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Research article

Generation rate of hospital solid waste from different services: A case study in the province of Bagua, northern Peru

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ABSTRACT

The objective of this research was to evaluate the unit generation rate of solid hospital waste at the Gustavo Lanatta Lujan Bagua Support Hospital (HAB). The calculations were based on the weights of hospital waste disposed periodically to the biosafety cell located 7 km from the city of Bagua since 2015. Nineteen services were identified and grouped into three areas: hospitalization area, emergency area and gynecology area, studied according to the group classification of Peruvian regulations. The results show that 92.77 kg/day-1 are generated, 62.26 % are biocontaminated waste, 26.45 % are common waste, 7.7 % are sharp-sharp waste and 3.6 % are special waste. It was also found that only 73.56 % is disposed of in the hospital's biosafety cell. In this sense, this study will contribute to promote the reduction of the entry of hazardous substances into the stream of an adequate waste management and save workers and the environment

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in the Amazon Region. Therefore, awareness should be raised at all levels of society through various means of communication and education, so that the risks of spreading health hazards can be minimized by improving hospital waste management. In addition, healthcare waste management should be implemented, taking into account the parameters to be monitored, the economic resources to be managed and the national plans for healthcare waste.

1. Introduction

Hospital waste is a worldwide concern about negative impacts, especially in developing countries [1]. During the development of their activities, and industrial health facilities generate waste that present potential hazardous risks, and inadequate management entails serious consequences for the health of the hospital community, the personnel in charge of external waste management, and the population [2,3]. Globally, it is estimated that about 85 % are common wastes and the remaining 15 % are hazardous, infectious and toxic wastes [4], their dangerousness lies in the possibility of favoring the transmission of diseases such as AIDS, hepatitis B and C and several resistant bacterial infections [5]. In this line are sharps waste, caused by infectious waste generated in health facilities, In this line are sharps waste, caused by infectious waste generated in healthcare facilities, these results can threaten urban as well as rural areas, and the environmental and social impact worsens as the world's population increases [6,7].

In European Union countries there is significant variation, defined as waste from human or ani-mal health care and/or related research [8], and there is concern about the impact on public health [9]. Health facilities are responsible for reducing and preventing the health problems of the population [10], given that hospital waste can vary significantly between countries in Latin America and the Caribbean, the European Union [11], and the different varieties of waste generated in health facilities are considered hazardous waste by the Basel Convention and have been classified with the acronym Y1 - Clinical waste resulting from medical care provided in hospitals, medical centers and clinics [12]. Therefore, these wastes must be properly managed and their mismanagement is a problem in most countries and especially in developing countries [13].

It has been observed in several studies that solid waste from health care facilities for general and hazardous waste varies within a country [14]. Solid waste management, particularly medical solid waste, is emerging as a major problem. The amount of solid waste generated by 1 in 3 health care facilities does not safely manage medical waste, and 3 in 10 health care facilities lack systems to segregate waste globally [15]. In Uganda, they quantified and characterized the general waste management patterns at the Mulagodonde referral hospital and found that the average solid waste generation rate was 111.4 kg per day and the wards produced the largest amounts, followed by the operating rooms, kitchen, public areas, laundry and administration. Therefore, pre-treatment systems should be implemented [16]. In the district of Sheikhupura, Pakistan, five public hospitals were evaluated, as a result of which it became evident that by applying an integrated approach, it would be possible to mitigate GHG emissions by 37,756.44 kg CO^2 -eq. per ton of waste annually [17].

In Latin America and the Caribbean, the management of biocontaminated waste is still in its infancy, where the presence of various health determinants and educational factors deteriorate the health of the population [18]. Therefore, it is necessary that health workers involved in its management understand the integral link between human health and environmental health [19].

Peru is no stranger to the problems of waste management in many hospitals, which is very deficient. Most of the biomedical waste produced is not adequately treated [20]. The average production of biocontaminated waste from health facilities at the national level ranges between 0.15 and 840 kg/day, depending on the grade and category. National health facilities administered by MINSA generate approximately 67,000 kg/day [21] and these are in the non-municipal management area [22]. It is important to mention that approximately 20,000 tons of biocontaminated waste are generated per year, 75 % in Lima and the remaining 25 % in the provinces [23]. Studies related to hospital waste management in Peru are still lacking. Likewise, the hospital waste disposal and treatment system and public statistics are very limited, which limits its proper management [24]. Therefore, policy makers should formulate policies for the development of comprehensive waste management databases to effectively develop the necessary policies [25], as well as the implementation of new management techniques instead of building new facilities [26].

