



Research article

Community identified characteristics related to illegal dumping; a mixed methods study to inform prevention

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ARTICLE INFO

Handling Editor: Lixiao Zhang

Keywords:

Illegal dumping

Community engagement

Vacant land

ABSTRACT

Illegal dumping is a public health burden for communities suffering from historical disinvestment. We conducted a mixed methods study to answer: 1) What are stakeholder perspectives on social/environmental determinants of illegal dumping? and 2) Do these or other characteristics predict known locations of illegal dumping? We employed an exploratory sequential design in which we collected and analyzed in-depth interviews (n=12) with service providers and residents and subsequently collected and analyzed data from multiple secondary sources. Stakeholders endorsed nine determinants of illegal dumping: Economic Decline, Scale of Vacancy, Lack of Monitoring, Poor Visibility, Physical Disorder, Illegal Activity, Norms, Accessibility, and Seclusion. Results demonstrate important community-identified, modifiable, social, and environmental characteristics related to illegal dumping with the potential to inform effective prevention.

1. Introduction

Communities across the United States and the globe are faced with the problem of widespread illegal dumping. Illegal dumping is the improper disposal of waste such as garbage, construction and demolition debris, tires, furniture, or auto parts at any location other than a permitted waste management facility (US Environmental Protection Agency (US EPA), 1998). National estimates of the scale of illegal dumping are not available, but we know from local reports that illegal dumping is frequently experienced by communities across the US and around the globe, particularly among those that are marginalized and under-resourced (Brandt, 2017; Forsyth, 2011; Tunnell, 2008; United States Environmental Protection Agency, 1998). While some areas of the globe experience large-scale dumping associated with illegal practices of industries for example, hazardous or medical wastes (Akpan and Olu-kanni, 2020; Borowy, 2020), in this article we address smaller-scale but ubiquitous scattered-site dumping that affects cities and neighborhoods with high rates of vacancy in the United States.

Illegal dumping has important negative environmental impacts, effects on public health, and results in a significant economic burden on communities struggling with remediation and prevention. For example, illegal dumping creates health risks associated with the habitat that it provides for rodents and insects which often carry pathogens and disease. Illegally dumped tires, in particular, have been found to harbor high concentrations of mosquitos carrying disease such as West Nile virus (LaDeau et al., 2013). Illegal dumping and trash accumulation also increases risk of fires, either intentional or unintentional (US EPA, 1998). In addition, illegal dumping of hazardous materials can contaminate nearby soils, air and water, and dumped waste can block proper stormwater drainage and cause flooding. Beyond the direct effects on health and the physical environment, illegal dumping is associated with negative neighborhood social environment. Aside from being a crime in and of itself, illegal dumping can be both an indicator of social disorganization (Brandt, 2017) and signal to others that there is a lack of social control and potential opportunities for other illegal activities (Garvin et al., 2013).

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<https://doi.org/10.1016/j.jenvman.2023.118930>

Received 12 June 2023; Received in revised form 21 August 2023; Accepted 1 September 2023
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Illegal dumping is also an environmental justice issue, as it tends to concentrate in urban areas that have experienced institutional neglect, economic decline, and structural racism (McKinney, 2018; Pellow, 2004). Vacant land, which is plentiful in many locations after decades of population decline and subsequent abandonment, is often a pre-cursor to illegal dumping (Selani, 2017; United States Environmental Protection Agency, 1998). A survey of illegal dumping in San Jose, California, for example, indicated that it was concentrated in areas with low median family incomes and high percentages of non-English speaking individuals and renters (Brandt, 2017). Matsumoto and Takeuchi (2011) found in a study in Japan that illegal dumping occurred in areas with higher rates of unemployment. Communities of color are also disproportionately targeted and adversely affected by patterns of illegal dumping (Pellow, 2004). Not surprisingly, the same communities struggling with issues of vacancy and illegal dumping are often those that have a history of discriminatory policies and practices including redlining, urban renewal projects, and zoning regulations (Nelson, et al; Digital Scholarship Lab, n.d.; Sadler and Lafreniere, 2017).

Managing and remediating dumping poses significant costs to the public because the responsibility to address this issue most often falls on local government agencies and community organizations. The Genesee County Land Bank, for example, reported removing 725 tons of illegally dumped waste from their properties in Flint, Michigan, in 2021. The city of Camden, New Jersey, reported spending \$4 million to remediate approximately 58 chronic dump sites over 340 times in 2019, removing more than 7000 tons of illegally dumped material (Keefer, 2019; Nuri, July 24, 2019). A study across nine cities in Pennsylvania estimated that more than \$68.5 million annually is spent on prevention, education, abatement, and enforcement efforts to address litter and illegal dumping (Burns and McDonnell, 2020).

Communities are motivated to install strategies to prevent illegal dumping. A first step for prevention is to understand the causes and predictors of dumping. Researchers have established that the most vacant and disinvested areas are vulnerable to dumping due to diminished social organization, capacity for surveillance and enforcement, and ability to pay for removal of waste (Brandt, 2017; Matsumoto and Takeuchi, 2011; Yang et al., 2019). Illegal dumpers are typically motivated by avoiding the costs of proper disposal. Certain items such as tires and hazardous waste are banned from landfills, and disposing of them properly can be costly. In Japan illegal dumping was most likely in areas with relatively higher waste disposal costs, and lower enforcement capacity (Matsumoto and Takeuchi, 2011). Certain physical and land use characteristics can attract illegal dumping such as vacant lots and proximity to major arterials (Du et al., 2021). Yet most previous research has not focused on potentially modifiable social and environmental causes and predictors.

