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An Assessment of Carpet Waste Generation and Waste Disposal Management Practices in the Carpet Industry of Bhadohi District, Uttar Pradesh, India

Shameena Ansari* and Victoria Amit Masih

Department of Agricultural Economics, SHUATS, Naini, Prayagraj, India

**Corresponding author*

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A B S T R A C T

The present study assessed carpet waste generation and waste disposal management practices in the carpet industry of Bhadohi district, Uttar Pradesh, with particular emphasis on identifying the major sources of industrial waste and evaluating existing disposal mechanisms adopted by carpet manufacturing units. A purposive-cum-random sampling technique was employed to select 60 respondents representing small, medium and large carpet manufacturing units across four major carpet-producing blocks. Primary data were collected through a pre-tested structured interview schedule, personal interviews and field surveys, while secondary information was obtained from government reports, regulatory agencies and published literature. The collected data were analysed using percentage analysis, Garrett Ranking Technique and the Chi-square test. The findings revealed that the majority of respondents were experienced middle-aged entrepreneurs and production personnel possessing adequate industry knowledge. Dyeing and washing operations emerged as the principal sources of hazardous industrial waste, with all respondents reporting the generation of spent dye liquor, chemical residues and wastewater containing high pollutant loads. Fibrous solid waste generated during spinning, weaving and finishing also constituted a significant proportion of the overall waste stream. The study further revealed that environmentally unsustainable disposal practices were predominantly observed among small-scale manufacturing units, where untreated effluents were frequently discharged into open drains or agricultural land, accompanied by widespread open dumping and burning of solid waste. In contrast, larger units demonstrated relatively better environmental compliance through the installation of Effluent Treatment Plants and the adoption of fibre recycling practices. The findings highlighted substantial disparities in waste management practices across unit sizes and underscored the need for improved environmental infrastructure, stricter regulatory enforcement and wider adoption of sustainable waste management technologies. The study concluded that strengthening institutional support, promoting cleaner production practices and expanding common waste treatment facilities would significantly enhance environmental sustainability, resource efficiency and the long-term competitiveness of the carpet industry in Bhadohi district.

Introduction

The carpet industry has long been recognised as one of the most significant traditional manufacturing sectors, contributing substantially to employment generation, rural industrialisation, export earnings, and socio-economic development in many developing countries. In India, the hand-knotted carpet industry occupies a prominent position in the handicraft sector, with Uttar Pradesh accounting for a major share of national carpet production and exports. The manufacturing process, which encompasses yarn preparation, dyeing, weaving, washing, finishing, and packaging, generates considerable quantities of solid, liquid, and chemical waste. Carpet fibre trimmings, rejected yarn, dye sludge, wastewater containing synthetic dyes and chemicals, packaging residues, and hazardous by-products constitute the principal forms of industrial waste generated during production. The increasing expansion of carpet manufacturing has consequently intensified concerns regarding waste generation and its adverse environmental implications. Inadequate disposal of industrial waste has been associated with soil degradation, water pollution, deterioration of air quality, depletion of natural resources, and occupational health risks for workers engaged in production activities. Despite the existence of environmental legislation and pollution control guidelines, waste management practices within many carpet manufacturing units continue to remain inadequate owing to financial constraints, limited technological adoption, weak regulatory compliance, and insufficient awareness of sustainable waste management practices. Small and medium-scale enterprises, which dominate the carpet manufacturing sector, often face greater challenges in adopting environmentally sound disposal systems because of high capital investment requirements, inadequate institutional support, and limited access to technical expertise. The growing emphasis on sustainable industrial development, circular economy principles, cleaner production technologies, and environmentally responsible manufacturing has further highlighted the necessity for systematic assessment of industrial waste generation and disposal practices within the carpet industry. Effective waste management not only minimises environmental degradation but also enhances resource efficiency, improves occupational safety, strengthens international market competitiveness, and facilitates compliance with national and global environmental standards. Furthermore, increasing consumer preference for environmentally sustainable products and stringent environmental requirements imposed by international markets have made responsible waste management an essential component of industrial competitiveness. In this context, a comprehensive assessment of carpet waste generation and waste disposal management practices is essential to identify the nature and magnitude of waste generated, evaluate existing disposal mechanisms, examine the effectiveness of regulatory compliance, and formulate appropriate strategies for sustainable industrial waste management. Such an assessment provides valuable empirical evidence for policymakers, environmental regulatory agencies, industry stakeholders, and researchers in promoting environmentally sustainable, economically viable, and socially responsible practices within the carpet manufacturing sector.

