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Uncovering the Historic Environmental Hazards of Urban Brownfields

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ABSTRACT *In Baltimore, over 1,000 vacant industrial sites persist across its urban landscape, yet little is known about the potential environmental health risks that may undermine future cleanup and redevelopment activities and the health of those in communities near these sites. This study examined the characteristics of urban brownfield properties in southeast Baltimore, Maryland, and screened sites for their potential environmental hazards. In addition, demographic and health data were evaluated to profile the social and health status of those in brownfield communities. The results show that brownfields in southeast Baltimore represent a range of historic operations, including metal smelting, oil refining, warehousing, and transportation, as well as paints, plastics, and metals manufacturing. The screening method identified a range of substances associated with these properties, including heavy metals, chlorinated hydrocarbons, and polycyclic aromatic hydrocarbons, all of which are suspected or recognized toxicants, and many of which are persistent in the environment. Spatially, these sites are concentrated in white, working class neighborhoods in which poverty levels exceed and educational attainment lags behind state and national averages. Moreover, these sites are concentrated in communities in which excess mortality rates due to respiratory disease, cancer, and heart disease exist when compared to the city, state, and national averages. This investigation demonstrated the usefulness of historic archives, real estate records, regulatory files, and national hazard-tracking systems based on standard industrial classification (SIC) to screen brownfield properties for their hazard potential. This analysis provides the foundation for further site monitoring and testing, cleanup and redevelopment priority setting, risk management strategies, and neighborhood planning, and it illustrates the need for increased health surveillance and disease prevention strategies in affected communities.*

KEYWORDS *Brownfields, Hazard screening, Urban redevelopment, Waste management.*

INTRODUCTION

Health and environmental conditions of aging industrial properties and surrounding communities remain unknown.[1] This article examines the environmental and physical characteristics of urban brownfields in southeast Baltimore, Maryland, and the social and health characteristics of those living in communities near these prop-

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erties to understand better the hazard potential of such sites and the potential environmental health risks to those in nearby residential communities.

Throughout the United States, there are approximately 400,000 to 500,000 abandoned and underused commercial and industrial facilities with real or perceived contamination, also referred to as "brownfields."* (The US Environmental Protection Agency [EPA] defines *brownfields* as "abandoned, idle, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination.")[1] Many of these sites are located in urban centers and distressed areas in the Northeast and Midwest, where heavy manufacturing, other industrial activities, and related businesses once thrived.[2,3] Moreover, brownfields do not exist in isolation and thus may present individual and cumulative risks to workers and communities. As Greenberg and others have noted, "in the worst cases, brownfields are the neighborhood equivalent of cancer";[4(p.1759)] abandoned properties become magnets for illicit activities, including illegal dumping of hazardous materials and drug use. As the economic and physical conditions decline, residents may leave affected areas if they can afford to do so, thus perpetuating neighborhood decline and the creation of more brownfields.[3,4] These sites typically range in size from less than 1 acre to hundreds of acres of land[5,6] and are perceived to be less hazardous than sites currently regulated by the EPA or state environmental agencies.[7]

Over the past two decades, conservationists and public health practitioners, together with planners and economic developers, have had a renewed interest in the issue of urban redevelopment and the need to bring vacant industrial and commercial land to productive use. The term *brownfield* captures the broad nature of such discussions and activities. Today, brownfield policies are rapidly emerging across the nation to address the vast numbers of vacant lots in urbanized areas, to link environmental cleanups with redevelopment projects, and to curb or suspend sprawling development into pristine lands. A report by the US Department of Housing and Urban Development estimated that over 90% of states have established some aspect of a voluntary cleanup program to facilitate the cleanup and redevelopment of brownfield sites.[8] On January 11, 2002, President Bush signed the Small Business Liability Relief and Brownfields Revitalization Act into law.[9]

In general, brownfield policies (e.g., voluntary cleanup programs) have aimed to remove barriers to redevelopment by increasing flexibility and reducing liability in the cleanup of affected sites as stipulated in such existing environmental laws as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). Such actions, however, have raised concerns among public health practitioners and affected communities regarding the adequacy of such policies to protect public health and the environment. While the potential benefits of redeveloping derelict industrial land are recognized, questions and concerns remain as to determining appropriate cleanup activities and future land uses that protect and lift up affected communities.[4,10,11]

Current national hazard-tracking systems do not capture a large subset of uncontrolled hazards in the urban setting that stem from over a century of heavy

*This range does not include sites already regulated by federal and state environmental, energy, and defense agencies. For example, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), approximately 1,300 of the nation's most toxic sites are inventoried on the National Priority List.

industrial operations.[12] Prior to the implementation of the RCRA of 1976, the nation's hazardous waste disposal practices were neither tracked nor regulated. These historic hazards represent a long era of industrial practices that, in general, neglected environmental stewardship.[13,14] Consequently, the absence of effective tracking of historic releases of hazardous substances and past industrial practices has obfuscated our present understanding of the potential physical and chemical risks to human health and the environment associated with the majority of such sites.

To address this gap in knowledge, historic evidence is increasingly necessary to inform environmental health practice, policymaking, and research, particularly in the area of hazardous waste and in the reuse and sale of industrial and commercial properties where there is real or perceived chemical contamination.[15] Such information can aid in the profiling of a company's growth, production, and housekeeping practices over time. Such historic data can also guide further scientific inquiry and priority setting for subsequent investigations, including environmental monitoring. Colten suggests that without thorough consideration of the historic component of past industrial practices, inventories will remain incomplete and of limited use.[16] Contemporary works in urban environmental history have used such historic analyses to document the transformation of the urban landscape due to industrialization, the potential impacts of historic hazards on the environment, and the dearth of site-tracking information that catalogues historic hazardous waste sites and past industrial operations. These works are necessary in adding context and insight to discussions on contemporary urban environmental and public health issues.[12,14,17–20]

This article presents the results of a screening approach to characterize urban brownfields and characterizes those living in the neighborhoods in affected areas of southeast Baltimore; we drew on historic archives and current data sources and public health tools, including geographic information systems, risk assessment, and epidemiologic methods. In this analysis, we describe the extent of brownfield properties in the study area, their history of industrial and commercial operations (phase 1), and finally, the chemicals linked to their past uses (phase 2). Together, these screening data provide a detailed view of the spectrum of brownfields in southeast Baltimore and a basis for understanding their hazard potential to workers and communities.

