25)	Pollution Control Board (n-24)	Tertiary Care (n-24)	Secondary District Hospital (n-25)	Primary Care			
					Urban		Rural	
					Public (n-49)	Private (n-99)	Public (n-147)	Private (n-94)
Building system capacity								
(training/ well trained staff; guidelines availability; BMWM team/ manpower/ staff; co-ordination between different stakeholders; patient safety)	36.0	58.3	66.7	72.0	57.1	75.8	77.6	63.8
Additional resource allocation								
(financial aid; BMW equipment/ incinerator; indenting & procuring material; improve infrastructure; providing logistics; segregation resources; transportation; storage)	32.0	20.8	33.3	44.0	53.1	30.3	55.1	33.0
Streamlining processes								
(monthly meeting; monitoring/ action against defaulters/ protective measures by handlers; segregation processes; disposal system to be put in place; transportation process; avoid handing over to rag pickers; storage process)	20.0	20.8	25.0	20.0	22.5	15.2	17.0	16.0
Improved governance								
(improved administration; separate department for BMWM; penalty on implementing agencies; strict rules implemented/ maintain supervision; alternate system to be made available/ private providers/ municipality; action against quacks/ unregistered practitioners; steps reducing BMW-generation)	36.0	50.0	25.0	20.0	10.2	12.1	18.4	17.0
Community awareness		20.8	8.3		2.0	6.1	2.7	2.1

private, urban and rural settings. This approach also helped to assess and interpret the current BMWM state in a consistent manner. One potential limitation in this scoring system is that on a visual analogue scale, only three points were identified. Hence only significant improvements or deteriorations may be picked up for individual domains. However, each broad domain was assessed through several sub-domains or items to reduce this limitation. Though enough private facilities from primary care settings were included in the study, fewer private facilities in secondary and tertiary care settings were involved. Other BMW generating units like dental clinics/ hospitals and laboratory/diagnostic facilities were not assessed and the findings do not reflect these sectors.

The processes of BMWM were poor and unacceptable across the levels of health facilities; poorest in primary care settings as compared to secondary and tertiary care settings. All domains in BMW processes required improvement in primary care settings. Some systems existed for processes of segregation of BMW in secondary and tertiary hospitals and management of sharps in tertiary hospitals but required additional efforts to achieve optimal standards. The study indicated deficient or lack of processes particularly in those areas where resource allocation was poor. Interviews with personnel responsible for waste management at hospitals revealed that least importance was given to the treatment of infected plastic wastes before terminal disposal which is strongly recommended by expert body like the National Centre for Infectious Diseases and the Healthcare Infection Control Practices Advisory Committee (HICPAC)[29].

In general, there was consistency between the scores for system capacity, resources available and process adopted from a particular type of health care facilities. However, during in-depth interviews, the gap in knowledge and practice in relation to availability of resources and processes in place was found as was the need for organized training and structured supervision to bridge this gap. A study on tertiary care hospitals in India found that people with higher education such as consultants, residents and scientists had good knowledge of biomedical rules but was not reflected in their practices[30]. Studies reported from geographically diverse, large States of India (Andhra Pradesh, Maharashtra and Uttar Pradesh) showed that awareness among hospital staffs regarding segregation of BMW was slightly higher in urban areas compared to rural areas; and that employee training and awareness can be a major determinant of establishing optimal BMWM[31]. The current study revealed that surveillance and monitoring of BMWM were consistently deficient and respondents from pollution control board emphasized better governance and penal provisions for effective implementation of BMWM guidelines. These factors need close consideration while designing systems to improve compliance with the BMWM guidelines.

Multivariate modelling in this study revealed several important predictors for achieving acceptable scores for the BMWM system. Significant predictors were: presence of guidelines or charts at point of waste segregation (system capacity), accountability of a dedicated person, availability of appropriate containers or bags for waste segregation, availability of functional needle destroyers, personal protective equipment for waste handling staff (resources), segregation of wastes at point of generation, availability of register for record maintenance and disinfection of plastic wastes or sharps at point of waste generation (processes). There are only a few studies which have correlated presence of good BMWM with different predictors. Many of the published studies acknowledge all the above components as integral part of BMWM system but their relative significance or value as a predictor for good BMWM has not been reported[25,32]. Recently published Indian BMW rule update also emphasized the above components as an integral part of waste management system[33]. Careful analysis of these specific indicators of system capacity, resources and process reveals that besides greater investment, mechanisms of accountable and responsive governance is required to get a functional BMWM system in health facilities.

In conclusion, BMWM is grossly deficient at both macro and micro levels in different parts of India. Urgent interventions for improving systems capacity and greater resource commitment are required, specifically focussing on primary care health facilities both in public and private sectors. Accountable and responsive governance is likely to institute appropriate processes and establish acceptable BMWM system[34].

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