Hospital waste is classified into three groups, according to their characteristics. Group A includes biocontaminated waste; in group B, special waste; in group C, common waste [22]. This classification is essential for the hospital solid waste management system to be effective in controlling health risks. Where group A is the hazardous waste generated in the process of medical care that is contaminated with infectious agents, with a high content of microorganisms of high risk for the person who comes into contact with such waste. Group B is hazardous waste, with physical and chemical characteristics of potential danger due to its corrosive, flammable, toxic, explosive and reactive properties for the exposed person. Group C includes waste generated in the administration, waste from the cleaning of gardens, yards, public areas, remains from food preparation, etc., as well as waste from the cleaning of the public areas In this sense, it is important to manage it from containment, storage and final disposal according to the Hospital Waste Management Standard [27], incorporating the commitment and active participation of all hospital personnel [28].

Therefore, appropriate waste management strategies should be formulated [29]. Health facilities should comply with certain management measures, such as the formation of the Integrated Management and Solid Waste Management Committee, and have a Plan or Program for Minimization and Management of Non-municipal Solid Waste.

Based on the above, the objective of this research was to evaluate the unit generation rate of hospital waste at the Gustavo La-Natta Lujan hospital.

2. Materials and methods

*Description of the study area*The province of Bagua is geographically located at 05°38′21″ south latitude and 78°31′54″ west longitude (Fig. 1). It is located in the northern jungle of Peru, at an altitude of 420 m above sea level [30]. It has an approximate population of 74, 100 inhabitants [31]. It has an average annual accumulated precipitation of 1832 mm and an annual air temperature of 30 °C [32], and is characterized by a very warm climate. Favorable climate for metaxenic diseases such as dengue caused by mosquito bites [33].

The Bagua biosafety cell for hospital waste has an airtight design and has been in operation since 2015. In addition, its resistance is 210 kg/cm^3 and it is waterproofed with Sika®-1 additive. Its integrated decontamination system uses 02 bags of lime and 02 bags of soil for each final disposal to guarantee the complete elimination of pathogens (Fig. 2A). In addition, the personnel responsible for the disposal of hospital waste have all the clothing (overalls, safety glasses, steel-toed boots, leather gloves), in accordance with the regulations in force by the Health sector [22].

The area is 2 ha and was donated by the Regional Government of Amazonas. It is located 7 km from the city of Bagua, its dimensions are 8.00 m × 4.00 m x 3.50 m (112 m^3) and its final disposal accepts all types of hospital waste (Biocontaminated and special) (Fig. 2).

The hospital waste from the 19 services was grouped in 03 areas, and the transfer was done using an exclusive-use (Fig. 2B), totally enclosed truck with a capacity of 6 m^3 owned by the institution; the frequency of waste removal to the biosafety cell is twice a week. The average daily rate of hospital waste generation is 92.77 kg/day.

The Gustavo Lanatta Lujan hospital is public and its category is II - 1, and for a better attention it offers services that were grouped in 03 areas: (i) hospitalization area, (ii) emergency area, and (iii) gynecology area, being the only referential hospital located in the area and that allows attending the provinces of Condorcanqui, Utcubamba and the district of Santa Rosa - Province of Jaen.

2.1. Data collection and grouping

Hospital waste data collected through field notebooks expressed in kg/day and m^3/day by type of solid waste (bioconta-mined, common, sharps and special), the collection was from April 26 to May 02, 2023. Data from nineteen (19) services were used in this work with a total of 123 beds, of which seven (07) services are in the hospitalization area with 59 beds, three (03) services are in the emergency area with 21 beds and nine (09) services are in the gynecology area with 43 beds (Table 1). All data collection was carried out taking into account the “Technical Health Standard: Integral management and handling of solid waste in health facilities, medical support services and research centers".