Materials and Methods

The methodology adopted for the selection of the district, blocks, villages, industrial clusters, and respondents was based on a purposive-cum-random sampling technique. Bhadohi district of Uttar Pradesh was selected purposively because it is the largest carpet manufacturing cluster in India and is characterised by substantial carpet waste generation and diverse waste disposal management practices. All four major carpet-producing blocks, namely Bhadohi, Gyanpur, Aurai, and Suriyawan, were selected purposively on the basis of the concentration of carpet manufacturing units, dyeing clusters, and industrial waste generation. A comprehensive list of carpet-producing villages and industrial clusters within the selected blocks was obtained from the District Industries Centre (DIC), Bhadohi, and twenty villages and industrial clusters having the highest concentration of carpet manufacturing and dyeing units were selected for the study. From the selected villages and industrial clusters, lists of carpet manufacturing units were prepared and classified into three categories based on unit size, namely small, medium, and large units. A total of 60 respondents, comprising carpet manufacturers, dyeing-unit operators, production supervisors, workers involved in waste handling, and waste management functionaries, were selected through a purposive and multi-stage stratified random sampling technique to represent all categories of manufacturing units. Primary data were collected through a pre-tested and well-structured interview schedule using personal interviews and field surveys. Secondary data were collected from the District Industries Centre (DIC), Uttar Pradesh Pollution Control Board (UPPCB), Ministry of Textiles, Export Promotion Council for Handicrafts (EPCH),

Central Pollution Control Board (CPCB), government reports, published books, research journals, official records, and relevant websites. The collected data were analysed using simple percentage analysis, Garrett Ranking Technique, and Chi-square test to fulfil the objectives of the study. The data pertained to the academic year 2025–2026.

Analytical Tools

- **Chi-Square Test** $\chi^2 = \Sigma [(Oi - Ei)^2 / Ei]$
- **Percentage (%)** = (Number of Respondents / Total Number of Respondents) × 100
- **Garrett Ranking**: Per cent position = 100 $(R_{ij}$-0.5) /N_j

Results and Discussion

Table 1: The findings indicated that the largest proportion of respondents (46.67%) belonged to the 30–45 years age group, suggesting that the workforce was predominantly composed of middle-aged individuals possessing substantial practical experience in production activities. Educational attainment showed that 50.00 per cent of the respondents had completed secondary or higher secondary education, while nearly one-quarter had attained graduate-level qualifications or above, implying a comparatively better capacity for understanding regulatory requirements and adopting improved production technologies. Furthermore, 53.33 per cent of the respondents possessed between 5 and 15 years of experience in the industry, reflecting a well-established and experienced respondent base capable of providing reliable and informed responses for the study. These findings were consistent with those reported by Verma and Singh (2023), who observed that dyeing and production units in the Bhadohi–Mirzapur carpet cluster were predominantly managed by experienced, middle-aged entrepreneurs with educational qualifications generally limited to the secondary level. Such a demographic profile was found to have a significant influence on the level of awareness and adoption of environmental management practices within the industry.

