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ORIGINAL RESEARCH

Distance and Direction Matters: Risk Perception Among Residents Around a Dump Yard in Kerala, India

Antony Paul Payyappilly, Priya Babu, Manju R Nair

Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, Kerala, India

Correspondence: Manju R Nair, Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, Kerala, India, Email manjun@scitmst.ac.in

Purpose: Waste mismanagement is a growing concern in developing countries where unsustainable practices such as open dumping and open burning are rampant. This study examined the risk perceptions of the residents living in proximity to the Brahmapuram dump yard, situated in Ernakulam district of Kerala State, India- A site marked by persistent local protests, public outrage, and legal disputes arising from issues related to waste mismanagement. The study focused on the geospatial and sociodemographic factors that might influence these perceptions.

Patients and Methods: A cross-sectional survey was conducted among 302 respondents living within 4 kilometers from the borders of the dump yard using a structured interview schedule. The responses of the participants were used to compute a risk perception score, which reflected participants' risk perception regarding the environment and their health.

Results: Among the participants in the study, those who lived within 2 kilometers (2.3 (95% CI 0.96, 3.7; p<0.001)), those who lived to the east (2.7 (95% CI 1.1, 4.2; p<0.001)) and those who reported perceiving strong malodor from the dump yard (2.0 (95% CI 0.54, 3.4; p=0.007)), had a higher risk perception in the multivariate linear regression model. Women had a lesser risk perception compared to men (−2.6 (95% CI −3.7, −1.4; p<0.001)).

Conclusion: The findings highlight the importance of geospatial characteristics (distance and direction), malodor and gender differences in shaping the risk perceptions among the proximate residents living around a waste dump yard. Consideration of geospatial and sociodemographic determinants in risk assessment and management could potentially reduce the perceived risks and public discontent around waste management facilities.

Keywords: geospatial analysis, waste management, waste dump yard, urban health, Kerala, India

Introduction

The worldwide generation of municipal solid waste (MSW) is projected to escalate from the current estimate of 2.7 billion tons to approximately 4.5 billion tons by 2050.[1]. This increase in waste generation is attributed to factors such as population growth, elevated standards of living, increasing income levels and rising material consumption in an increasingly urbanized world.[2] Unfortunately, at least one-third of the waste generated currently is not sustainably managed, particularly in the developing countries.[3] Weak institutional frameworks, financial and technological constraints and a general disregard for municipal solid waste management are the factors that underlie unsustainable waste management practices such as open dumping and burning in these countries.[4,5] Open burning, uncontrolled dumping of waste and improper leachate management from discarded waste result in significant environmental contamination and public health sequelae.[6] Malodor, greenhouse gas emissions ground and surface water pollution are significant environmental consequences of such practices.[4] Unregulated open disposal of plastic waste heightens the risk due to eventual degradation and entry into the water bodies.[7,8]

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Improper waste disposal, leading to adverse environmental consequences such as soil, water, and air pollution, has a significant impact on the health of populations residing in close proximity to the poorly managed waste facilities.[9] A wide range of health effects due to exposure to hazardous landfill waste have been reported including respiratory symptoms, irritation of skin, nose and eyes and birth defects etc.[10] Malodorous conditions near such facilities are found to affect the psychological well-being of nearby residents.[11] Marginalized communities, including the migrant population, caste, racial minorities, and individuals from lower socioeconomic classes, are most likely to bear the adverse impacts of inadequate waste management practices.[12,13] Socially disadvantaged communities have been found to be historically living in malodorous conditions, particularly in the caste-influenced social structure of India.[14] Globally, several studies suggest that this disproportionate disparity is primarily linked to the siting of waste management facilities in areas where people with little or no power and capacity to resist such installations reside.[15–19] Public protests and demonstrations against poorly managed waste treatment facilities, such as landfills and dump yards are reported from across the world.[6,20,21]