Land management agencies in post-industrial cities have identified illegal dumping as the most critical barrier that undermines vacant land stabilization (Torres and Rupp, 2019). While these agencies reported needing more contextual data on the determinants of illegal dumping, very few studies have been conducted in the United States to explore this topic. The purpose of our study is to identify potentially modifiable social and environmental risk factors related to illegal dumping sites to support effective prevention programs and policies. Using stakeholder interviews and analysis of the social and spatial predictors of illegal dumping sites in Flint, Michigan, we examined the following research questions: 1) What are resident and service provider perspectives of the social and environmental determinants of illegal dumping sites? And 2) do these or other characteristics predict known locations of illegal dumping?

2. Methods

Given the limited empirical knowledge of spatial predictors of illegal dumping and the phased approach of the overall pilot intervention study, we chose to employ an exploratory sequential mixed methods

design. Exploratory-sequential designs are appropriate to identify unknown variables in phase 1 for subsequent analysis in phase 2. First, we analyzed qualitative data collected through open-ended interviews with Land Bank staff and crew and Clean & Green leaders who are community residents engaged in vacant property maintenance from Flint, Michigan. Then, using the emerging themes from the interviews, we gathered administrative data and publicly available sources with conceptually relevant measures to conduct a cross-sectional analysis of neighborhood and site-level factors that stakeholders (Land Bank staff, Clean & Green leaders, and Land Bank crew members) considered to be determinants of illegal dumping activity. The University of Michigan Institutional Review Board reviewed and approved protocols for human subjects' protections.

2.1. Study context

Our study took place in Flint, Michigan. The city was the home of General Motors (GM) and had one of the highest per capita incomes in the U.S., but has experienced population declines since the 1960s, when white flight started from many of its newly integrating neighborhoods. This process accelerated when GM began to close plants resulting in deindustrialization and the departure of tens of thousands of automotive industry jobs during the 1970s and 1980s. As people left the city and new demand for housing failed to materialize, the need for demolition of vacant homes increased sharply.

The Genesee County Land Bank (GCLBA or Land Bank) is a quasi-governmental agency responsible for acquiring, managing, and maintaining tax-foreclosed properties in Flint, Michigan. As of 2019, the GCLB reported owning 14,414 properties, approximately 25.9% of the total properties in the city. Their Clean & Green (C&G) program engages residents in vacant land stewardship program. In a 2021 survey of the more than 60 C&G groups, approximately 80% reported that illegal dumping happened in their service areas and 20% reported that illegal dumping activity was increasing. In 2021, residents engaged in the C&G program assisted with the removal of an additional 50 dumpsters worth of dumped debris from vacant properties, estimated at an additional 225 tons. The GCLBA used a combination of dumping reporting records and surveys with C&G groups to assess severity of illegal dumping and identified 11 illegal dumping problem sites for potential intervention.

2.2. Qualitative methods

2.2.1. Participants & context

We used purposive sampling to conduct a total of 12 interviews with three types of stakeholders who were knowledgeable about illegal dumping problem sites in Flint: 1) Clean & Green leaders who are community residents who maintain these sites ($n = 8$); 2) Land Bank staff who identified/prioritized illegal dumping sites for intervention ($n = 2$); and 3) Land Bank crew members who were responsible for remediating illegal dumping on GCLBA-owned problem sites across the city ($n = 2$). Clean & Green leaders were recruited by email and phone calls. Our sample included three GCLBA staff involved in planning and installing interventions on illegal dumping problem sites and eight Clean & Green leaders involved in maintaining the 11 sites selected for intervention.

2.2.2. Procedure

We used semi-structured, in-depth interviews to gather information about the determinants of illegal dumping sites. The interview questions elicited information about illegal dumping sites identified for intervention, including "What was this site like before the dumping prevention projects were implemented," and "What do you think makes these sites prime for illegal dumping?" We obtained consent from all participants before beginning the video recorded interviews. Semi-structured interviews lasted between 40 and 60 min. All interviews were conducted virtually on Zoom and were video-recorded and transcribed verbatim.

Participants received a \$25 gift card to thank them for their time.

2.2.3. Coding & analysis

Codebook development. Coding was completed by two research assistants and the project manager. The coders met regularly with the project manager for discussions to guide the coding and analysis process.

The codebook was generated using a recursive deductive-inductive process. We first added deductive codes based on our research questions. Deductive codes included **dumping activity** to denote any mention of illegal dumping and **community- and site-level characteristics**. Community characteristics were defined as city- or neighborhood-level features related to illegal dumping activity, while site characteristics included features specific to the vacant lots targeted for illegal dumping. Coders then used line-by-line inductive coding of incoming interview transcripts to elaborate upon these deductive codes relating to illegal dumping activity, and level. For example, poor visibility due to out streetlights was added to the codebook as characteristics at the community-level, while poor visibility due to vacant lot features such as tree cover was added as a characteristic at the site-level. Each code included a definition and inclusion and exclusion criteria. We continued to add new codes to fit data found in incoming transcripts until no new codes or sub-codes were needed to describe the transcripts.

Once the codebook was established, the research assistants applied the codes to all text segments from two transcripts (1 staff and 1 Clean & Green leader). Transcripts were divided into text segments to reflect complete thoughts, beginning at the start of a concept/topic and concluding at the end of that topic (Fusch and Ness, 2015). The project manager and coders reviewed coding decisions and used consensus decisions to resolve any discrepancies.

2.2.4. Thematic analysis

Analysis began with the full research team meeting to discuss their impressions regarding the salient characteristics at the community- and site-level that stakeholders reported were related to illegal dumping. We used the Dedoose qualitative coding software (Dedoose, 2018) to export all text segments coded as Dumping Activity and Community or Site Characteristics. We assessed whether each characteristic was reported at the site-level, community-level, or both, and calculated the percentage of respondents who endorsed each characteristic as a feature related to illegal dumping.