The volume of hospital waste was designed according to the capacity of the container (200 L cylinder), with the amount generated

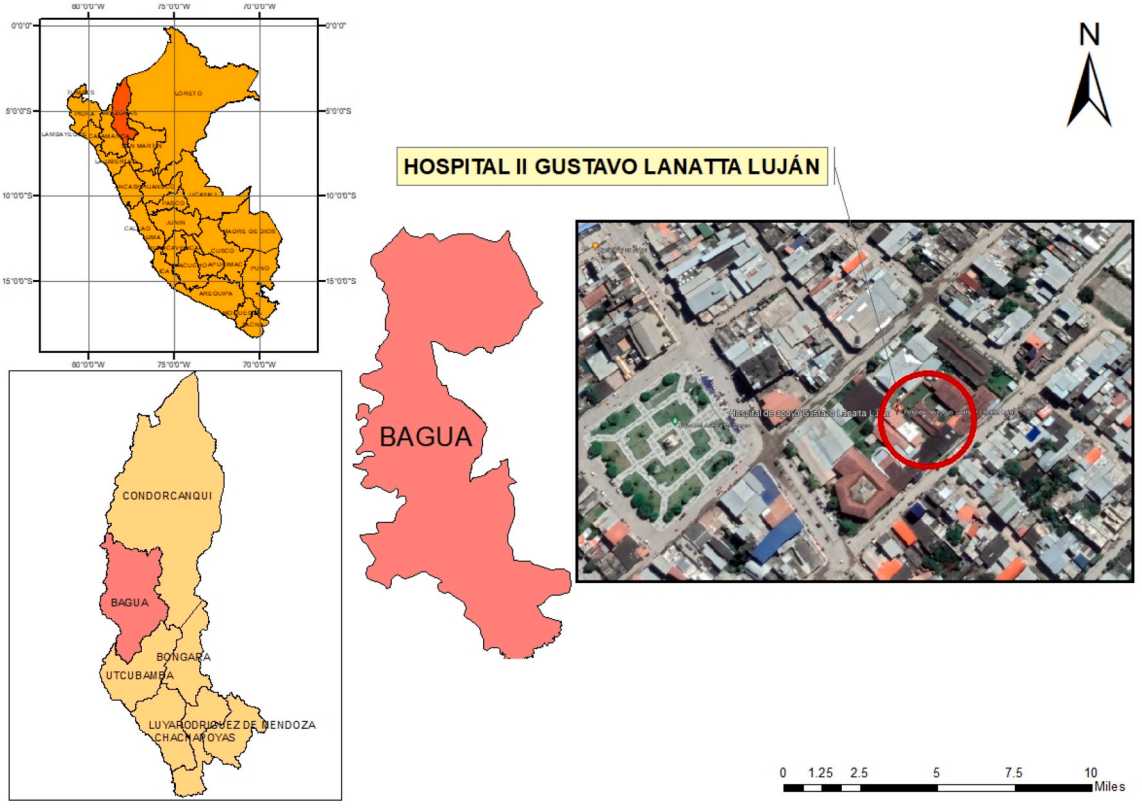

Fig. 1. Location map of the province of Bagua.

Fig. 2. Infraestructura destinada a la disposición final de residuos hospitalarios (A); Truck for exclusive use in the transport of hospital waste (B).

Table 1
Description of the 19 services evaluated.

Area	Service
Hospitalization	Medicine
	Surgery
	Pediatrics
	Isolated
	Uci
	Respiratory ICU
	Uviclin
Emergency	Trauma shock
	Obsrv. Women
	Male Observers
Gynecology	Hospitalization 1
	Hospitalization 2
	Hospitalization 3
	Topical gynec. Obstetrics
	Obs. Ginic.
	Accommodation con-jointly
	Neonatology
	Emergency gynecology
	Maternity ward

in the day [22,34] (Equation (1)).

$$Volume\ of\ hospital\ waste = \pi\left(\frac{D}{2}\right)^{2} x\left(H_f - H_o\right) \quad (1)$$

π = constant (3.1416); H_f = Total cylinder height; H_o = Cylinder free height; D = Cylinder diameter.

Likewise, the 19 services used in this study were also grouped into three (03) areas that dispose biocontaminated waste (Group A, A - 5) and special waste (Group B) and group C, as established by Peruvian regulations (since both groups are disposed of in the biosafety cell).

2.2. Statistical analysis

Statistical analysis of the data was performed for each service, group and type of waste, classifying it according to the production of the different services and visualizing graphs to determine the behavior of biocontaminated waste. The analysis was carried out using the minitab 19 [35].

3. Results

3.1. Generation of solid hospital waste

The nineteen classified services generate 92.77 kg/day^{-1} of waste and their generation range from 1.01 kg/day^{-1} trauma shock service to 11.67 kg/day^{-1} ICU hospitalization service (Table 2). Biocontaminated waste is at 57.76 kg/day^{-1} (62.26 %), these come from patient care Solid waste contaminated with secretions, excretions and other organic liquids from patient care, including food waste. Among them, sharps waste reaches up to 7.14 kg/day-1 (7.7 %), including hypodermic needles, pipettes, scalpels, lancets,

Table 2
Description of solid hospital waste from the "Gustavo Lanatta Lujan" - Bagua support hospital.