Responsible disposal of hazardous and non-hazardous wastes is considered an essential public health imperative to ensure sustainable human settlements.[22] However, most developing countries persist with poorly managed landfills, dump yards and informal sector waste scavenging despite the adverse environmental and public health consequences of waste mismanagement.[23] Such poorly regulated and unsustainable waste management methods and facilities lead to the disruptions of local ecosystems, negative public health outcomes and adverse socioeconomic impacts on the adjacent communities.[24]

Risk and Risk Perception

Risk refers to potentially negative experiences as a consequence of something that is generally feared or disliked and what is perceived as a risk is influenced by several social and cultural factors.[25,26] Risk perception is a subjective assessment of risk which is rich and complex but is one that is colored with objective reality as well.[25,27] A scientific evaluation of risk through toxicological characterizations and quantification of the extent of exposure in the proximate communities are challenging as emissions from polluting facilities are multifaceted and dynamic.[28,29] Moreover, the risk estimates and opinions often differ among stakeholders and the resultant controversies lead to confusion and uncertainty among the public, leading to trust erosion and triggering public outrage and opposition.[30] Risk perception becomes a useful tool in such situations as it can give insights on the perceived health hazards and health impacts.[31] Risk perception can help inform risk management and communication strategies for the communities living in close proximity to waste management facilities.[31,32]

Brahmapuram Dump Yard

In the present study, we looked at the Brahmapuram dump yard located in the coastal city of Kochi, in Ernakulam district of the state of Kerala, India. Operational since 2007, its intended transformation into a scientific waste treatment plant has not come to fruition, leading to its use as a dump yard by the city corporation and nearby municipalities.[33] Shortly after its inception, an independent fact-finding committee had identified numerous environmental violations and in 2016, the National Green Tribunal (NGT) found it illegal due to its leachate discharge into the adjacent Kadambrayar River.[34] Fire incidents are reported frequently from the dump yard[35–37] and the latest incident in 2023 resulted in a week-long blaze, the smoke from which had enveloped the entire neighboring city.[38] The close proximity of the dump yard to the adjacent river (Figure 1), and reports of residents vacating the surrounding areas due to unbearable malodor and environmental pollution[39] have led to its listing as an environmental and public health hazard in the Global Atlas for Environmental Justice.[40] The site has witnessed persistent local protests, widespread public dissent and legal disputes due to the issues related to waste mismanagement. Nevertheless, residents continue to live within 2 kilometers of the dump yard, a proximity classified as hazardous exposure by the WHO.[9] This study aimed to assess the risk perceptions of the residents residing in close proximity to the dump yard and understand the various socio-demographic and geospatial factors associated with their perceptions.

