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Environmental Justice through Community-Policy Participatory Partnerships

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Abstract

Geographical information systems (GIS) are often used to design environmental justice (EJ) policy interventions. Leveraging GIS and other graphics, overburdened EJ communities can learn from maps that geographically link environmental burden (EB) and social disparity (SD) data. Visually representing EB and SD data concretizes the unjust distributions of environmental and broader inequitable societal policies. These maps can be used to efficaciously assess EJ disparities created by such policies through exploring socioeconomic characteristics with local communities. Given the great variation in how GIS EJ applications measure and visualize EB and SD, we present a community-based participatory design (CBPD) lens to collaboratively work across overburdened communities and support making EJ data accessible to all stakeholders. Our location proximity approach is a powerful way to assess overburdened EJ communities because it relies on user-predefined boundaries, and it doesn't use a single fixed unit of reference to prioritize areas of intervention. Moreover, most areal unit applications use ordinal measures, such as percentiles, and multidimensional indexes, which are intelligible to understand by many residents. Leveraging a community-based participatory design methodology, we present our novel Proximity to Hazards Dashboard (PHD) that includes data on asphalt plants and industrial corridors, hazards often missing from state-level dashboards but very relevant for city policymaking, as well as more traditionally used environmental hazard sources. The use of the tool by policymakers and community members suggests that EJ categorization should focus less on procedural benchmarks and more on systemic change for policy impacts in ways that sustain the participatory nature of our approach.

Keywords

Environmental Justice, Visualizations, Community-Based Research

1. Introduction

In 1987, the pioneering work of Charles Lee and his coauthors led to the first visualization of the "socio-economic characteristics of communities with hazardous waste sites" [1]. Three decades later, the 2021 executive order (EO) 14008 [2] and the Justice40 Initiative [3] highlighted the plight of overburdened communities. "Overburden communities" are those where environmental burdens (EB, e.g., high pollution, proximity to hazardous facilities) and socio-economic disparities (SD, e.g., low income or minority status) coincide cumulatively to produce harmful living conditions. Environmental Justice (EJ) policies aim to reduce these environmental health inequalities and ensure equal access of all communities to policymaking [4]. And, indeed, based on Lee's more recent work [5] we find a steppingstone toward broader EJ goals, with cautious historical words of wisdom:

> [EJ can only be actualized in more just ways through the] fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of laws, regulations and policies that affect the environment and/or public health. Environmental justice strives to ensure the equitable and just distribution of resources and benefits in a manner that prioritizes communities experiencing the greatest inequities, disproportionate impacts, and unmet needs. It also strives to prevent and mitigate environmental harms and burdens, identify and address policies and practices contributing to disproportionate impacts, and eliminate systemic barriers to the achievement of healthy and sustainable communities for all people.

These definitional shifts move from a procedural focus to a systemic focus around the EPA's explanation of EJ and align with the EPA's prior recommendations from their own 2010 report, *Proximity to Environmental Hazards*: *Environmental Justice and Adverse Health Outcomes* [6]:

> …based on the evidence of disparities by race and income in relation to proximity to environmental hazards, the adverse health outcomes for populations in close proximity to environmental hazards, and acknowledgment of the health disparities experienced in general by communities of color and lower-income communities, we suggest that these factors be given serious consideration in the decision-making process by governmental environmental and health agencies regarding the siting of environmentally-burdensome facilities and land uses, in regulatory and enforcement efforts concerning pollution, and in the active promotion of environmental health justice and

environmental health protection.

Geographically understanding the relationship between EB and SD is essential to promoting EJ. In turn, geographical information systems (GIS) are critical to designing EJ policy interventions where stakeholders (e.g., policymakers, grass-roots organizations, public interest groups, activists, and researchers) can identify overburdened communities by geographically linking both EB and SD data on a map [7] [8]. This dual spatial representation is essential to visualize outcome distributions of EJ policies, as well as to identify and assess environmental health disparities created by policies that are biased due to socioeconomic characteristics of those communities. However, there is great variation in how GIS EJ applications measure and visualize both EB and SD, leading to different approaches to identiyfing overburdened communities and making EJ data accessible to the public [9].