METHODS

Profile of Study Area

Data at the census tract level were used for this research project. Census tract boundaries, which are defined by the US Census Bureau, represent approximately 4,000 persons. There are 203 census tracts in Baltimore, 28 of which define the southeast Baltimore study area. While these lines are political in nature, they provide the basis for examining the social and economic characteristics of southeast Baltimore. For this research, indicators were created and evaluated using the 1990 census data. These indicators include measures of wealth, income, education, occupation, and housing tenure in addition to population demographics. The selection of these indicators was based on the social indicators and social epidemiology literature.[21–25]

Data on the leading causes of mortality were obtained for the population aged 45 years and older in Baltimore City for the years 1990–1996 to describe the health status of potentially affected communities. These end points included heart disease,

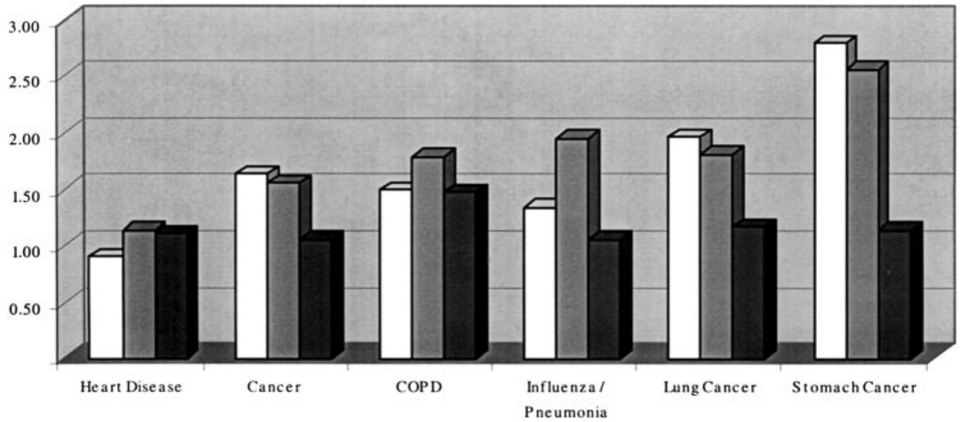


FIGURE 1. Rate Ratios for Key Mortality Endpoints in Baltimore. □ = SE/ROC: ■ = SE/MD; ■ = SE/US. [SE = Southeast Baltimore; ROC = Rest of City; MD = Maryland; US = United States.]

cancer, stroke, chronic obstructive pulmonary disease (COPD), diabetes, influenza and pneumonia, and liver disease. These end points were selected to capture the diseases that bear the greatest public health impact on Baltimore's communities for populations aged 45 years and older and that have been identified in the literature as being plausibly determined or influenced by environmental exposures.[26–29] Age-adjusted mortality rates were developed at the US census tract scale using the direct method of adjustment.[30] The 1940 standard population was used for direct adjustment to facilitate comparisons with state and national data. Because the denominator consists of population aged 45 years and older, the 1940 population standard weights were readjusted accordingly. Population estimates for intercensal years 1991 through 1996 were calculated by linear interpolation between the 1990 and 1997 US census figures.[31] In Fig. 1 we present rate ratios comparing the study area (southeast Baltimore) with the rest of Baltimore, the state of Maryland, and the United States. We also calculated confidence intervals for the rate ratios; these are presented in Table 1.[32]

TABLE 1. Rate ratios and confidence intervals for key mortality end points in Baltimore

Mortality end point	Ratio ratio and confidence interval (SE/US)	Rate ratio and confidence interval (SE/MD)	Rate ratio and confidence interval (SE/ROC)
Heart disease	0.90 (0.85, 0.95)	1.13 (1.07, 1.20)	1.11 (1.04, 1.17)
Cancer	1.63 (1.55, 1.71)	1.55 (1.47, 1.63)	1.05 (0.99, 1.10)
COPD	1.49 (1.30, 1.67)	1.78 (1.56, 2.01)	1.47 (1.28, 1.67)
Influenza/pneumonia	1.33 (1.13, 1.54)	1.95 (1.64, 2.26)	1.06 (0.89, 1.23)
Lung cancer	1.96 (1.80, 2.12)	1.80 (1.65, 1.95)	1.16 (1.06, 1.27)
Stomach cancer	2.79 (2.11, 3.47)	2.56 (1.93, 3.20)	1.14 (0.85, 1.44)

MD, Maryland; ROC, rest of city; SE, Southeast Baltimore; US, United States.

Data Resources

Sites were identified and mapped based on the Baltimore City Planning Department's (BCPD's) *Inventory of Vacant and Under-Used Parcels*. The inventory included residential, commercial, and industrial parcels. Site-specific address information, parcel size, current occupancy, land value, and several other parameters were available for each site. We collected information on past land use, length of site dormancy, duration of operation, changes in operation, acreage of parcels, and chemical use. Duration of operation and era of operation are considered to be important determinants of contaminant levels.[12] When data gaps existed, newspaper archives, technical documentation on industrial processes, and national inventory databases were consulted. Table 2 identifies the resources used in this analysis.