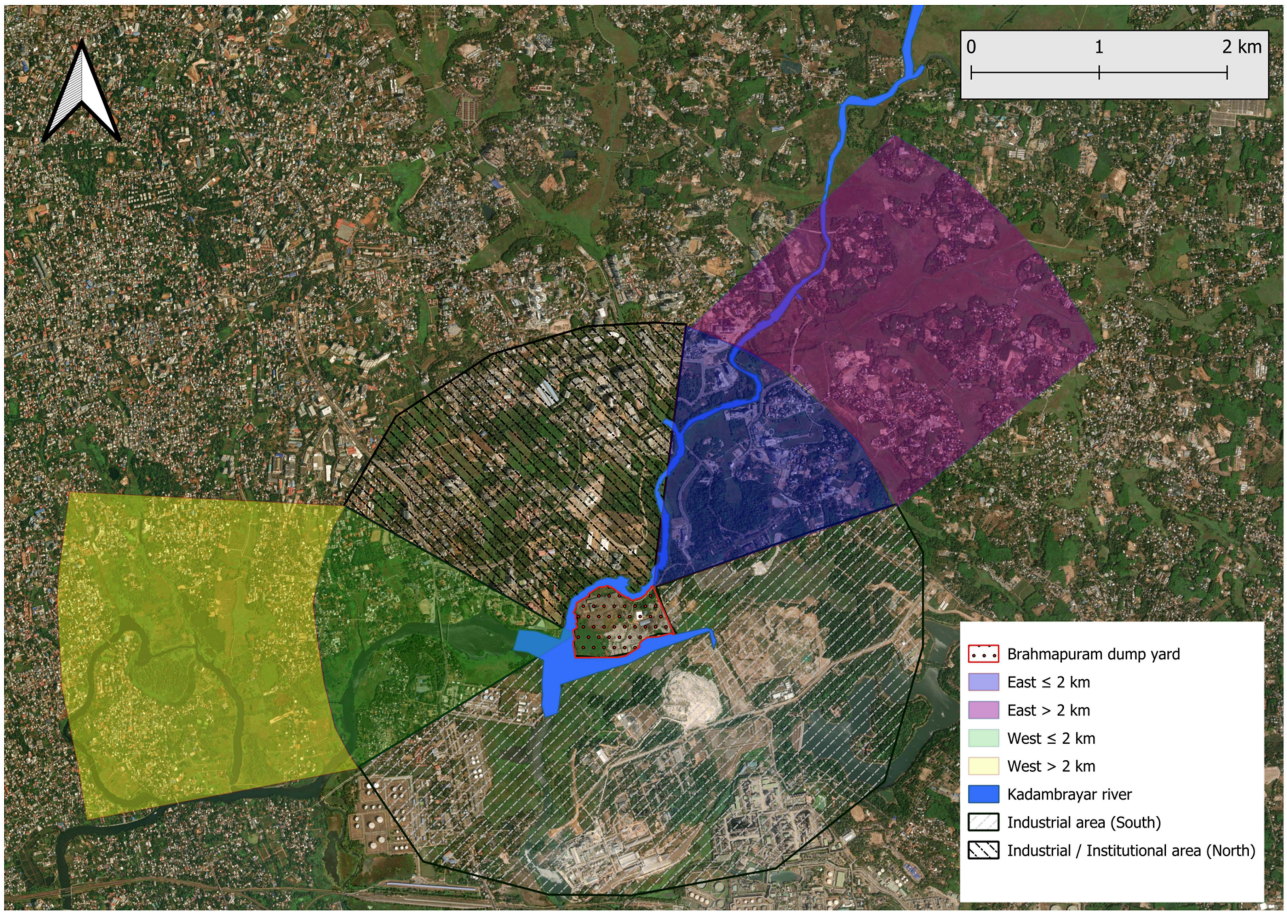

Figure 1 Sample area selected for the study.

Materials and Methods

The present study was conducted as a cross-sectional survey among residents living near Brahmapuram dump yard from 18th March 2022 to 14th May 2022. The study was carried out within a radius of four kilometers from the borders of the dump yard, which included areas under the jurisdiction of four different local self-governments. Distance from the borders (within two kilometers and beyond two kilometers) of the dump yard and direction (east or west) with respect to the dump yard were the two criteria for selection of the four sample areas (Figure 1). This was done to account for geospatial variability during the sampling process. QGIS Desktop 3.22.0 was used to visualize and select the sample areas for the study. The study excluded the industrial zones situated directly north and south of the dump yard due to the absence of residential buildings in those areas.

A structured interview schedule was used for collecting the necessary information from the participants. The questions in the interview schedule were adapted from surveys on risk perception conducted in Italy and Japan.[41,42] It consisted of questions related to socio-demographic details of the participants, their perceptions regarding the dump yard and its effect on the environment, their perception of malodor from the dump yard, its strength and frequency and their perception regarding likelihood of developing health problems. The study was approved by the Institutional Ethics Committee of Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum (SCT/IEC/1823/JANUARY/2022). Data were collected via face-to-face interviews using the KoboToolbox application and the analysis for the study was done using R software version 4.2.2.[43] R packages used for analysis were "tidyverse"[44] for data wrangling, "gtsummary"[45] for regression analysis, "rempsyc"[46] for making summary tables, "psych"[47] was used for conducting principal component analysis.

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Statistical Analysis

The study looked at 2 analyses

a) Association of socio-demographic variables such as sex and educational level and geospatial variables, distance and direction with perception regarding dump yard proximity, perceived strength and frequency of malodor.

b) Risk perception score with socio-demographic variables such as sex and educational level and geospatial variables, distance and direction and perception regarding dump yard proximity, perceived strength and frequency of malodor.