2.2.5. Determination of themes to report

We applied criteria from Hill et al. (2005) to which themes to report based on how widely the themes were endorsed across the sample: general, typical, variant, and rare (See Table 1).

2.2.6. Methodological integrity

To check the validity of our findings, we presented our findings to Land Bank staff (Creswell and Plano Clark, 2023). The staff confirmed that the findings reflected and validated their shared understanding of the city-wide and site-specific contributors to illegal dumping.

2.3. Quantitative methods

In addition, we assessed whether social and environmental

determinants reported by our participants, or other characteristics, predict locations of illegal dumping. The study team identified available spatial datasets with indicators that conceptually matched the community-identified determinants from qualitative interviews (Supplementary Table S1).

2.3.1. Study sample

We began with a list of all Land Bank-owned vacant parcels that received community-engaged mowing (N = 5598) across the city of Flint. Based on reporting from community groups who maintain these areas, we categorized parcels as illegal dumping or non-dumping sites. Parcels were defined as dumping sites if they had at least one report of illegal dumping during 2020. Illegal dumping was determined based on quantity and type of trash on a site. Non-dumping sites were those sites that received mowing but did not have a report of illegal dumping during that time. Parcels were excluded if their community group was unable to fully report their activities for the summer. We excluded 102 parcels from our analysis based on these criteria. Our final sample included a total of 5496 parcels (5154 non-dumping sites and 342 dumping sites).

2.3.2. Measures

We obtained small area data from the 2020 U.S. Census Bureau American Community Survey (ACS), city of Flint Planning and Development Department data, the Land Bank, and the Michigan Incident Crime Reporting (MICR) system for the independent variables. Each of the independent variables was selected for exploratory purposes based on the themes identified from the qualitative analysis.

Neighborhood Demographics. For each study parcel, we assigned Census block-group level sociodemographic values (percent unemployment, population density, and percent below poverty). We also assigned a neighborhood disadvantage index value constructed using variables from the American Community Survey (ACS). The index included percent below poverty, percent using public assistance, percent renter, and percent vacancy.

Redlining. We defined redlining as the following: “a discriminatory practice that consists of the systematic denial of services such as mortgages, insurance loans, and other financial services to residents of certain areas, based on their race or ethnicity” (Cornell Legal Information Institute, 2023). We used data from the Mapping Inequality database of the federal government’s Home Owners’ Loan Corporation (HOLC) maps to identify redlined areas and grades. We matched each study parcel to its historic grade assigned in HOLC if it fell within a graded area. Response options included A = “Best”, B = “Still Desirable”, C = “Definitely Declining”, D = “Hazardous”. We assigned each parcel a rating of “0” for favorable (codes A & B) and “1” for unfavorable (codes C & D).

Blockbusting. We defined blockbusting as “the intentional action of a real estate broker to place an African American resident in a previously all-white neighborhood for the express purpose of the excessive profit to be made by panicking whites into selling low, then in turn charging marked-up prices to incoming minority residents” (Helper, 1969). We assigned each study parcel a blockbusting value (“0” no; “1” yes) if the percentage of white population that left a census tract within the time period between any two decennial census periods was greater than 50% (Sadler and Lafreniere, 2017). This metric has been shown to be more strongly correlated to negative neighborhood outcomes (e.g. food access) in more recent work (Sadler et al., 2021).

Public Housing and Urban Renewal. Using Renewing Inequality data as an indicator of proximity to historic public housing projects, we calculated the distance from each study parcel (centroid) to the nearest Urban Renewal Project that occurred between 1950 and 1980 (Digital Scholarship Lab, n.d.).

Crime. Using incident crime data provided by the Michigan State Police, we created a 50-m resolution crime density (crimes per square mile) surface for the city of Flint. We then extracted the crime density at

Table 1
Representativeness of themes to the sample.

Frequency	Definition
General	Codes that all or all but one of the participants discussed
Typical	Codes that were discussed by more than half but less than all but one of the participants
Variant	Codes discussed by more than three and up to half of the participants
Rare	Codes that were discussed by two or three participants. In this case, rare also will refer to codes that were discussed by only one participant based on the importance of negative case analysis

the center of each study parcel for analysis. We assigned crimes classed as Part 1 crimes by the Federal Bureau of Investigation Uniform Crime Report which includes both violent and significant property crime. In addition, we further split these crimes into violent (homicide, murder, assault, rape, robbery) and property (burglary, theft, larceny, arson) crime sub-categories. We also assigned densities of drug crimes and assault.

Streetlight Outage. We obtained streetlight locations, size, and type from a 2014 administrative dataset from the city of Flint. The location and functioning of streetlights in this dataset were verified and updated in 2019 by a city employee. We assessed spatial clusters, or “hotspots”, of out/non-functioning streetlights using the Getis-Ord G_i^* spatial statistic. We built a hotspot variable for each study parcel that indicated whether the parcel was located within a significant cluster of out streetlights, and if so, the level of statistical significance of the cluster (“0” not significant; “1” a 90% confidence level; “2” 95% confidence level; “3” 99% confidence level).

Vacancy. Using parcel-based land use data, we assessed the percent commercial land, percent commercial vacant land, percent residential land, and percent residential vacant land falling within a 200-m radius of the center of each study parcel. In these data, non-vacancy indicated some type of structure on the site; vacant parcels did not have structures or pavement. These files also contained parcel area data.

Demolitions & Structural Conditions. From the GCLBA, we acquired data regarding the location of demolitions throughout Flint in 2020 and the property condition of parcels in 2019. We calculated the number of demolitions that occurred within 200 m of each study parcel. GCLBA assesses property conditions biennially assigning one of six classifications: good, fair, poor, substandard, vacant lot, or parking lot. For each study parcel, we calculated the percent of parcels evaluated as either poor or substandard within a 200-m radius.