Table 2: The findings revealed that liquid effluents generated during the dyeing and washing stages constituted the most prevalent and environmentally hazardous waste streams within the carpet production process. All respondents (100.00%) engaged in dyeing activities reported the generation of spent dye liquor, discarded dye containers and mordant residues, while washing and rinsing operations were identified as major sources of wastewater by 98.33 per cent of the respondents. Collectively, these production stages represented the greatest environmental risk due to the substantial volume of chemical-laden liquid waste generated. Fibrous solid waste originating from hand-knotting and spinning operations was reported by between 81.67 and 91.67 per cent of the respondents, indicating that fibre residues also constituted a significant component of the overall waste stream. In contrast, only 31.67 per cent of respondents reported the generation of effluent treatment plant (ETP) sludge, suggesting the limited adoption of formal wastewater treatment facilities, particularly among small-scale production units. These findings were consistent with those of Kumar and Yadav (2022), who reported that dyeing operations generated the most hazardous category of waste in small and medium-sized carpet manufacturing units in Uttar Pradesh, while fibrous residues constituted the largest proportion of solid waste by volume.

Similarly, Verma and Singh (2023) observed that dyeing and washing processes accounted for nearly three-quarters of the total liquid effluent generated within the Bhadohi–Mirzapur carpet cluster, thereby supporting the high reporting rates observed in the present investigation. Furthermore, the stage-wise classification of waste identified in this study corroborated the typology proposed by Bhatia (2022), who categorised carpet industry waste into primary fibrous residues, secondary chemical wastes and tertiary processing by-products, thereby reinforcing the validity of the present findings.

Table 3: The findings indicated a widespread prevalence of informal and environmentally unsustainable waste disposal practices, particularly among small-scale carpet production units. A substantial majority of small units (90.00%) discharged untreated liquid effluents directly into open drains or adjoining agricultural land, while 85.00 per cent disposed of solid waste through open dumping. Furthermore, 75.00 per cent of these units practised the open burning of fibrous residues, a method that contributes significantly to air pollution through the emission of particulate matter and volatile organic compounds. In contrast, larger production units demonstrated comparatively better environmental management practices, with 55.00 per cent operating functional Effluent Treatment Plants (ETPs) for regulated wastewater disposal. Additionally, 40.00 per cent of large units reported recycling fibre waste, indicating the gradual adoption of resource recovery and circular economy practices with considerable potential for wider

implementation across the sector. These findings were consistent with those of Sharma and Tiwari (2022), who reported that more than three-quarters of small dyeing units in eastern Uttar Pradesh discharged untreated effluents into open drains or agricultural land. The higher incidence observed in the present study suggested a further intensification of environmentally non-compliant disposal practices among small enterprises. Similarly, Ghosh (2022) attributed the continued reliance on informal waste disposal methods to the high cost of treatment technologies and the limited availability of Common Effluent Treatment Plant (CETP) infrastructure, a conclusion strongly supported by the present findings. Furthermore, Mishra and Chandra (2023) reported that the open burning of fibrous waste was associated with increased respiratory and dermatological health problems among workers, thereby emphasising the urgent need for stricter environmental regulation, improved waste management infrastructure and greater adoption of sustainable disposal practices within the carpet industry.

Table.1 Socio-Demographic Profile of Respondents

S. No.	Characteristic	Category	Number	Percentage (%)
1	**Age Group**	Below 30 years	12	20.00
		30–45 years	28	46.67
		Above 45 years	20	33.33
2	**Educational Qualification**	Illiterate / Primary	14	23.33
		Secondary / Higher Secondary	30	50.00
		Graduate and above	16	26.67
3	**Category of Respondent**	Carpet Manufacturers / Unit Owners	24	40.00
		Dyeing-Unit Operators	15	25.00
		Production Supervisors / Workers	12	20.00
		Waste Handlers / Management Staff	6	10.00
		Waste Collectors / Transport Operators	3	5.00
4	**Unit Size**	Small (Below 10 looms)	20	33.33
		Medium (10–50 looms)	20	33.33
		Large (Above 50 looms)	20	33.33
5	**Experience in Industry**	Below 5 years	8	13.33
		5–15 years	32	53.33
		Above 15 years	20	33.33

Table.2 Types and Nature of Industrial Waste Generated at Each Stage of Carpet Production