For a) variables which were found to be statistically significant in the bivariate analysis using chi-square test were further analyzed in a logistic regression model. For b) variables which were independently found to be statistically significant in the one-way ANOVA were included in a linear regression model for further analysis.

Risk Perception Score

The structured interview schedule had multiple variables that were designed to capture the risk perceptions of the participants regarding the environmental and health risks of the dump yard. The responses to these questions were scored on a scale of 1–4 as shown in Table 1. Principal component analysis (PCA) with varimax rotation was performed on this set of variables to combine these correlated variables into a singular outcome variable, the risk perception score which can quantify the risk perception for each participant. The risk perception score was calculated for each participant by multiplying the score for each variable with the PCA loading and then adding them up. Since the dump yard was a sensitive issue among the local residents, some individuals had declined to answer certain questions and were omitted from the computation of the risk perception score.

Results

Among the 302 participants who took part in the study, 52.3% were male and 47.7% females. Half of them lived within 2 kilometers from the borders of the dump yard and most of the participants lived to the east of the dump yard. The mean age of the participants was 47.2 years with a standard deviation of 14.3. The socio-economic classification of the participants was determined using the modified Kuppuswamy scale.[48] The scale uses educational qualifications, occupation and the monthly income of the head of the family to categorize the participants. More than two-fifths of the participants 44.2% were categorized as "Upper Lower" socio-economic class as per the Kuppuswamy scale. The socio-demographic characteristics of the study participants are given in Table 2.

Perceptions About the Dump Yard

A large proportion of the participants (282 (93.4%) reported that they experienced malodor from the dump yard. Almost one-third of the participants perceived this malodor to be very strong (36 (11.9%)). More than two-thirds (85 (28.1%)) perceived that the proximity of the dump yard to their residence was unfair (Table 3).

Table 1 Principal Component Analysis of Perceptions About the Impact of the Dump Yard on Environment and Health

Variable	Response and Corresponding Score	PC1
Perception regarding swimming in adjacent river	Is dangerous in any case-4 Is dangerous, except for the zone-3 Not very dangerous-2 Is not dangerous/ Do not Know −1	0.674
Perception regarding eating fish from adjacent river		0.704
Perception regarding the environmental situation	Serious but unsolvable-4 Serious but solvable-3 Acceptable-2 Excellent-1	0.53
Perceived likelihood of developing allergies	It is certain-4 highly Probable-3 Less Probable-2 Impossible/ Do not Know −1	0.79
Perceived likelihood of developing temporary respiratory problems		0.836
Perceived likelihood of developing permanent respiratory problems		0.778
Perceived likelihood of developing cancer		0.635

Table 2 Sociodemographic Characteristics

Variable	n	%
Sex of the participant		
Male	158	52.3%
Female	144	47.7%
Distance from the borders of the dump yard		
>2km	151	50.0%
<=2km	151	50.0%
Direction w.r.t the dump yard		
West	84	27.8%
East	218	72.2%
Ownership of residence		
Own House	291	96.4%
Rented	11	3.6%
Education level		
Graduate or higher	101	33.4%
School or lower	201	66.6%
Socio-economic class as per Kuppuswamy scale (N=285)*		
Lower	13	4.6%
Upper Lower	126	44.2%
Lower Middle	108	37.9%
Upper Middle	34	11.9%
Upper	4	1.4%

Note: *Socio-economic class for 17 participants could not computed.