The Inventory Profile

Phase 1: Site Inventory Real estate tax assessments and street directories provided information on industrial operations over time, past and present facility ownership, total acreage per facility, and tax information (phase 1). These records from 1935 to 1995 were reviewed by 10-year intervals to reveal changing activities on or near respective properties[17] and in 1997 for follow-up and validation of current status. Other resources included the Baltimore Association of Commerce, the Directory of Maryland Manufacturers, and newspaper clippings.[33]

Once site-specific data were collected, a detailed file search was carried out. This search focused on the three prevailing uses for each site, which were determined by the total number of years for each use and intensity of past land use (e.g., smelting operations vs. commercial office space). In this approach, including

TABLE 2. Data resources

Data	Date	Source
Inventory of vacant lots	1998	Baltimore City Planning Department
Baltimore city real estate tax assessments	1935–1997	Enoch Pratt Public Library
Chemical information and historic site information	1900–1999	Baltimore City Health Department Baltimore City Public Works Department Maryland Department of the Environment US Environmental Protection Agency
Maryland Manufacturers Directory	1980–1995	Available from the Enoch Pratt Public Library. Published by Harris Publishing Company in cooperation with the Maryland Department of Economic and Employment Development.
Accidental Release Information Program	1986–1998	www.epa.gov/swercepp
Priority pollutants	1999	Agency for Toxic Substances and Disease Registry (ATSDR), www.atsdr.cdc.gov/99list.html
Toxics Release Inventory (TRI)	1986–1997	US Environmental Protection Agency, www.epa.gov
Scorecard	1999	The Environmental Defense, www.scorecard.org

additional uses beyond the top three uses could potentially add to the hazard potential of sites. However, including additional uses would not reduce hazard potential since none of the previous uses included site remediation and cleanup. Therefore, a more detailed analysis of all uses is not likely to alter our findings significantly.

This phase included a detailed review of facility-specific files, particularly at the Baltimore City Health Department and the Maryland State Department of the Environment (MDE). The review of historic records and regulatory files offered information on the type of operations at these sites and in most cases revealed a standard industrial classification (SIC) or enough information to assign a SIC. The SIC is the statistical classification standard established by the Office of Management and Budget.[34] The industry numbers are designated by one- to four-digit codes. The two-digit SIC provides a broad classification of industrial practices. Within these broad categories, however, is a wide range of operations. For example, SIC 28 represents chemical manufacturing. This category represents paints, plastics, pesticides, inorganic substances, organic substances, and so forth. The four-digit SIC provides the greatest level of detail on industrial activities and, in the example above, would capture the range of manufacturing activities within chemical manufacturing. For our analysis, the four-digit SIC was an essential parameter for better defining past practices across inventory sites and tapping into additional resources to populate the data on site histories and practices if site-specific data were lacking.

A Freedom of Information Act (FOIA) request was submitted to the Maryland Department of the Environment's Divisions of Water Management, Air and Radiation Management, and Waste Management for the purposes of reviewing files for sites listed on the inventory and all regulated sites in southeast Baltimore that were managed under the Toxics Release Inventory (TRI), the RCRA, and CERCLA programs. The last request was conducted to capture additional point sources in the study area that may be important for understanding the potential impact of off-site migration of contaminants, waste-handling activities, and application of knowledge of current industrial processes to inventory sites with similar past practices yet without historic data. The request for data on regulated sites in southeast Baltimore generated data on 77 facilities. Of these sites, 16 facilities were listed under the TRI program, 28 facilities were listed under the RCRA program, and 33 facilities were listed under the CERCLA program.

Phase 2: Creating the Chemical Inventory From the review of facility files and other reference materials, we developed a chemical substance database (phase 2). Chemical abstract service (CAS) numbers were identified and assigned to each chemical. EPA fact sheets also provided chemical information on industries, including ground transportation, lumber and wood products, metal casting and fabrication industry, and petroleum refining. The latter references are part of the EPA's EnviroSense program, which includes the sector notebook project that can be found at http://es.epa.gov/oeca/sector/.

When chemical information was not available for specific sites, the EPA Accidental Release Information Program (ARIP) was consulted to identify the types of chemicals released or spilled at similar SIC sites.* The ARIP information is recorded in a database, which includes the type of industry (4-digit SIC), the type and

*ARIP is a hazard-tracking system created by the EPA to track industrial operations and chemical spills across all aspects of the industrial sector, from transportation activities to warehousing, to industrial operations.[35]

amount of substances released, the location of the spill, and various other parameters. The ARIP database was used to identify the types of chemical accidents and spills that might have occurred at vacant lots that were once home to similar industries and included spills data from 1986 through 1998 (www.epa.gov/swercepp). SIC data on facilities in southeast Baltimore were linked to the ARIP data to generate a list of substances one might expect to find at these sites. These data reflected substances that accounted for at least 99 percent of the total releases by volume recorded in the ARIP inventory.[36–37]

A final list of substances was cross-checked with national inventories of chemicals released to the environment to determine how the substances and industries in the study sample compared to the federal inventories of chemical releases. These lists included the Agency for Toxic Substances and Disease Registry's (ATSDR's) list of priority pollutants and the EPA's TRI.*

RESULTS

Study Area Profile

The population of southeast Baltimore was 81,790 in 1990, representing approximately 11% of the total city population. The study area population is largely working class, with 45% of the population aged 25 years and over earning less than a high school degree and 51% of the population living in owner-occupied homes. On average, 20% of the southeast Baltimore population lives below the poverty level compared to the US average of 13%.