S. No.	Stage of Production	Type of Waste Generated	Nature	% Reporting
1	Wool Scouring / Raw Material Prep.	Organic wash water, grease, dirt	Liquid — high BOD	**76.67**
2	Yarn Spinning and Preparation	Fibre fly, broken yarn, short staple	Solid — fibrous, low hazard	**81.67**
3	Dyeing of Yarn / Carpet	Spent dye liquor, dye containers, mordant residues	Liquid + Chemical — hazardous; heavy metals	**100.00**
4	Washing and Rinsing	Turbid wastewater, dye & chemical residues	Liquid — high TDS, COD, pH imbalance	**98.33**
5	Hand-Knotting / Weaving	Pile trimmings, broken yarn, loom dust	Solid — fibrous, low hazard	**91.67**
6	Shearing and Clipping	Pile shearings, fine fibre dust	Solid — airborne particulates	**88.33**
7	Finishing and Quality Inspection	Rejected carpets, packaging waste, trimmings	Solid — mixed	**83.33**
8	**Effluent Treatment (ETP — where present)**	**ETP sludge**	**Solid/Hazardous — heavy metal bearing**	**31.67**

Table.3 Current Waste Disposal Methods by Unit Size.

S. No.	Waste Disposal Method	Small Units (%)	Medium Units (%)	Large Units (%)
1	Open discharge of untreated effluent into drains / land	90.00	70.00	**20.00**
2	Open dumping of solid waste in fields / roadside	85.00	65.00	**15.00**
3	Open burning of fibrous / solid waste	75.00	50.00	**10.00**
4	Partial treatment through primary sedimentation	5.00	20.00	**35.00**
5	Full ETP treatment and regulated disposal	0.00	10.00	**55.00**
6	**Fibre waste sold / recycled to secondary users**	**10.00**	**25.00**	**40.00**

The study concluded that the carpet industry in Bhadohi district generated substantial quantities of solid, liquid and hazardous waste throughout the various stages of carpet production, with dyeing and washing operations emerging as the principal contributors to environmentally hazardous waste streams. The findings demonstrated that chemical-laden wastewater, spent dye liquor and associated residues represented the most significant environmental concern, while fibrous wastes generated during spinning, weaving and finishing also accounted for a considerable proportion of industrial waste. Waste disposal practices varied markedly according to the size of manufacturing units. Small-scale enterprises were found to rely predominantly on environmentally unsustainable disposal methods, including the direct discharge of untreated effluents into open drains and agricultural land, open dumping of solid waste and open burning of fibrous residues, all of which posed serious risks to environmental quality, public health and occupational safety. Conversely, larger manufacturing units exhibited comparatively higher levels of environmental compliance through the operation of Effluent Treatment Plants, regulated waste disposal systems and limited adoption of fibre recycling practices, indicating greater institutional capacity and financial resources to implement sustainable waste management measures. The findings further suggested that inadequate treatment infrastructure, high compliance costs, limited technological adoption and weak enforcement of environmental regulations continued to constrain effective waste management, particularly among small and medium-sized enterprises. Therefore, strengthening environmental governance through stricter regulatory monitoring, expanding access to Common Effluent Treatment Plants, promoting cleaner production technologies and encouraging waste recycling and resource recovery should be accorded greater policy priority. Financial incentives, technical assistance and capacity-building programmes should also be extended to facilitate the adoption of environmentally sound waste management practices among smaller production units.

Greater collaboration among government agencies, pollution control authorities, industry associations and manufacturers would further enhance regulatory compliance and environmental awareness. Overall, the implementation of integrated and sustainable waste management strategies would not only minimise environmental degradation and improve occupational health but would also enhance resource efficiency, strengthen export competitiveness and support the long-term sustainable development of the carpet industry in Bhadohi district, Uttar Pradesh.

Author Contributions

Shameena Ansari: Investigation, formal analysis, writing—original draft. Victoria Amit Masih: Validation, methodology, writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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