Area	Service	Common		Biocontami-nates		Punzocortan-tes		Specials		Total[a]		N° BEDS	Kg/bed/day	m^3/bed/day
		Kg/day	m^3/day	Kg/day	m^3/day	Kg/day	m^3/day	Kg/day	m^3/day	Kg/day	m^3/day			
Hospitalization	Medicine	1.87	0.01373	6.80	0.03489	1.2	0.00849	0.171	0.00159	10.04	0.0587	12	0.8368	0.0049
	Surgery	1.32	0.01039	3.60	0.02079	–	–	0.32	0.00212	5.24	0.0333	14	0.3743	0.0024
	Pediatrics	1.21	0.00978	3.04	0.01654	–	–	0.151	0.00106	4.40	0.0274	9	0.4890	0.0030
	Isolated	1.35	0.01183	2.60	0.01540	–	–	0.097	0.00053	4.05	0.0278	3	1.3490	0.0093
	Uci	2.43	0.01259	7.37	0.04088	1.87	0.01292	–	–	11.67	0.0664	9	1.2967	0.0074
	Respiratory ICU	2.29	0.01388	6.94	0.03921	1.21	0.00831	0.314	0.01168	10.75	0.0731	8	1.3443	0.0091
	Uviclin	0.94	0.00751	1.86	0.01289	–	–	0.58	0.00372	3.38	0.0241	4	0.8450	0.0060
Emergency	Trauma shock	0.68	0.00452	0.126	0.00106	–	–	0.206	0.00159	1.01	0.0072	1	1.0120	0.0072
	Obsrv. Women	2.22	0.01292	3.86	0.02533	–	–	–	–	6.08	0.0382	10	0.6080	0.0038
	Male Observers	1.83	0.01221	2.63	0.01752	–	–	–	–	4.46	0.0297	10	0.4460	0.0030
Gynecology	Hospitalization 1	0.59	0.00602	2.18	0.01813	1.46	0.01009	–	–	4.23	0.0342	6	0.7050	0.0057
	Hospitalization 2	0.57	0.00540	2.48	0.01494	–	–	–	–	3.05	0.0203	8	0.3813	0.0025
	Hospitalization 3	0.84	0.00796	1.74	0.01199	–	–	0.92	0.00690	3.50	0.0268	8	0.4375	0.0034
	Topical gynec. Obstetrics	0.766	0.00705	1.36	0.00895	–	–	–	–	2.13	0.0160	3	0.7087	0.0053
	Gynecology Observation Room	0.880	0.00667	1.28	0.00842	–	–	–	–	2.16	0.0151	3	0.7200	0.0050
	Accommodation con-jointly	1.410	0.01407	1.84	0.01418	1.4	0.00956	–	–	4.65	0.0378	2	2.3250	0.0189
	Neonatology	1.21	0.00789	3.01	0.01904	–	–	0.58	0.00478	4.80	0.0317	4	1.2000	0.0079
	Emergency gynecology	1.42	0.00966	1.94	0.01267					3.36	0.0223	8	0.4200	0.0028
	Maternity Ward	0.712	0.00726	3.1	0.02003	–	–	–	–	3.81	0.0273	1	3.8120	0.0273
Total		24.54	0.18133	57.76	0.35284	7.14	0.04937	3.339	0.03397	92.77	0.6175	123	1.0163	0.0050

[a] Type of waste by groups disposed in the biosafety cell; "Group A (Biocontaminated), Group A - 5 (Sharps), Group B (Special), Group C (Common)"; -Data not reported.

broken culture plates, catheters with needles, venoclysis equipment, broken ampoule vials, slides and covers, among other broken glass or sharps discarded. Common waste is generated in the amount of 24.54 kg/day^{-1} (26.45 %), being those wastes that have not been in contact with patients (generated in offices, corridors, common areas, cafeterias, auditoriums, etc.). Offices, corridors, common areas, cafeterias, auditoriums) and special wastes 3339 kg/day^{-1}, these wastes have physical and chemical characteristics of potential