Figure 2 provides information on key neighborhood-level socioeconomic indicators for southeast Baltimore and the rest of the city. Three maps (Figs. 2A–2C) on poverty, educational attainment, and percentage minority illustrate the spatial distribution of these indicators and demonstrate one aspect of a geographic information system (GIS) used as a tool to profile neighborhood characteristics.

Table 3 provides tabular data on a more comprehensive list of indicators derived from 1990 census data. The spatial and tabular display of data revealed important demographic and socioeconomic insight about Baltimore's neighborhoods, particularly for those living within close proximity to Baltimore's vacant and underused industrial land. In southeast Baltimore, those in the communities living near these sites are white and tend to have low educational attainment. Importantly, however, these neighborhoods have a higher rate of home-owner occupancy, which is recognized as an important measure of wealth and offers insight about the viability of neighborhoods and the willingness of residents to remain in their neighborhoods.

Figure 1 displays mortality rate ratios comparing southeast Baltimore to the rest of Baltimore, Maryland, and the United States. Table 1 displays 95% confidence intervals for the rate ratios. These comparisons illustrate that southeast Baltimore experienced excess mortality from heart disease, total cancers and specifically cancers of the lung and stomach, chronic obstructive pulmonary disease, influenza, and pneumonia. For diabetes, stroke, and cancers of the colon and bladder, excess

*ATSDR's list of priority pollutants is an inventory of chemical substances frequently found across the nation's abandoned hazardous waste sites as classified under CERCLA.[38] The TRI tracks emissions of toxic substances to the air, water, and land.[39]

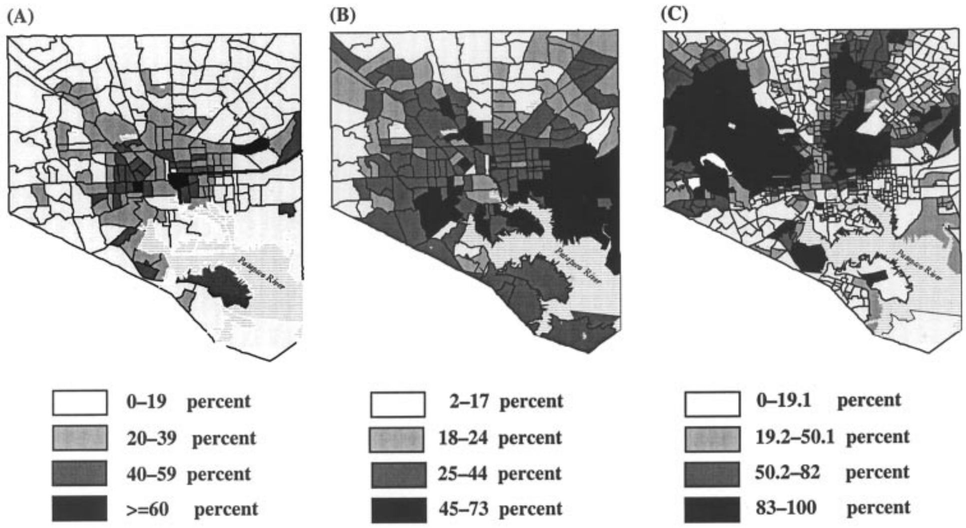


FIGURE 2. Socioeconomic characteristics for Baltimore City (1990): (A) percentage below poverty by census tract; (B) percentage of population aged 25 years and older with less than a high school degree by census tract; (C) percentage minority population by census block group.

deaths were not observed when compared to the rest of the city, Maryland, and US averages.

Site Inventory, Identification, and Profiles

Across the city, over 1,000 brownfield properties were identified by the planning department. These sites included residential, commercial, and industrial parcels. Of those citywide properties, there were over 480 sites 1 acre or greater in area. Figure

TABLE 3. Tabulated data on socioeconomic characteristics

Socioeconomic indicator	Mean value southeast Baltimore	Mean value rest of city (ROC)	Mean ratio of southeast to ROC
Population density (population/square mile)	21,807	16,228	1.3
Population density: aged 45 years and older (population/square mile)	6,814	4,674	1.5
Families with income greater than or equal to $50,000, %	16	21	0.8
Homes that are owner occupied, %	51	48	1.1
Persons below poverty, %	26	22	1.2
Minority population, %	32	62	0.5
Working class, %	73	70	1.0
Adults aged 25 years and older with less than a high school degree, %	45	28	1.6
Vacant homes, %	12	9	1.3

Note: Unit of aggregation is census tract. Data were obtained from the 1990 US census. Density is total persons per square mile. Density is adjusted for parkland and urban waterways.

3 provides a spatial display of the *Inventory of Vacant and Under-Used Parcels* in Baltimore City. The shaded area in this figure is southeast Baltimore, where 182 sites were identified as 1 acre in size or greater. These represent the sites analyzed for this study.