Landcover. Using ESRI 2020 Land Cover data, we calculated the percent land classified as trees within 200-m of each study parcel.

Nearest Major Road. We calculated the distance from each study parcel to the nearest major road using a street segment dataset from the State of Michigan. We considered a major road to be any road with a National Functional Classification of interstate, other freeway, or other principal arterial.

2.3.3. Analytic approach

We performed a descriptive analysis exploring the characteristics of and around illegal dumping sites compared to non-dumping sites. We estimated means with standard deviations (SDs) of continuous variables and percentages of categorical variables among the overall population of sites and by illegal dumping status. We used t and chi-square tests to look for differences by exposure status. For ease of interpretation, we standardized continuous exposure variables using a z -scores and produced odds ratios using unadjusted logistic regression to model the association between each determinant of illegal dumping. Stata v17 was used for all analyses (StataCorp, 2021).

3. Results

3.1. Qualitative results

Stakeholders reported determinants at both the community and site level of illegal dumping: Economic Decline, Scale of Vacancy, Lack of Monitoring, Poor Visibility, Physical Disorder, Illegal Activity, Norms, Site Accessibility, and Site Seclusion. Table 2 indicates the geographic level(s) at which determinants were endorsed and the percent of participants who endorsed each determinant.

Results of the qualitative analysis, modeled in Fig. 1, describe how the stakeholders perceive community and site characteristics contributing to illegal dumping.

Table 2

Geographic level(s) at which each characteristic was endorsed.

Characteristics	Community-Level	Site-Level	% of Participants Endorsing	Level of Endorsement
Economic Decline	Yes	Yes	6/12 (50%)	Variant
Scale of Vacancy	Yes	Yes	12/12 (100%)	General
Lack of Monitoring	Yes	No	10/12 (83%)	Typical
Poor Visibility	Yes	Yes	6/12 (50%)	Variant
Physical Disorder	Yes	Yes	11/12 (92%)	General
Negative Activity	Yes	No	8/12 (67%)	Typical
Norms	Yes	Yes	11/12 (92%)	General
Accessibility	No	Yes	5/12 (42%)	Variant
Seclusion	No	Yes	9/12 (75%)	Typical

General: discussed by all or all but one, Typical: more than half but less than all but one, Variant: more than three and up to half, Rare: one, two or three.

3.1.1. Economic decline

Community-Level. Stakeholders reported that economic decline related to the loss of industry in Flint has contributed to the illegal dumping problem in the city. They cited the closure of large auto manufacturing plants as a catalyst because it reduced population and traffic to monitor neighborhood activity. As one staff member described,

“We’ve had a serious [dumping] problem in that area for years ... it’s dark and remote and there’s no houses down there, very little traffic. That’s where Buick used to be, it’s gone from 26,000 people going up and down the neighborhood, and now there’s nothing.” (LB Staff 2)

Based on the types of materials dumped and knowledge of waste removal costs, stakeholders explained that economically depressed conditions and low wages have created a situation where local contractors need to dump illegally to save money. “You’re going to find shortcuts to try to save yourself money ... contractors, they have to pay to get rid of their environmental waste and they just don’t want to pay the price, and so this is a workaround for that.” (C&G lead 7) But this was not limited to construction companies, as another community leader described similar dumping activity on the part of workers in the informal sector, “it’s like somebody had an odd job, paid a small amount of money, so they’re looking for places to get rid of the material without incorporating additional costs.” (C&G lead 4).

Site-Level. In addition to community-wide economic decline, stakeholders reported that the closure of local businesses was related to the creation of localized problem dumping sites; acknowledging both the impact of specific stores on illegal dumping, “ever since the paint business [next door] closed down” (C&G lead 7) as well as the shuttering of busy corridors, “Well [the dumpsite] it’s not far ... it’s on Franklin Avenue, which used to be a major corridor through the city of Flint with a lot of mom and pop shop businesses.” (C&G lead 7).

3.1.2. Scale of Vacancy

Community-Level. Stakeholders were unanimous in their theory that dumpers target areas with concentrated vacancy (i.e. low density housing), including neighborhoods where extensive demolition had taken place. Some stakeholders reported that dumping activity had increased in proportion to the amount of demolition, “[Our Clean & Green site] was prime for illegal dumping because there are not many homes in that particular area where they’ve been torn down.” (C&G lead 3), “And the more houses were torn down, the more people dumped.” (C&G lead 2). Stakeholders believe that illegal dumpers look for areas where the remaining housing stock is largely abandoned and with few residents around. “... as far as dumping, they pick the sites where there’s no streetlights, no residents, no houses, nobody to watch, nobody to see. Those are the sites getting picked.” (LB Crew 1) Another community

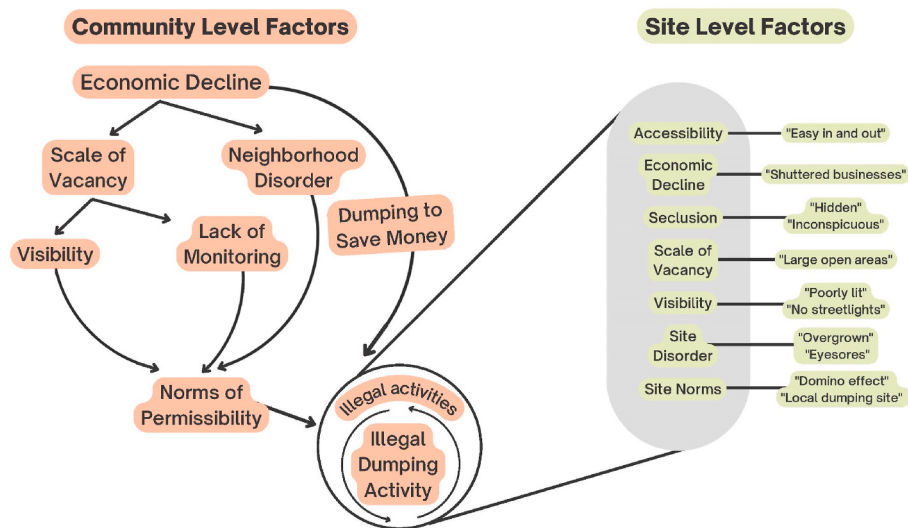


Fig. 1. Stakeholder model of characteristics related to illegal dumping. Stakeholders described the relationships between community and site level factors and illegal dumping in their community.