This paper presents the Proximity-to-Hazard Dashboard (PHD) developed by a group of diverse researchers at the University of Illinois Chicago across multi-disciplinary colleges leveraging a community-based participatory design (CBPD) approach involving the southwest communities of Chicago. Based on the notions of "proximity to a specified location" and "cumulative burden," the PHD supports the identification of overburdened communities and addresses the need of local communities to know "Which polluters are near my home?" and "How does my exposure to pollution compare to other communities?" The dashboard makes two substantial advancements to current EJ GIS applications. First, it proposes a situated decision support tool targeted to local communities and policymakers by providing an easily accessible representation of the cumulative EB. Second, it leverages a location proximity approach with Socioeconomic Disparity (SD) data from the information provided by State Level Education Agencies (e.g., Illinois State Board of Education Report Cards) and emphasizes the concrete impact of unequal and racist distribution of policy-ignored burdens on sensitive populations, namely Asian, Black and Brown schoolchildren.

2. Background Literature

An increasing number of government agencies are implementing EJ GIS applications to facilitate public participation with data and provide support to policymaking. In 2015, the US Environmental Protection Agency (EPA) released the EJSCREEN after a three-year long deployment process. With California leading the way [10], state environmental departments are also releasing EJ GIS applications. A recent review shows that approximately one out of five US states provide data that is accessible, complete, and usable enough for the public to identify a community's EB and SD [11]. Based on Fusi and colleagues' review [11] and dataset [12], we have identified and analyzed the main EJ GIS applications used by U.S. environmental agencies illustrated in **Table 1**. Differences in how EB and SD are visualized and measured delineate two approaches: The *aerial unit approach* classifies pre-defined geographical areas into various EJ levels while the *location proximity approach* identifies EB in a user-identified area. Both approaches have strengths and limitations.

Table 1. Summary of EJ tools implemented by state environmental agencies[1].

General information		Approach	Data				Scale
State	Dashboard name	Areal unit or location proximity	SD data	EB data	Other data	Are EJ areas identified?	Unit of reference
USA	EJSCREEN	Mixed (Tract)	Percentiles (6 individual and multidimensional indicators)	Percentiles (11 individual and multidimensional indicators on exposure, potential threats, and proximity)	Health disparities, climate change data, critical service gaps. (EJSCREEN 2.0, June 2022)	11 EJ indexes (combines multiple social indicators with a single environmental indicator to identify most overburdened communities)	State, EPA region, national
CA	CALSCREEN	Areal unit (Tract)	Percentiles	Percentiles (multidimensional indicators on exposure, potential threats, and proximity)	Overall indexes of burden (pollution burden, social vulnerability, EJ burden)	Yes (based on overall EJ index)	State
MN	Understanding EJ in Minnesota	Areal unit (Block group)	Percentages	Air pollution score—multidimensional index including multiple sources of air pollution		Yes (poverty only, minority only or both)	State
MN	What's in my neighborhood	Location proximity (Tract/ Municipality)	None	# sites and facilities that pose an environmental risk (e.g., formerly contaminated sites, permitted businesses…)		No	Local
NM	OpenEnviroMap	Mixed[2] (Block group)	Percentages	Location of facilities		No	State
NC	NC DEQ Community Mapping System	Mixed/Location proximity[3] (Block group)	Percentages	Location of facilities, permits, and incidents		Yes (higher percentage compared to state, county or both)	State, county
PA	Pennsylvania's Environmental Justice Viewer	Areal unit (Tract)	Percentages (for EJ communities only)	Location of facilities		Yes	State
RI	RIDEM Environmental Resource Map	Mixed	Percentages (for EJ communities only)	Location of facilities, impaired waters		Yes	State