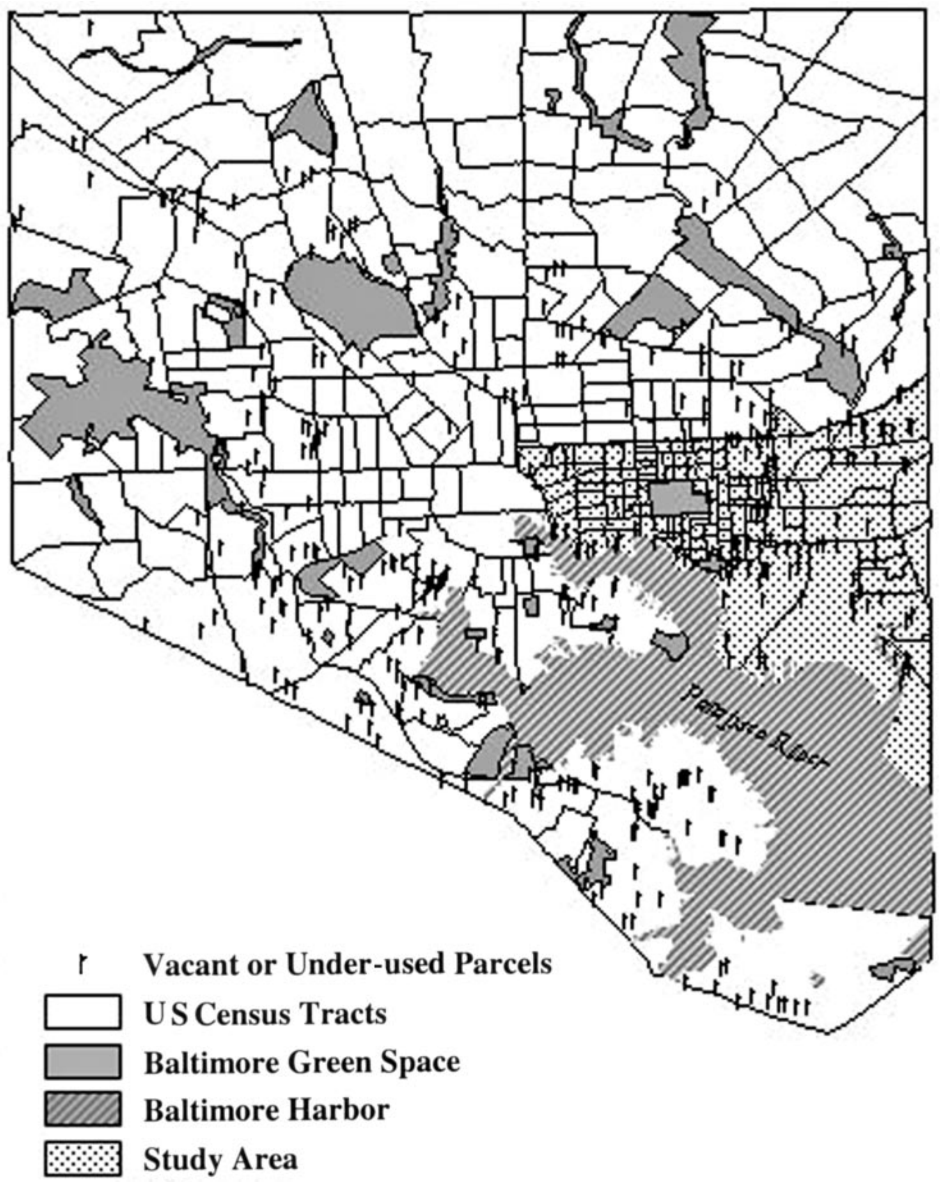


FIGURE 3. Baltimore *Inventory of Vacant and Under-Used Parcels* (1 acre or more). This figure displays 480 vacant and underused industrial and commercial properties in Baltimore that are 1 acre or greater in size. These sites were identified by the Baltimore City Planning Department in 1997 through a grant from the US Environmental Protection Agency's brownfields pilot program. Within southeast Baltimore, there are 182 sites that are 1 acre or greater.

Of the 182 facilities identified, health department files were available for 68 of those sites (37%). Regulatory agency files on inventory sites were available for 53 sites (29%). Files on currently regulated sites in southeast Baltimore, which were managed under the TRI, the RCRA, and CERCLA programs, were available for 37 of the 77 regulated sites identified (48%). Archive file reviews generated information on 50% of inventory sites and facilitated the assignment of industrial codes to 84% of the sites. Information on duration of operation was ascertained for 66% of the sites, time since closure was determined for 36% of the sites, zoning classification was identified for 95% of the sites, and area of parcel was available for all sites. Together, these data provided information for subsequent screening analyses of 90% of the facilities (n = 164).