stakeholder noted the distinction between places that do and those that do not have illegal dumping, “It doesn’t happen in neighborhoods where there’s a lot of people that stay in the neighborhood, it’s places where there is nobody staying, or one or two houses.” (C&G lead 2).

Site-Level. Stakeholders reported that illegal dumping frequently takes place on large, open, vacant, and unclaimed areas. “It’s just a wide-open space and completely dark, so people can get in and out of there and do their thing.” (C&G lead 7). They explained how they think problem sites are established. Large vacant lots without a clear purpose contribute to the perception among dumpers that these areas are available to be dumped on, “And that’s why that [dumping] area is so huge because there’s nobody in there ... That’s why it was such an open [dump] site. It’s not used for anything, it’s open property that’s available.” (C&G lead 1).

3.1.3. Lack of Monitoring

Community-Level. Stakeholders described how vacant areas are vulnerable to dumping because there are few residents available to observe and deter dumping, “... a very common theme amongst some of our larger [dump] sites was that there just wasn’t anyone really living on the block to be able to have their eyes on the street ...” (LB Staff 1) The lack of residents on each block also contributes to the lack of law enforcement to catch offenders. “Because there’s no housing, there was nobody to really assist [...] If you have no people, no structures or people staying in a structure or homeowners, you have no say. What you can’t see, you can’t prevent.” (C&G lead 2) Stakeholders believed that lack of formal enforcement, paired with diminished informal social control in neighborhoods enables illegal dumping by giving the impression that people can dump with impunity, “The whole entire block is completely gone ... If it’s not being monitored, then they [the dumpers] feel they can do whatever.” (C&G lead 2).

3.1.4. Poor visibility

Community-Level. Stakeholders described the issue of visibility as linked to dumping in two ways, directly through the lack of street lighting and indirectly through the issue of vacancy which resulted in little or no illumination from residences.

“I think lack of street lighting, lack of occupancy nearby, that was a very common theme amongst some of our larger [dump] sites ... There just wasn’t anyone really living on the block to have their eyes on the street and that means there weren’t any lights that were coming off of people’s porches or their backyards.” (LB Staff 1)

Stakeholders believed that a lack of lighting created an environment where dumping is less risky to offenders. “You know you can get away with dumping at night when there’s no streetlights and there’s no one living in the area to actually watch you do it.” (LB Crew 1).

Site-Level. Stakeholders also described illegal dumping site characteristics such as trees, overgrown grass, and bushes that made places “dark” but also impeded visibility by blocking sightlines. This was noted by community leaders, staff and crews. “There were overgrowth in the back of the yards. Kind of dark and dreary. The sight lines were not there.” (LB Staff 1).

3.1.5. Physical Disorder

Community-Level. Stakeholders almost unanimously agreed that the physically disordered environments, including the high concentrations of abandoned and distressed buildings, were implicated in patterns of illegal dumping. “Since General Motors is going out of the area, and most of the homes have been vacated, and blighted homes are torn down or burned down. They just felt that this area was neglected enough that they could dump whatever they want in there. So, it became a dump site.” (C&G lead 1) Stakeholders reported that areas that could afford to keep their environments in good condition were protected from illegal dumping while more disadvantaged areas with more deteriorated conditions became vulnerable to illegal dumping activity.

“The low income areas are gonna have more blight and dumping, than you’ll see in some of the other areas that are a little more you know higher income [...], you don’t see any of the blighted houses standing [in the higher income areas] or [at least] they’re taking care of them, even if no one’s living in them- they’re still mowing and neighbors keeping them up, but that’s not the case in this particular area.” (C&G lead 5)

Site-Level. Again, we found a majority consensus among stakeholders that the specific sites used for illegal dumping were physically deteriorated. “Overall, the sites were not in good shape. They were looking pretty rough. There was overgrowth in the back of the yards.” (LB Staff 1) Stakeholders explained that they were often poorly maintained and frequently adjacent to ‘eyesores’ such as abandoned buildings that accumulated trash. Of note was the progression in their description from unkempt to unmanageable spaces.

“Every mow, we were constantly cleaning up trash out of the site as well as having to mow around vehicles and furniture and then there was this other trash that was accumulating next to the house- on the

Table 3

Characteristics of sample by dumping status and Bivariate Logistic Regression estimates of odds ratios for dumping outcome (z-scores).