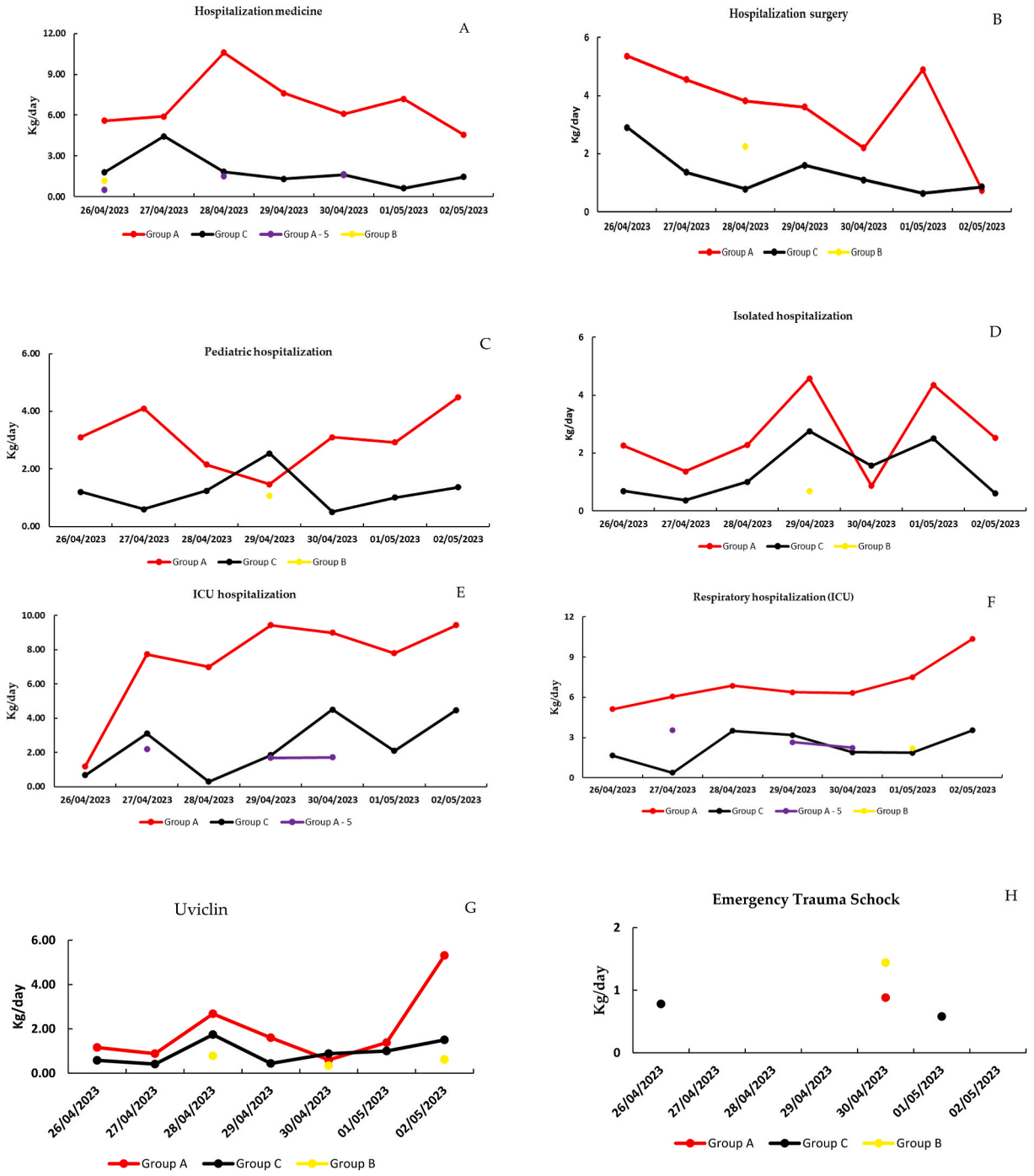

Fig. 3. Behavior of hospital waste; A)Hospitalization medicine; B) Hospitalization surgery; C) Pediatric hospitalization; D) Isolated hospitalization; E) ICU hospitalitalization; F) Respiratory hospitalization; G)Uviclin; H) Emergency Trauma Schock; I) Emergency Women's Observation; J) Emergency Male Observation; K) Gynecology Hospitalization 1; L) Gynecology Hospitalization 2; M) Gynecology Hospitalization 3; N) Topical Gynecology; O) Gynecology Observation Room; P) Gynecology joint accommodation; Q) Gynecology Neonatology; R) Emergency gynecology; S) Maternity ward