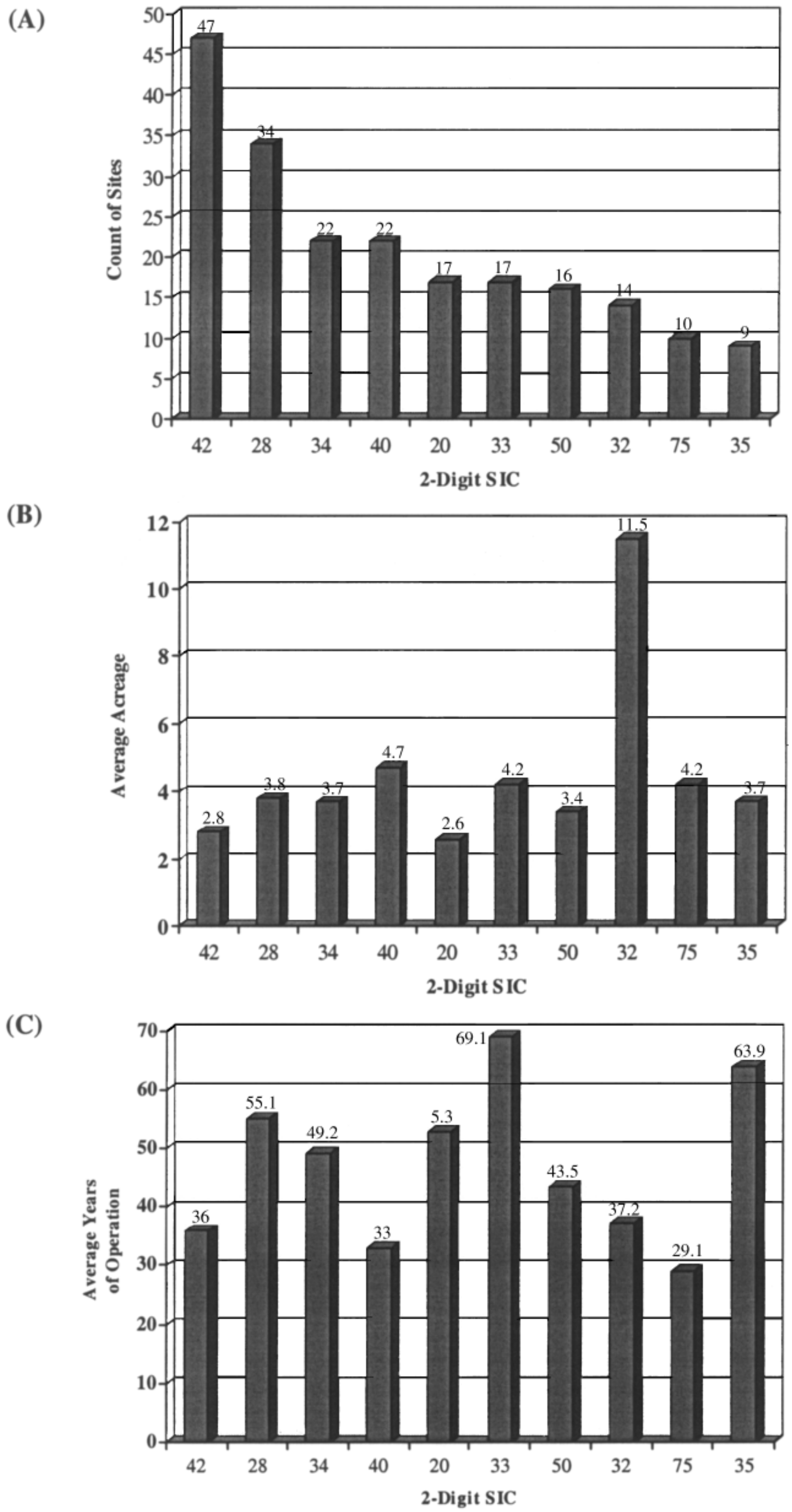
At the time of the inventory, 87% of the sites were zoned industrial, less than 8% were zoned commercial, and 5% were zoned residential. Approximately 30% (55 sites) were vacant and inactive. For the remaining sites, the limited uses ranged from parking lots, storage, waste disposal, warehousing, retail, auto repair, and light industrial activities. Of the sites, 20% were once or are currently regulated under the TRI (11 sites), RCRA (22 sites), and CERCLA (9 sites) programs. (Five sites overlapped across programs and therefore were only counted once for regulatory status.)

Figures 4A and 4B display the top 10 SICs by their count in southeast Baltimore and the average acres per two-digit SIC, respectively, for the study sample. In total, SICs were assigned to 84% of the sites (n = 153), representing 40 two-digit SICs. Many sites had multiple SIC codes. Each parcel averaged 1.6 industrial codes, with 1 SIC assigned to 68 sites, 2 to 3 SICs assigned to 45 sites, and 3 or more SICs assigned to 40 sites. As discussed in the Methods section, chemicals linked to multiple-site processes and operations are included in the chemical inventory.

Based on the information gathered, the top 10 most frequent industrial uses linked to vacant lots based on the two-digit SICs were motor freight transportation and warehousing (SIC 42); chemical manufacturing (SIC 28); fabricated metal products, except machinery and transportation equipment (SIC 34); railroad transportation (SIC 40); food and kindred products (SIC 20); primary metals (SIC 33); wholesale trade and durable goods (SIC); stone, clay, glass, and concrete (SIC 32); automotive repair, services, and parking (SIC 75); and industrial and commercial machinery (SIC 35).

Figure 4C displays the average duration of operation by two-digit SIC. Based on available information, primary metals industries have existed in southeast Baltimore, on average, for 69.1 years. Industrial commercial machinery manufacturing has operated in southeast Baltimore, on average, for 64 years, followed by the chemical manufacturing sector with an average duration of operation of 55 years.

Because each two-digit classification represents a range of industrial activities, the four-digit SIC was also examined since it provides a more specific description of past industrial operations. For the sites in southeast Baltimore, the inventory sites represented 130 four-digit SICs. The top 10 most frequent industrial uses linked to vacant lots, based on four-digit SICs, include railroad switching and terminal establishments (SIC 4013; n = 21); terminal and joint terminal maintenance facilities for motor freight (SIC 4231; n = 19); general warehousing and storage (SIC 4225; n = 18); scrap and waste materials (SIC 5093; n = 10); phosphatic fertilizers (SIC 2874; n = 7); petroleum refining (SIC 2911; n = 7); top, body, and upholstery repair shops and paint shops (SIC 7532; n = 6); steel works, blast furnaces (includ-


(A)
Count of Sites
47
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17
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10
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0 5 10 15 20 25 30 35 40 45 50
42 28 34 40 20 33 50 32 75 35
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2.8
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0 2 4 6 8 10 12
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29.1
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42 28 34 40 20 33 50 32 75 35
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ing coke ovens), and rolling (SIC 3312; n = 6); coating, engraving, and allied services, not elsewhere classified (SIC 3479; n = 6); pesticides and agricultural chemicals, not elsewhere classified (SIC 2879; n = 5).

The Chemical Inventory

Phase 2 generated a chemical inventory containing 122 substances. Based on the preliminary file search, 90 hazardous substances that had been used, released, or disposed on site were identified. Linking site-specific four-digit SICs to national hazard-tracking data (e.g., ARIP) generated an additional 32 substances, providing more information on the potential hazards of vacant industrial properties. Over 50% of these substances are listed on both ATSDR's list of priority pollutants and EPA's TRI. A complete list of substances, including those identified from the ARIP database and their overlap with national inventories, is available from the us on request.