Exposure	Dumping		Non-dumping		OR	(95% CI)	P
	(N = 342)	SD	(N = 5154)	SD			
Neighborhood disadvantage ^{a b}	0.32	0.08	0.31	0.09	1.17	(1.04, 1.30)	0.006
Unemployment (%) ^b	0.19	0.13	0.22	0.16	0.82	(0.72, 0.92)	0.001
Population change (%) ^{b c}	−931.55	837.51	−1148.11	779.32	1.31	(1.17, 1.45)	<0.000
Poverty (%) ^b	0.42	0.16	0.4278	0.16	0.94	(0.83, 1.04)	0.233
Redlining (0,1)	0.61		0.59		1.06	(0.91, 1.16)	0.617
Blockbusting (0,1)	0.37		0.36		1.02	(0.91, 1.14)	0.66
Commercial vacant land (%) ^d	0.07	0.10	0.0589	0.08	1.12	(1.01, 1.23)	0.02
Residential vacant land (%) ^d	0.26	0.14	0.24	0.11	1.15	(1.02, 1.27)	0.013
% Commercial land ^d	0.13	0.12	0.12	0.13	1.10	(0.98, 1.21)	0.08
% Residential land ^d	0.57	0.12	0.57	0.12	0.99	(0.88, 1.10)	0.866
Population density ^{b,c}	1200.89	626.24	1257.92	585.29	0.90	(0.80, 1.01)	0.082
Number of demolitions ^d	3.18	4.99	3.09	4.77	1.02	(0.91, 1.13)	0.736
Drug Crime ^e	20.70	13.96	20.80	12.70	0.99	(0.88, 1.10)	0.881
Crime ^e	131.80	47.04	124.66	49.98	1.15	(1.03, 1.27)	0.01
Violent crime ^e	62.66	24.42	57.35	24.76	1.23	(1.10, 1.36)	<0.000
Property crime ^e	69.02	27.87	67.24	29.79	1.06	(0.95, 1.17)	0.282
Aggravated Assault ^e	49.24	19.38	43.57	20.52	1.29	(1.16, 1.43)	<0.000
Violent crime involving a gun ^e	35.12	17.07	31.83	16.02	1.21	(1.09, 1.33)	<0.000
% Poor/Sub-Standard parcels ^d	0.12	0.07	0.13	0.06	0.80	(.711, .895)	<0.000
Area of parcel ^f	556.24	553.46	490.22	307.90	1.10	(1.02, 1.17)	0.005
Streetlights not working	0.34	0.90	0.17	0.60	1.22	(1.12, 1.32)	<0.000
Trees (%) ^d	0.01	0.04	0.00	0.03	1.11	(1.03, 1.19)	0.003
Nearest major road ^d	438.17	338.25	529.19	366.54	0.76	(.676, .85)	<0.000
Nearest public housing project ^d	2737.39	1458.63	2315.44	1290.40	1.37	(1.22, 1.52)	<0.000
Nearest urban renewal project ^d	1900.30	852.25	1546.24	829.55	1.49	(1.34, 1.65)	<0.000

^g distance in meters.^a includes % below poverty, % public assistance, % renter occupied, % vacancy;^b Census block group;^c calculated: 2020 ACS population density – 2000 ACS population density;^d within 200 m buffer around parcel;^e density per square mile at parcel centroid;^f distance in square meters;

driveway, as you see. And it just kept growing and growing and growing and we just didn't have any means of trying to stop it." (C&G lead 5)

3.1.6. Illegal activity

Community-Level. Stakeholders described illegal dumping activity as co-occurring alongside a cluster of other negative, usually illegal activity. "When people are doing stuff illegal, they're doing more than just illegal dumping, they're doing a lot of other things." (C&G lead 1) Specifically, they perceived that illegal dumping takes place in areas of the city where prostitution, drug dealing, and violent crime are prevalent. Two community leaders describe their observation regarding illegal activities, "It was kind of a high area for prostitution as well. [...] There was also a lot of drug sale down there." (C&G lead 2) and "They're dealing ... selling crack cocaine and all these things. [...] It was reported that someone was found dead on this very street. (C&G lead 6).

3.1.7. Norms

Community-Level. Community perception was an important theme wherein stakeholders reported that the issue of illegal dumping has created a public perception among the external community that Flint is available to be dumped on. Stakeholders described dumping as a big problem not only to their areas of their neighborhood but to the entire city of Flint because, "They think that this city is a dumping place." (C&G lead 6) and "Oftentimes people that aren't even part of the community they're just using Flint as a dumping ground." (LB Staff 1) Stakeholders believe that dumpers capitalized on the perception that Flint is available for dumping, along with characteristics such as vacancy and darkness, and this is what make certain areas of the city vulnerable to dumping. "... there are people from outside of Flint coming into Flint

and dumping [in] these areas ... that's what's going on. They're trying to find a place where they can be hidden, [they] come at night, and they dump things." (C&G lead 6).

Site-Level. At the site level it was apparent that stakeholders believed that repeated dumping activity and accumulated dumped material on specific sites contributed to a norm that these sites are dumpsites. Staff and community leaders described the "domino effect" of illegal dumping: "They just want to see if they dump, how long is it going to stay here. If it does stay here, then they're going to bring some more of that, and some more back, and some more back." (C&G lead 2) And, once a site is established as a dumping place, stakeholders describe how dumpers become habituated to dumping there, which perpetuates dumping activity. "I don't even know if it's the location [that causes the dumping], truthfully it's just that they've been dumping on those certain blocks for years and years." (LB Crew 2).

3.1.8. Accessibility

Site-Level. Stakeholders reported that illegal dumping is more likely to happen on sites that are accessible and convenient to dumpers. Stakeholders described the ease of access, "It was so easy, I guess, to keep driving on the driveway and dumping it." (C&G lead 5) and the convenience of "drive-through" dumping, "Because you could drive through, I think that was [what happened] people would just come in and dump some things and keep on moving." (C&G lead 4) Dumping sites were also reported to be accessible to major roads allowing individuals from outside the community to dump and go, making them both convenient and low-risk. "Dort Highway is the main road and you can't see it. It's kind of secluded, so it makes a very convenient place for people to come and dump their trash." (C&G lead 7).