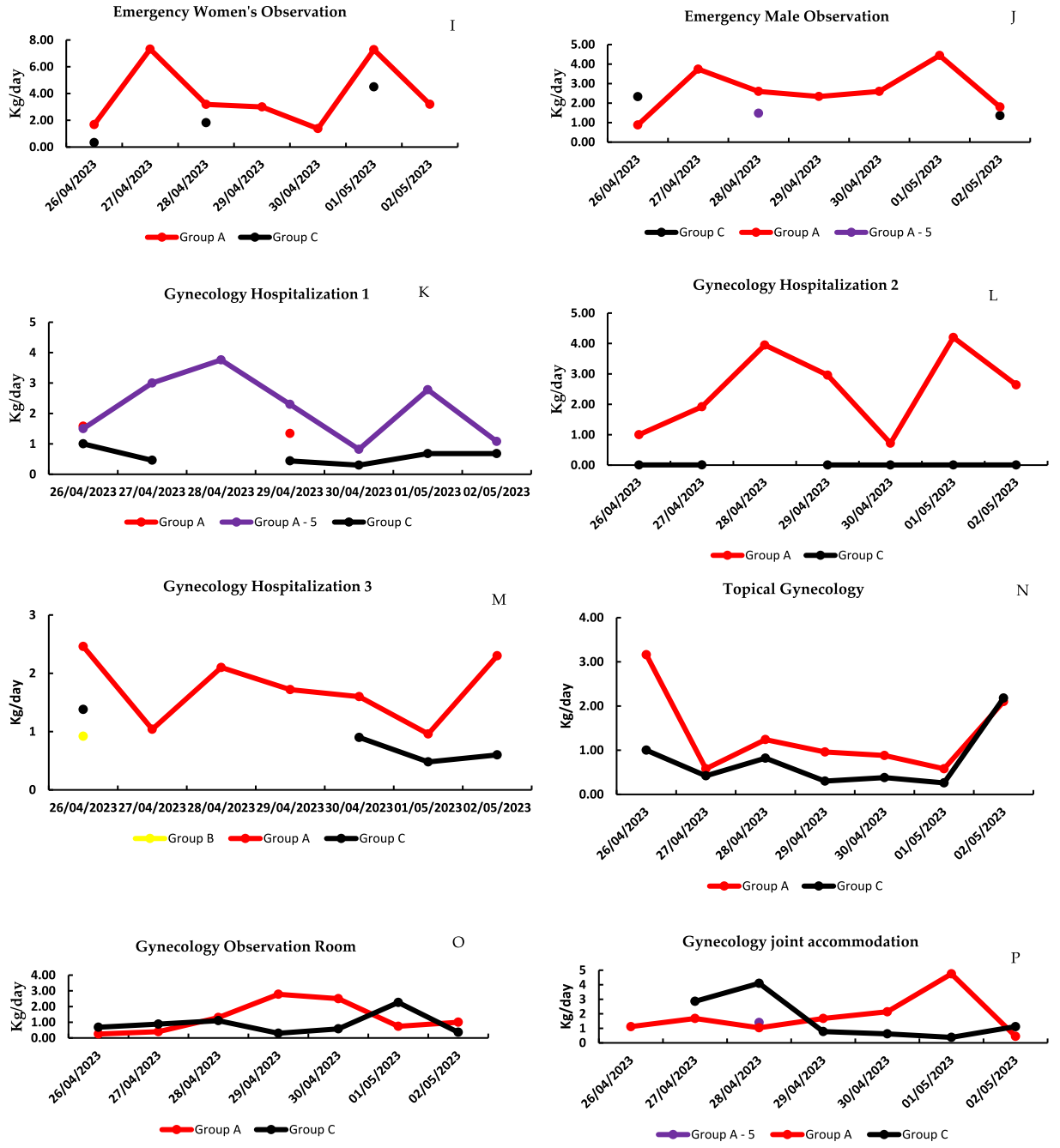

Fig. 3. (*continued*).

danger due to their corrosive, flammable, toxic, explosive, reactive and radioactive nature for the exposed person. A total of 73.56 % of the waste is disposed of in the biosafety cell and 26.45 % is transported by a compactor vehicle of the Bagua Provincial Municipality.

Fig. 3 shows that there is inadequate segregation of solid hospital waste in the 19 services; it can be seen that the red line for biocontaminated re-waste is above the black line for communal waste, which shows that the capacity of the containers is inadequate. In addition, it is evident that in the "ICU respiration" area up to 2.29 kg/day of common waste was generated, with respect to special waste it reached 0.314 kg/day (Fig. 3F) and in the ICU area the largest amount of sharps waste (1.87 kg/day) was evidenced (3E).