Continued

WA	Information By Location—Washington Tracking Network	Areal unit (Tract)	Deciles	Deciles (single environmental indicators)		No ("You should not interpret rankings as absolute values. Do not use them to diagnose a community health or to label a community")	State
WA	What's in my neighborhood: Toxics Cleanup	Location proximity	None	Count of cleanup sites within a one-mile radius		No	Local
UT	DEQ Interactive Map Viewer	Mixed[4] (Block group)	Percentages & Percentiles	Location of facilities and indexes of pollution and exposure (e.g., air toxics respiratory hazard index, proximity index)	EJ indexes drawn from EJSCREEN	Yes	State
NJ	NJ DEP EJ mapping, assessment, and protection tool (EJMAP)	Areal unit (Block group)	Percentages & Values (EJ communities only)	Location of sites and facilities (e.g., major sources of air pollution, resource recovery facilities or incinerators, sewage treatment plants…)	Stressor summary index combining 26 environmental or public health stressors for each community. Comparison with the lower of the 50th percentile of the state or relevant county non-overburdened community	Yes	State
MD[1]	MDE EJ Screening Tool	Areal unit (Tract)	Percentages and percentiles (and EJSCREEN indicators)	Location (and EJSCREEN indicators)	Socioeconomic score	Yes	State
MI	EGLE MiEJScreen *(draft)*	Areal unit (Tract)	Percentile	Percentile (exposure, environmental effects, proximity)		Yes	State

Areal unit approach. The areal unit approach relies on a color-coded scheme to rank order pre-defined geographical areas that could be categorized as EJ, generally at a Census tract or a block group level, according to SD and EB in that context. California's CalEnviroScreen shown in **Figure 1** is an example. This approach provides a quick, high-level view of SD and EB experienced by com-

[1]Website coding updated on 06/10/2022. Only applications developed by state governments' departments in charge of environmental quality were included. We exclude dashboards developed by non-governmental organizations or city and county governments.

[2]It is possible to draw circles of a given radius on the map and count the number of facilities. The count is not automatized.

[3]Using the "Screening" option in the NC dashboard, it is possible to count facilities, permits, and incidents in a predefined mile-radius from a given point

[4]The dashboard allows for a radius-based search, but results are not very clear.

munities across the state allowing state policymakers to identify and prioritize areas for intervention. SD and EB indicators are generally reported in absolute values (amount or percentage) and as rankings (e.g., percentiles). EB data also may include other sources of impactful pollution (e.g., permit-requiring facilities, brownfields, superfunds and cleanup sites) and pollution levels (e.g., water or air quality). A few states have chosen multi-dimensional EB scores, such as the Minnesota's Air Pollution Score[5], the California's EB scores[6], and the New Jersey's stressor summary index[7] (see Table 1). However, this aerial approach has three foundational drawbacks.

First, the unit of analysis for this approach is at the Census track or block group. This choice offers granularity, as these are the smallest geographical units from which SD and EB data are typically available. However, they, unfortunately, represent abstract localities, and residents are unlikely to know their block group (or tract) number and cannot identify them. Moreover, since these EB/SD measures are reported at an aggregated scale, they lack address level specificity. State government agencies might also miscalculate an area's EB by excluding sources of pollution that are adjacent to but not part of the defined area. EPASCREEN provides a proximity ring inclusion of all known facilities at a given distance from the Census block/tract, or exactly at the Pin level (see Figure 2). Unfortunately, these platforms aren't easily interpretable or utilized by marginalized communities.