The substances found to be associated with the top 10 industrial uses included heavy metals (lead, cadmium, chromium, copper compounds, zinc); solvents (tetrachloroethylene, methylene chloride); polycyclic aromatic hydrocarbons (napthalene, ethylbenzene, benzene, toluene); wood preservatives (creosote); and plasticizers (phthalates and polychlorinated biphenyls).

Table 4 provides information on the chemicals associated with these industrial groups. For example, substances linked to railroad switching and terminal establishments (SIC 4013) included lead, polychlorinated biphenyls, iron compounds, creosote, boric acid, ammonia, and aluminum chloride. These substances are associated with a range of activities, including application of herbicides to control weeds and creosote to preserve wood from termites as well as lead contamination from ship refurbishing operations.

DISCUSSION AND RECOMMENDATIONS

The results of this study reveal a history of heavy industrial uses associated with vacant and underused land in southeast Baltimore. These sites concentrate in low-income communities and in areas where excess mortality trends persist when compared to the rest of Baltimore, Maryland, and the United States. While this study does not provide information on population exposures and does not make any claims about current exposures from past industrial uses, the screening results suggest that urban brownfields are not benign and require more detailed analyses of and attention to their potential hazards from both site- and neighborhood-specific perspectives.

To the best of our knowledge, this is the first study to systematically examine the descriptive characteristics of brownfields within a neighborhood context. State regulatory programs have collected information on specific pollutants at thousands

FIGURE 4. Top 10 two-digit SICs for inventory sites in southeast Baltimore: (A) count of sites; (B) average property acreage; (C) average years of operation (42, freight warehousing; 28, chemical manufacturing; 34, fabricated metal products; 40, railroad transportation; 20, food and kindred products; 33, primary metals industries; 50, wholesale trade, durable goods; 32, stone, clay, glass, and concrete; 75, automobile repair, services, and parking; and 35, industrial and commercial machinery.

TABLE 4. Chemical substances associated with top 10 past industrial uses

2874 Phosphate Fertilizer	2879 Pesticides and Agricultural Chemicals	2911 Petroleum Refining	3312 Steel Works, Blast Furnaces (including coke ovens)	3479 Coating, Engraving, and Allied Services
Ammonia	Ammonia	Acetic acid	Acetaldehyde	Ammonia
Calcium phosphate	Arsenic acid	Ammonia	Ammonia	Benzene
Fluorine	Benzene	Benzene	Benzene	Cadmium
Fluosilicic acid	Calcium phosphate	Chlorine	Beryllium	Chloroform
Lead	Chlorine	Chloroform	Chlorine	Chromium
Liquid sulfur	Chloroform	Chlorotrifluoroethylene	Chromic Acid	Cyanide
Magnesium oxide	Ethylene oxide	Chromic acid	Creosote	Epoxy phenolic acid
Nitrous oxide	Formaldehyde	Cumene	Dioxin	Ethylbenzene
Phosphoric acid	Hydrochloric acid	Dichloroethane	Formaldehyde	Iron compounds
Sodium fluoride	Hydrogen sulfide	Dimethylbenzene	Hydrochloric acid	Lead
Sulfur dioxide	Iron compounds	Furfural	Hydrofluoric acid	Naphthalene
Sulfuric acid	Magnesium oxide	Hydrochloric acid	Hydrogen sulfide	Polychlorinated biphenyls
	Methanol	Hydrocracker heavy naphtha	Iron compounds	Toluene
	Naphthalene	Hydrofluoric acid	Naphthalene	Zinc
	Nitric acid	Hydrogen sulfide	Nitric acid	
	Phosphoric acid	Lead	Phosphoric acid	
	Phosphorus oxychloride	Mercury	Polychlorinated biphenyls	
	Sodium hydroxide	Naphthalene	Sodium hydroxide	
	Sulfur dioxide	Phenol	Sodium hypochlorite	
	Sulfuric acid	Polychlorinated biphenyls	Sulfuric acid	
	Toluene	Sodium hydroxide	Tetrachloroethylene	
	Vinyl acetate	Sulfur dioxide		
		Sulfuric acid		
		Toluene		
		Xylene		

of individual sites throughout the nation.[39] However, there is limited information describing historic site activities and the cumulative impact of brownfields at the neighborhood level, where there is the potential for scores of economically undesirable and chemically contaminated vacant or idle industrial and commercial sites to persist.

As such, there is little literature with which to compare our results. Earlier studies on hazardous waste sites and the health effects associated with exposures from hazardous waste sites, however, can instruct us on the potential risks associated with brownfield sites since many of the sites on current brownfield inventories were once regulated and/or represent similar past uses.[41]

Finally, in our analysis, scores of the inventory properties examined had multiple intensive uses over time, further underscoring the importance of detailed historic investigations of past uses for the purposes of informing contemporary public health and environmental issues such as urban brownfields.

In our screening approach, we identified several criteria for including and evaluating sites in our analysis. Regarding parcel size, we narrowed the list of candidate sites to facilitate our analysis and provide a starting point for further investigation. Consequently, we omitted 520 sites that were less than 1 acre in size. These sites mostly reflected vast tracts of vacant land zoned for residential or light commercial

4013 Railroad Switching and Terminal Establishments	4225 General Warehousing and Storage	4231 Terminal/Joint Terminal Maintenance for Motor Freight Transportation	5093 Scrap and Waste Materials	7532 Autobody Repair and Maintenance
Aluminum chloride	Iron compounds	Aluminum chloride	Acetaldehyde	Acetone
Ammonia		Boric acid	Chlorine	Butyl acetate
Boric acid		Chloroform	Formaldehyde	Toluene
Creosote		Ethylene oxide	Methylene chloride	
Ethylene oxide		Iron compounds	Sulfuric acid	
Iron compounds		Sulfuric acid		
Lead		Toluene diisocyanate		
Polychlorinated biphenyls				

use. These sites, while excluded from this screening evaluation, represent an important component of the urban brownfields story given the magnitude of vacant residential land in industrial cities and the proximity of such land to industrial and commercially zoned land. As redevelopment strategies are developed, it will be important to consider these types of sites when developing comprehensive neighborhood plans and making decisions about cleanup and reuse of urban brownfields.