3.1.9. Seclusion

Site-Level. Seclusion was an important theme wherein stakeholders reported that dumping takes place in secluded areas that have little traffic to observe activity. Places where there's "normally nobody around." (LB Crew 1) and are "dark and remote and there's no houses down there, very little traffic." (GCLBA CR) make it convenient for illegal dumping. Stakeholders believe that dumpers targeted inconspicuous, hidden places where they could dump unnoticed. "They're trying to find a place where they can be hidden, come at night, and they dump things." (C&G lead 6) Often, they selected areas where they could hide the dumped materials, for example at the back of a dark vacant lot, or between abandoned houses. Community leaders repeatedly described how dumping is hidden, "... they always try to hide things. So, they'll start back to putting things back behind and alongside the house or at the back of a lot." (C&G lead 5) "Instead of putting it right out front, it seems like they're putting it [the dumped materials] so it's inconspicuous." (C&G lead 6).

3.2. Quantitative results

We included a total of 5496 sites for analysis (Table 3). The average number of reports of dumping for each illegal dumping site was 2.038 (SD 1.445). We found the average parcel size surrounding illegal dumping sites was larger than that of non-dumping sites. Illegal dumping sites were closer to a major road and had more tree coverage than non-dumping sites. The density of streetlight outages was greater at illegal dumping sites compared to non-dumping sites. Conversely, sites that did not report illegal dumping had higher rates of unemployment, greater population density, and more poor or substandard parcels in the areas around them compared to illegal dumping sites.

Results of unadjusted logistic regression models (Fig. 2) showed neighborhood disadvantage, population change, crime, violent crime, aggravated assault, violent gun crime, parcel size, streetlights outages, trees and distance to the nearest housing project and urban renewal project each increased the odds of sites having illegal dumping. Unemployment, poor parcel conditions, and distance to nearest major road each decreased the odds of being an illegal dump site. The rest of the exposure variables did not show a significant relationship with illegal

dumping.

4. Discussion

Our mixed methods study helps to contextualize the characteristics of communities that experience illegal dumping and lays the foundation for developing acceptable, community informed interventions. From stakeholder interviews, and comparisons of social and environmental characteristics of dumping and non-dumping sites, we learned that economic decline and neighborhood disadvantage, high vacancy, poor visibility, few eyes on the street, and deteriorated neighborhood environments all contributed to norms that crime and illegal dumping were permissible and low risk.

Stakeholders described a pattern in which economic decline caused individuals and businesses to seek ways to cut costs and suggested that illegal dumping of contractor waste was one such strategy. Cities are in a bind, where waste management is not free to provide, but residents and business owners do not have the means to dispose of items that might be by-products of small business operations, residential maintenance, or everyday life (e.g. used tires) (Ichinose and Yamamoto, 2011; Leavitt, 1994). At the same time, small businesses, and individuals maintaining their homes, are important elements of city economies. While large quantities of solid waste that often ends up in illegal dumping sites is derived from businesses and industry, it is most often local jurisdictions that bear the full costs of prevention and clean-up. The decline of industry and subsequent job loss exacerbates this situation and has negatively affected many communities as more economically disadvantaged areas had higher odds of illegal dumping.

Our results suggest that vacancy and related social and physical disorder that followed decades of population decline and disinvestment is also a precursor of illegal dumping. Stakeholders reported that economic decline from lost automotive industry jobs contributed to population loss and concentrated vacancy in many Flint neighborhoods. Two measures that have been used to indicate historically discriminatory policies were proximity to public housing projects and urban renewal projects. While both indicators were significantly different between illegal dumping and non-dumping sites, the average distance was farther from illegal dumping sites. Our quantitative analysis also indicated that

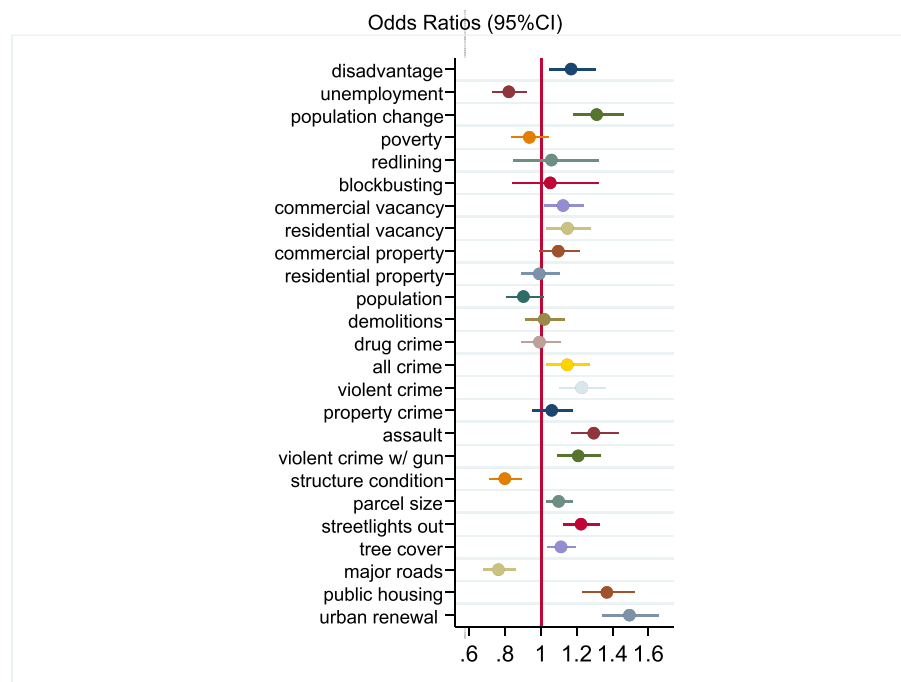


Fig. 2. Bivariate Logistic Regression estimates of odds ratios for dumping outcome (z-scores).

rates of overall crime and violent crime in particular were higher in areas with illegal dumping than areas without illegal dumping. In addition, both residential and commercial vacancies were associated with dumping. Stakeholders reported that poor maintenance on sites and proximity to eyesores such as abandoned buildings or shuttered businesses also attracted illegal dumping activity and crime. They also reported that illegal dumpers chose specific vacant properties for dumping that were large, open vacant lots with space available for dumped materials. Our quantitative analysis also indicated that the parcels that experienced illegal dumping were larger than non-dumping sites. Stakeholders believe that dumpers preferred properties that were convenient to enter, had opportunities for quick and efficient escape, and were close to major roads.