Table 3 Perception About Dump Yard

Variable	n	%
Presence of malodor from the dump yard		
No	20	6.6%
Yes	282	93.4%
Perceived frequency of malodor from the dump yard		
Seasonal	97	32.1%
Monthly	23	7.6%
Less than monthly	29	9.6%
Weekly	61	20.2%
Daily/ almost daily	60	19.9%
Did not respond	32	10.6%
Perceived strength of odour from dump yard		
Very Strong	98	32.5%
Fairly Strong	100	33.1%
Mild	49	16.2%
Negligible	36	11.9%
Did not respond	19	6.3%
Perception about proximity of dump yard to residence		
Unfair	214	70.9%
Not unfair /Not sure/ No opinion/ Do not know	85	28.1%
Did not respond	3	1.0%
Perception about other municipalities waste being dumped at the dump yard		
Unfair	197	65.2%
Not unfair/Not sure/ No opinion/ Do not know	101	33.4%
Did not respond	4	1.3%

(*Continued*)

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Table 3 (Continued).

Variable	n	%
Whether there is chance of catastrophe at dump yard		
Yes	99	32.8%
No	74	24.5%
Do not Know	115	38.1%
Did not respond	14	4.6%

Perception Related to Proximity of Residence to the Dump Yard

A logistic regression model was used to observe the association between geospatial and socio-demographic factors and perception regarding the proximity of residence to the dump yard. Responses of those who did answer certain questions were omitted from the multivariate model. According to the model, those residing to the east were more likely to perceive the proximity of their residence to the dump yard as unfair compared to those living to the west 10.4 (95% CI 4.42, 27.9; p<0.001). Additionally, those who had school or lower level of education had high odds of perceiving the dump yard proximity as unfair (Table 4).

Perception Regarding Strength of Malodor from the Dump Yard

A multiple logistic regression was done with geospatial factors as the independent variable and perceived strength of malodor as the dependent variable. Those who reported that the malodor was "very strong" or "fairly strong" were grouped into the "strong" category and the rest were categorized as "mild/negligible" for fitting the logistic regression model. The responses of those who did not respond were not considered in the model. The geospatial factors were significantly associated with the perceived strength of malodor in the model (Table 5).

Perception Regarding Frequency of Malodor from the Dump Yard

When perceived frequency of malodor was taken as the dependent variable for multiple logistic regression, those who responded "daily" or "almost daily" were categorized as "Daily/Weekly" and the rest were grouped into "Monthly/ Less than monthly/ Seasonal". In the multivariate model, those living to the east had higher odds of perceiving the malodor more frequently 2.33 (95% CI 1.17, 4.72; p=0.017). Moreover, those who lived within two kilometers from the dump yard also had higher odds of perceiving frequent malodor 3.08 (95% CI 1.63, 5.96; p<0.001) (Table 6).

Risk Perception Regarding the Impact of the Dump Yard on Environment and Health

Principle component analysis (PCA) of variables related to participants' perceptions about the adjacent river, the environment and likelihood of diseases was done (Table 1) to create a synthetic risk perception score variable, that

Table 4 Multivariate Logistic Regression - Perception Regarding Proximity of Residence to Dump Yard

Variable	Category	OR	95% CI	`p-value`
Sex	Male			
	Female	0.52	0.29, 0.91	**0.023**
Direction w.r.t the dump yard	West			
	East	10.4	4.42, 27.9	**<0.001**
Distance from the borders of the dump yard	>2km			
	<=2km	2.41	1.05, 6.29	**0.051**
Education level of the participant	Graduate or higher			
	School or lower	2.00	1.12, 3.58	**0.019**

Note: Bold value means the P < 0.05.

Table 5 Multivariate Logistic Regression - Perceived Strength of Malodor from Dump Yard

Variable	Category	OR	95% CI	`p-value`
Sex	Male			
	Female	0.68	0.40, 1.14	0.14
Direction w.r.t the dump yard	West			
	East	0.88	0.40, 1.92	0.7
Distance from the borders of the dump yard	>2km			
	<=2km	1.77	0.92, 3.52	0.093

Note: Bold value means the P < 0.05.

Table 6 Multivariate Logistic Regression - Perceived Frequency of Malodor from Dump Yard

Variable	Category	OR	95% CI	`p-value`
Sex	Male			
	Female	0.50	0.30, 0.83	**0.007**
Direction w.r.t the dump yard	West			
	East	2.33	1.17, 4.72	**0.017**
Distance from the borders of the dump yard	s>2km			
	<=2km	3.08	1.63, 5.96	**<0.001**

Note: Bold value means the P < 0.05.

reflects the risk perception of the participants regarding the dump yard. The score ranged from 4.94 to 19.76 with a mean of 13.08 and standard deviation of 4.18.