4. Discussion

The study showed that there is limited information on the quantities and characteristics of the various types of waste generated in

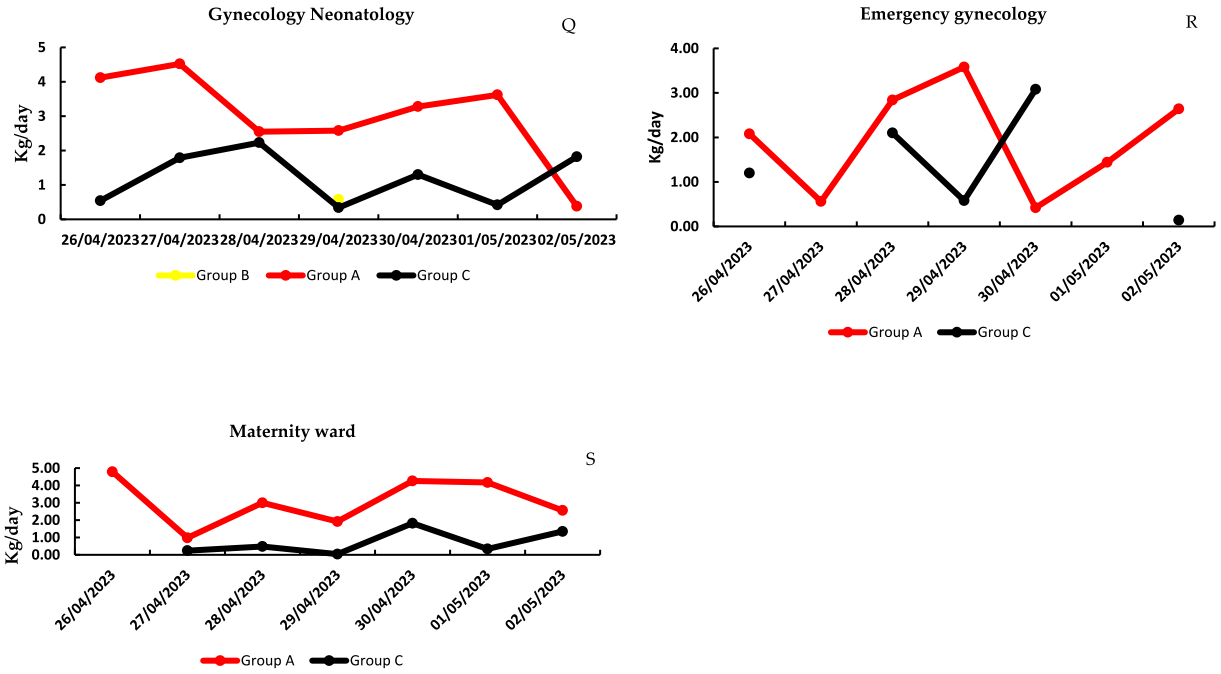

Fig. 3. (*continued*).

health care centers. In this case, of the nineteen (19) services studied, 92.77 kg/day^{-1} were generated; these values are higher than those found by Ref. [36], who reported 3.23 kg/day-bed; this may be associated with the facilities provided by the establishments; some services may be very basic and, therefore, the amounts of waste generated are relatively small. The study by Herrera [37] found that the class of waste with the highest generation corresponds to biocontaminated waste, which reached 391 kg/day, higher values than in our study. Biocontaminated waste may contain concentrations of microorganisms that are potential public health hazards [38] and their effects are continually increasing in the environment [39]. In this sense, it is important to characterize the waste for the implementation of biosafety cells, which allow controlling the contamination of waste generated in health facilities [39]. Given that every health care facility must implement a solid waste treatment method according to its size, level of complexity, geographic location, available resources and technical feasibility, it is essential that the facility's management system be adapted to the needs of the facility [40].

The generation of hospital waste ranged from 1.01 kg/day^{-1} trauma shock service to 11.67 kg/day^{-1} ICU hospitalization service. Other studies determined that ICU generates 7.1 kg/day of solid waste, the differences between the studies may be due to their focus on single patient diagnosis and variation in medical practice [41]. There are also evi-dences, that delays in transferring patients out of the ICU, decision making in procedures was among the most common that increases waste and varies depending on the medical staff [42].

Biocontaminated waste 62.26 % of the biocontaminated waste comes from medical waste and biocontaminated waste is the most common in hospitals, and can represent up to 80 % by weight [43]. These wastes belong to group A and are above the other groups (Group C–B), followed by group C of common wastes. However, specific studies on hospital waste management are very limited [44].