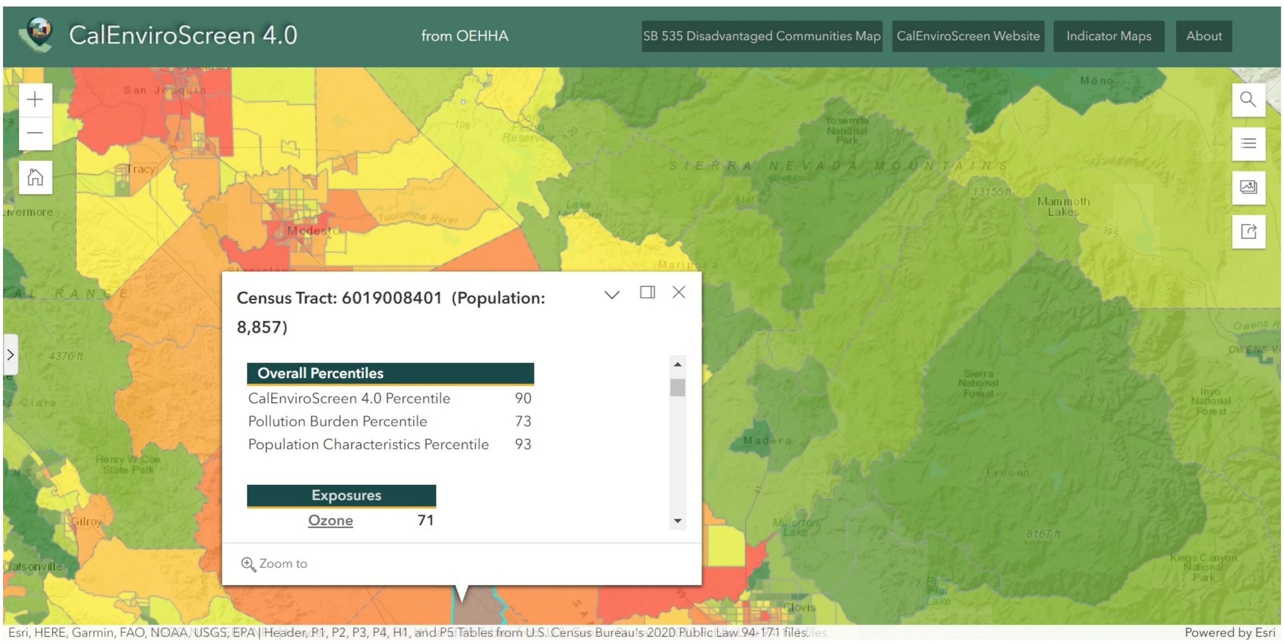

Figure 1. Screenshot of the CalEnviroScreen as of June 10th 2022.

[5]More information can be found: https://www.pca.state.mn.us/air/air-modeling-and-human-health

[6]More information can be found: https://oehha.ca.gov/media/downloads/calenviroscreen/report/calenviroscreen40reportf2021.pdf#page=126

[7]More information can be found: https://experience.arcgis.com/experience/548632a2351b41b8a0443cfc3a9f4ef6