In addition, our analysis focused on the time frame from 1935 through 1997. We chose this time frame as a starting point to understand historic operations and the range of potential hazards that are associated with past industrial and commercial uses. While 1935 was relevant for the Baltimore study given Baltimore's industrial history, this time frame may not be appropriate or sufficient in every place and may miss important operations that pre-dated 1935, such as plant operations around World War I.

Industrial classifications (e.g., SIC) provide a foundation from which public health officials, environmental regulators, and communities can understand the range of past operations associated with brownfield properties. Such a foundation can provide the basis for gathering more detailed information on the types of chemicals used in past operations and the range of environmental and public health hazards that might be associated with such substances. For example, in this analysis, the assignment of SICs to brownfield sites facilitated the development of a chemical inventory associated with past uses and ultimately the evaluation of potential health effects associated with the chemicals included on the list. For example, in subsequent research on the Baltimore sites, we developed a chemical screening algorithm to rank the substances based on their toxicity potential and chemical persistence. Of the top 10 chemicals with the greatest hazard potential, 80% were suspected or recognized as respiratory irritants.[42] Ultimately, by tracking the substances that have been historically released into the affected areas, the substances that are present at brownfield sites, population exposures, and community health outcomes, we can better understand the linkages between environmental pollutants and population health and begin to set priorities for further environmental monitoring and community prevention strategies.

While SICs provide important insights about the range of industries that once occupied urban brownfield sites, caution must be exercised when assigning SICs to past industrial processes since the SIC assignment may not reflect changes in industrial processes that occur over time and the chemicals used in these processes. For example, a paint manufacturer that operated during World War II may have had vastly different production processes than a paint manufacturer operating in the 1970s.

The information infrastructure to support such investigations is critical for public health and environmental management. Given the fragmentation of environmental health services at the local and state levels and inconsistent record keeping across agencies, however, the process of analyzing the range of risks associated with these sites is time consuming and labor intensive. Specifically, tracing past practices is complicated by misplaced, purged, or limited record keeping and is obscured by changes in oversight by different regulatory agencies, changes in ownership or operations, or limited oversight or enforcement activities. Therefore, a deliberate research effort is necessary to consolidate and organize disparate data resources that are available on past industrial operations, land use changes, local and regional ordinances and policies, and chemical spills and site violations.

The health department archives, together with the state environmental records and the real estate tax assessments, were the most useful resources for understanding past industrial and commercial uses of vacant land since they capture activities that pre-date modern waste management policies, regulations, and environmental health tracking systems. Newspaper archives and national hazard-tracking systems were useful in filling in the data gaps and providing estimates of potential hazards when facility-specific information was not available. Other potentially useful resources not used in this analysis but that contain information about urban growth and development, past industrial practices, and changes in operations over time include Sanborn fire insurance maps[43] and historic aerial photographs.

The review of social, health, and economic indicators highlighted the constellation of social and health disparities in affected brownfield neighborhoods. Contrary to conventional wisdom that pollution sources concentrate in low-income, minority communities, those at greatest risk from uncontrolled historic hazards in Baltimore's southeast neighborhoods were white, working class communities. Moreover, the health data revealed that residents of southeast Baltimore died in excess of the rest of the city, Maryland, and the United States, thus warranting more detailed health investigations and heightened surveillance of affected communities.

The national movement to bring brownfield sites to productive use has resulted in a range of policies and programs to expedite site cleanup activities and promote redevelopment.[9,44,45] As redevelopment opportunities increase and property passes to other uses, there will be an increased urgency for local health officials to work with planners, developers, and communities to ensure thorough cleanup activities, adequate consideration of public health hazards, sustainability of redevelopment projects, and appropriate long-term stewardship of affected sites. The rush to redevelopment should not override the protection of community health and well-being.

Public health involvement must reflect both site- and neighborhood-specific approaches. Appropriate site evaluations should include a comprehensive review of past uses of vacant industrial and commercial properties, an exploration of chemicals used at these sites, controlled and uncontrolled on-site storage and disposal activities, site monitoring and testing, and an inventory of neighboring land uses (both active and dormant sites) and potential impacts from adjacent sites due to off-site migration of chemical contaminants.

Neighborhood-level evaluations should consider the cumulative impacts of economic and environmental decline on public health and integrate such insight into future planning and long-term risk management strategies. Health assessments, including evaluations of mortality and morbidity trends in affected neighborhoods, will offer insight about community needs and insight into designing appropriate public health prevention strategies.

Improving and upgrading the information content of existing databases on hazard sources, exposures, and related health outcomes will be a critical step in planning for sustainable community development and economic revitalization. Improvements in information technology will facilitate the digitization of site information, the geographic mapping of these data, and the communication of potential public health and environmental risks to the public through local schools, libraries, and the Internet. In Pittsburgh, Pennsylvania, an information infrastructure project is under development to model the potential chemical risk associated with candidate redevelopment properties and to rank such properties based on their potential environmental liability.[46]

Such advances in information technology will improve public health capacity to ensure the right of communities to know about environmental toxins in the environment and the potential for harmful health effects. Regarding brownfields, such data resources and information will be useful in guiding permit decisions, master plans, and community development priorities and evaluating the long-term impacts of economic redevelopment on social welfare and public health at the local level; they will further inform national, regional, and state environmental health policies, program evaluations, and long-term planning strategies.

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