While vacancy is a product of broader structural forces, it also results from extensive federal, state, and local investments in demolition of abandoned homes and buildings (Hackworth, 2016). Programs such as the one run by the GCLBA in Flint, provide the needed maintenance for the vacant lots that result from building demolitions. Researchers have also demonstrated benefits of similar vacant lot treatment programs on crime, perceived safety and mental health such as programs that included fencing intended to prevent illegal dumping (Branas et al., 2018; South et al., 2018). Still, our community partners have reported that dumping has proven more difficult and costly to address with standard treatments and targeted, scalable treatments are needed. Given the limited experimental evidence demonstrating the effectiveness of illegal dumping interventions, many questions remain, such as whether adding low-cost fencing or other barriers (e.g. large boulders) to the perimeter of vacant lots is effective in the long term or if these treatments simply displace the dumping to other sites.

According to stakeholders, in order to avoid detection, dumpers also seemed to choose secluded lots hidden from view or with poor visibility due to overgrowth, non-functional streetlights, or more tree cover. It follows that improving lighting even in areas of high vacancy might help deter illegal dumping. Urban forests are also often hotspots for illegal dumping. In some communities, residents have formed “friends” groups to support these forested spaces for public use (e.g., by installing and maintaining a public-use trail). Cities can support and encourage these friend groups with capacity-building and technical assistance to help make these spaces look better and be used by people, thereby sending messaging to would-be dumpers that people may be around and witness their illegal dumping activity. This may also help address what stakeholders described as a ‘culture of dumping’. Such efforts may help change the view of an area as being an ideal dumping site to one that is less desirable because it shows use and attention and may have functional lighting and other eyes on the street. A key next step for future research would be to test different strategies that focus on high-risk areas for dumping and evaluate the effects of these types of interventions designed to make these areas less desirable for dumping.

We do acknowledge the complicated dynamics behind deploying any such intervention. Foremost, resident buy-in of being randomized to some new method or protocol—after years of dealing with blight and dumping in specific ways—would be complicated in many instances. Secondly, the added cost of providing and maintaining dumpsters—and the liability this creates from additional people choosing to dump on those sites—is out of reach in comparison to the basic necessary maintenance cost. Lastly, the scale of intervention remains enormous: Flint’s thousands of vacant properties means even once an intervention is deemed to have some efficacy, deploying it widely enough to have a citywide impact would be a massive undertaking. Part of the intent of our study is not only to illustrate what dynamics may predict dumping (our quantitative pieces) but also add an understanding as to why addressing dumping isn’t as easy as it may seem on the surface (our qualitative piece).

5. Limitations

Several study limitations require attention. The size of our qualitative sample could be considered inadequate. Recent systematic reviews, however, suggest that saturation can be achieved with sample sizes as small as nine (Hennink and Kaiser, 2022). Moreover, it is possible that our sample does not fully represent the phenomenon that we are trying to describe given it is restricted to one Land Bank agency and a handful of community members. For this reason, we are cautiously limiting the usefulness of our findings to similarly situated cities within the United States and recommend that this research is replicated in other settings to substantiate other potential theories to explain social and environmental conditions that predict persistent illegal dumping. Our quantitative analysis was limited to only Land Bank owned sites. This does not allow us to account for the universe of sites in the city, but the Land Bank does own over 10,000 vacant properties. Properties not owned by the Land Bank could be in foreclosure (waiting to be added to their inventory) and these are likely in the same neighborhoods as already owned properties. The sites we identified as dumping and non-dumping sites were based on current cross-sectional data, but it is possible, even likely, that such sites shift status over time. Thus, our dataset was just a snapshot in time and could not determine causal factors, but it is one of the first to take the various administrative data sources to characterize different types of sites to inform where to apply dumping prevention projects. In addition, our sample of sites was large. Nevertheless, longitudinal research is needed to understand how parcels may become a dumping site, remain a non-dumping site, or change back and forth over time. Finally, we limited our analysis to available data sources, which also required that we used measures that might only be considered proxies for the concepts described by our stakeholders. Yet, these proxies were conceptually relevant and did provide validating information for the qualitative data we collected.

6. Conclusion

This mixed methods study was one of the first to provide an in-depth look at the context in which illegal dumping persists in one U.S. city and identify some potential characteristics of sites and surrounding neighborhoods that might be high risk for dumping. Prevention strategies that follow might include factoring-in product- or industry-based life-cycle costs that include waste management, vacant lot maintenance measures such as fencing especially on large-area parcels, improved lighting even in high vacancy areas, or support for groups to maintain and monitor urban forests. However, these interventions still require testing, and return-on-investment calculations. Several experimental and quasi-experimental studies have helped to shape community-engaged greening as an evidence-based practice to address the negative impacts of vacant properties (Hohl et al., 2019; Kondo et al., 2018). Yet, we have fewer known evidence-based methods for addressing illegal dumping. Understanding modifiable characteristics that promote or impede dumping can help cities and land banks intervene more effectively to prevent such practices and improve the quality of life in communities that have experienced significant disinvestment, economic decline, and concomitant vacant properties that are high risk for illegal dumping.

Credit author statement

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Declaration of competing interest

The authors that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

This work was funded by the Centers for Disease Control and Prevention U01CE002698, 2015–2021 (PI Zimmerman).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jenvman.2023.118930>.

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