This risk perception score was used to compute a regression model to investigate the association between risk perception and the geospatial factors of distance and direction. Due to the sensitive nature of the topic, not all participants answered all questions regarding the dump yard. Therefore, the number of participants whose responses could be included in the PCA was reduced. As a result, among the total 302, the risk perception score could be calculated only for 177 participants whose characteristics were analyzed in the multivariate regression model. The model indicated that living to the east (2.7 (95% CI 1.1, 4.2; p<0.001)) and living within two kilometers from the dump yard (2.3 (95% CI 0.96, 3.7; p<0.001)) were associated with a statistically significant increase in the risk perception score (Table 7).

Table 7 Multivariate Linear Regression - Risk Perception Score

Variable	Beta	SE	5% CI	p-value
Sex				
Male				
Female	−2.6	0.585	−3.7, −1.4	**<0.001**
Direction w.r.t the dump yard				
West				
East	2.7	0.783	1.1, 4.2	**<0.001**
Distance from the borders of the dump yard				
>2km				
<=2km	2.3	0.698	0.96, 3.7	**<0.001**
Perceived strength of malodor				
Mild / Negligible				
Strong	2.0	0.729	0.54, 3.4	**0.007**
Perceived frequency of malodor				
Monthly/Less than monthly/Seasonal				
Daily/Weekly	−0.17	0.632	−1.4, 1.1	0.8

Note: Bold value means the P < 0.05.

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Discussion

The study aimed to understand the risk perception of people living around the poorly managed Brahmapuram dump yard that has been in operation for over 16 years and has accumulated huge quantities of legacy waste. The objective was also to examine the potential associations between sociodemographic and geospatial factors and the risk perceptions of the people. The perception of risk is a complex measure shaped by participants' experiences living in proximity to the dump yard and is a topic which remains largely unexplored in India. The current study has used Principal Component Analysis (PCA), a dimensionality reduction technique, to quantify risk perception and compute a composite risk perception score that has been used in the statistical analysis.

In risk perception studies proximity to a hazard is generally assessed in terms of distance.[49–52] These studies have reported consistently that those who live at shorter distances from the hazardous sites tend to have higher levels of risk perception. This study also found that the risk perception was significantly high among those who lived within 2 kilometers of the dump yard. In addition, the geospatial location in terms of the direction in which the residences were located with respect to the dump yard also influenced their risk perception. Similar findings have emerged from studies among people residing near waste treatment facilities including landfills, dump yards and waste incinerators, despite differences in measurement methods used.[51,53] Several studies have indicated that residing in close proximity to hazardous sites generates heightened risk perception among the adjacent populations, frequently leading to public outrage and dissent. Higher risk perception of people living in proximity to hazardous sites like nuclear energy plants, petrochemical industries and similar hazards have been reported from across diverse settings.[49,50,52,54]

Malodor has been reported as one of the primary concerns of people around landfills and other waste management facilities.[55–58] Malodor has been found to influence the health risk perception of proximate communities.[59] Studies have found their perception of the malodor to be associated with attitude towards the malodor source.[60,61] Previous studies indicate that people living in close proximity to waste management facilities and having a longer duration of residence are more likely to report concerns related to malodor.[56,62]

In the current study, the majority of the respondents reported malodor as a negative impact of the dump yard. Those who lived less than 2 kilometers from the dump yard and to the east had higher odds of reporting more frequent experiences of malodor. The occurrence of sea breeze during the day, blowing to the east may explain why those who live in that direction perceived malodor more frequently. Conversely, the nocturnal land breeze that carries the malodor towards the west coincides with the time when most residents are likely to stay indoors, resulting in a lesser perception of malodor among those in the west. These findings align with prior studies that have found that meteorological factors such as wind speed, intensity, direction and factors like temperature, humidity and rainfall influenced the magnitude of malodor from waste facilities.[56,63,64]