The common waste generated in the hospital was 24.54 kg/day^{-1}, which generally comes from food production, office work, sweeping, maintenance work and even gardening [45]. Therefore, management must be safe and efficient to avoid the proliferation of diseases [46]. Recently, strategies for the implementation of an effective management of hospital waste towards an environmentally friendly and sustainable health care environment should be addressed [47].

We found 7.14 kg/day^{-1} of sharps waste and 3.339 kg/day^{-1} (3.6 %) of special waste, which is generally the product of injections (needles), lancets, broken glass, sample tubes and can transmit blood-borne pathogens such as HIV [48]. Type III (special) waste would be infectious materials from anatomic pathology, microbiology, hematology and biochemistry laboratories [49] and should therefore be managed in a very efficient manner.

And, therefore, must be managed very efficiently, from its origin to its final disposal, in order to avoid occupational hazards in the establishments [50]. The Ministry of Health (MINSA) is responsible for regulating, supervising and overseeing the management and management of solid waste from medical establishments, as well as waste generated by health campaigns.

The study showed that only 73.56 % is disposed of in the Bagua biosafety cell and 26.45 % is collected by a Bagua Provincial Municipality compactor for final disposal. However, Supreme Decree No. 014 (MINAM, 2017b) establishes that the final treatment of hazardous and non-hazardous solid waste depends directly on the central government and should be treated differently from urban solid waste.

Therefore, it is recommended that future work address management strategies to improve hospital waste management in urban and rural areas of northern Amazonas, taking into account new and emerging appropriate technologies [51].

Peru has hospital waste management policies (Health Technical Standard N° 144-MINSA/2018/DIGESA) was approved by Ministerial Resolution N°1295-2018-MINSA, whose objective lies in the safety of employees, patients and visitors to medical facilities, health care services and public and private research centers, to prevent risks in medical management and environmental management. The Ministry of Health (MINSA), through the General Directorate of Health and Food Safety (DIGESA), is responsible for regulating, supervising and overseeing solid waste management in medical establishments and support services nationwide.

Likewise, the competent authority should control the health risks derived from the inadequate management of solid waste from medical establishments and inadequate medical support services [52]. Proper management of hospital waste has a great contribution to public health, and it is advisable to raise awareness about proper management. In addition, waste collectors should work with safety equipment [53].

Future research is expected to address a longer period of evaluation of hospital waste and to assess the level of perception by health care workers regarding hospital waste management. With the aim of predicting organizational changes [53] and formulating appropriate policies for public health. It is also important that future work incorporates evaluation criteria for hospital waste to avoid uncertainty in the identification of contamination [54].

5. Conclusions

Bagua is a resource-constrained province in the Amazon region that is experiencing rapid rural-to-urban migration. This has contributed to challenges such as the effective management of hospital waste. The study showed that 62.26 % is biocontaminated waste, so measures must be taken to strategically reduce excessive resource consumption and minimize the impact of health services on public health. It was also estimated that only 73.56 % is disposed of in the hospital biosafety cell and 26.45 % is treated as common waste (laundry and food waste). This also requires attention for proper management, as it can cause the transfer of infectious vectors.

The scope of the study can be expanded to include the remaining hospitals within the Amazon Region, as well as those operating in other cities in Peru (depending on data availability) in order to improve hospital waste management. These actions would improve public health in the cities.

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

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CRediT authorship contribution statement

Juan Eduardo Suarez Rivadeneira: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Eduardo Benjamín Suarez Chavarry:** Writing – review & editing, Writing – original draft, Validation, Supervision, Formal analysis. **Ítalo Maldonado Ramirez:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis. **Wilfredo Ruiz Camacho:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis. **Edilbrando Vega Calderón:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis. **Roberto Pérez Astonitas:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis. **Roberto Carlos Santa Cruz Acosta:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis. **Morales-Rojas Eli:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Heling Kristtel Masgo Ventura:** Writing – review & editing, Writing – original draft, Supervision, Investigation, Formal analysis. **Mayra Pamela Musayón Díaz:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Juan Eduardo Suarez Rivadeneira reports article publishing charges was provided by National University Toribio Rodriguez de Mendoza of Amazonas. Juan Eduardo Suarez Rivadeneira reports a relationship with National University Toribio Rodriguez de Mendoza of Amazonas that includes: employment. - If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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