In the current study, females reported significantly lower risk perception than the males. This finding contrasts with prior studies that have noted gender differences in risk perception, where females were found to have higher risk perception, especially to involuntary risks.[58,65] Risk perception is recognized as a subjective judgement influenced by variations in social, cultural, political and psychological factors and the observed differences could be attributed to these influences.[66–68]

Findings from studies among communities living near waste management facilities such as incinerators and landfills indicate that they perceive the proximity of the dump yard to their homes as unfair.[20,69,70] These sentiments are thought to stem from factors like the fear of loss of land value and NIMBY (Not in My Back Yard) syndrome driven by personal concerns.[71] The negative sentiments among them are thought to arise from the strong perception that the adverse consequences of the hazards are borne by the communities residing nearby, while the positive outcomes of such facilities benefit communities beyond the area of its installation. Local opposition, resentment and resistance from among residents near dump yards are thought to emerge from such perceptions of inequity; that the decision-making related to the siting of such facilities is led by external factors beyond their control, unilateral and hence unfair.[72,73]

Risk perception of the communities and their attitude towards the source of malodor also affect the perception of the malodor. The reception and management of waste originating from regions outside of waste facility locations have encountered resistance from the local communities in a prior study from Japan.[42] Consistent with this, in the present

study, over seventy percent of the respondents found the dump yard's proximity to their homes unfair and those residing to the east expressed a higher likelihood of the dump yard's proximity as unjust. The dump yard, in this study, receives waste from the areas under the local self-governments (LSG) outside the jurisdiction of the LSG in which the dump yard is located and is responsible for its operation.

Limitations of the Study

The study was conducted 15 years after the establishment of the dump yard, and people who had already relocated from its vicinity due to the issues related to the dump yard were not included, potentially resulting in a bias.The dump yard, being a politically sensitive local issue, made the participants reluctant to answer certain questions. Therefore, when the dimensionality reduction technique of principal component analysis was used to compute a synthetic risk perception variable, it had a smaller sample size. The dump yard is also located in proximity to industrial areas and therefore the risk perception could be influenced by other possible pollution sources in the vicinity resulting in "co-mingled" effects as noted by Zhang and Klenosky.[74]

Conclusion

The findings of the study highlight the enduring concerns of the residents regarding the Brahmapuram dump yard. Despite the fact that the dump yard has been in existence for more than fifteen years and marked by numerous protests and litigations, malodourous emissions continue to affect those residing in its proximity. The residents harbor a perception of unfairness regarding the dump yard's proximity to their homes. Risk perception regarding the impact of the dump yard on their health and surrounding environment was associated with geospatial factors, specifically the distance and direction relative to the dump yard. While distance is generally used to indicate proximity to point environmental pollution sources, the study revealed that the direction in which the respondents resided with respect to the dump yard also influenced their risk perception. The present study contributes to the environmental health literature by emphasizing the importance of the geospatial determinants in shaping risk perception. The findings of the study indicate that the sole consideration of distance as an indicator of proximity to a hazardous site may overlook the mediating effect of direction in studies related to risk perception. People's perceptions of risk are shaped by a variety of factors and must be carefully considered when the location of such waste management facilities is decided. Incorporating the risk perceptions of the nearby residents in the planning and operation of dump yards can help alleviate public dissent and opposition to such installations. The study findings emphasize the need for routine risk assessments to factor in the subjective views and social dimensions of people's risk perceptions. The inclusion of geospatial and socio-demographic determinants in risk assessment and management has the potential to reduce perceived risks and public discontent surrounding waste management facilities.

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Disclosure

The author(s) report no conflicts of interest in this work. The study was a self-funded one and was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee of Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum (SCT/IEC/1823/JANUARY/2022) on 2nd March 2022. Informed consent was obtained from all subjects involved in the study. The corresponding author will provide the dataset, and the R codes used for analysis of this current work upon reasonable request.

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