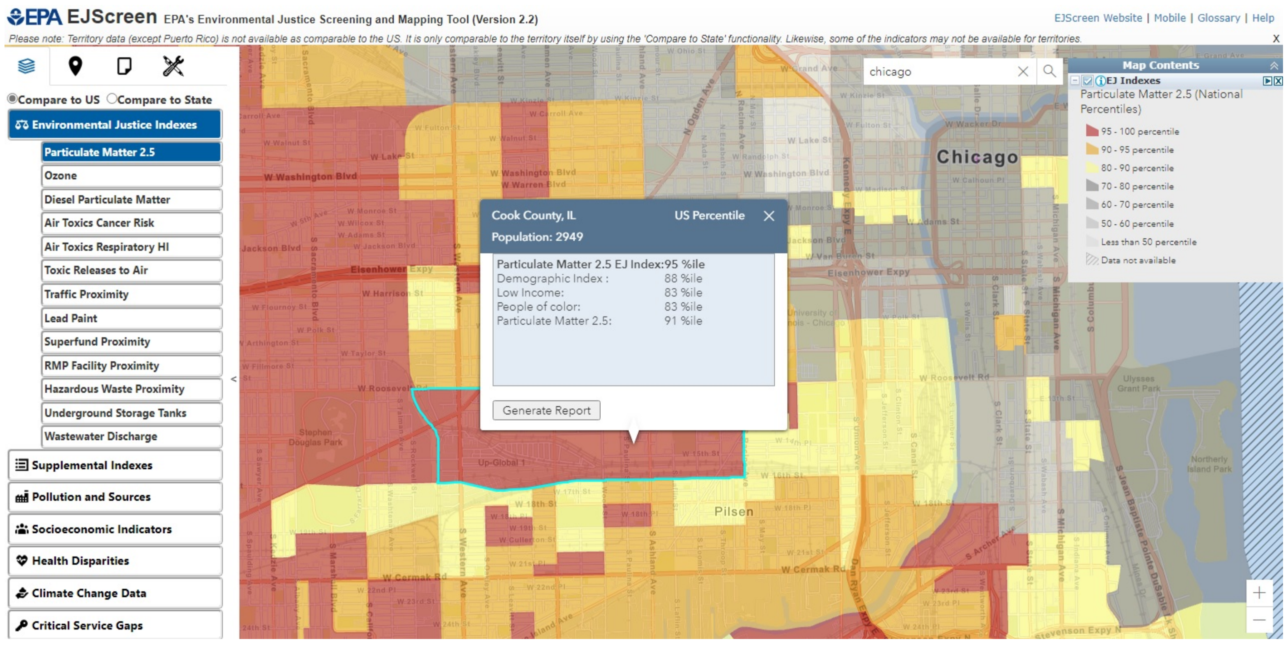

Figure 2. EJSCREEN Screenshot (https://ejscreen.epa.gov/mapper/; accessed on June 12th, 2023).

An additional drawback of this approach is the indicators and metrics being compared and ranked at the state level (e.g., percentiles show where an area falls in comparison to all other areas in the state). As disparities are defined in relative policy terms, this fixed unit of reference can distort the true magnitude of a community's EB and SD. For instance, SD indicators of major urban centers (which are richer and more diverse) can distort state-level rankings of rural towns (which are poorer and less diverse). By changing the unit of reference (e.g., counties or cities), a community's rankings as an EJ concern may be different, making it a higher (or lower) priority for intervention. Because of these limitations, available dashboards fall short of supporting EJ policymaking at more localized, disaggregated EJ levels (e.g., whether a city releases a permit for an industrial facility).

Finally, the identification of EJ areas of interest for intervention most prominently relies on SD indicators, and notably the percentage of minority population and the median household income have become the new categorization criteria for EJ areas. States might define SD threshold criteria to designate EJ areas (e.g., areas with a median household income less than the state's median). This simplified, and unidimensional, categorization excludes EB data entirely and overestimates the number of EJ communities. For instance, Massachusetts' EJ designation includes "cities and towns containing fairly high concentrations of EJ neighborhoods that one would hardly describe as environmentally overburdened" [13]. A similar issue was found in our research context, Illinois [14].

Location proximity approach. Alternatively, a location proximity approach allows the user to select a central location, define a customized area around it, and visualize sources of pollution within that specified area of interest. For instance, the North Carolina's Community Mapping System (**Figure 3**) allows users to pinpoint a location and displays the facilities within a customized radius for ease of hazard identification. Location proximity applications have a major advantage since residents can easily identify areas of concerns based on an understandable location (*i.e.*, an address or landmark) and define a walking distance space with familiar identifiers (*i.e.*, streets and landmarks). The EJ status of a community is defined by the number of environmental hazards within the area. Users can select multiple areas of interest and compare their exposure to EB. This approach has also a few important limitations. First, since map visualization of EB is limited by the scale of the selected area, it can be difficult to use location proximity tools to make big picture policy decisions but given Lee's (2021) argument we provided above, this limitation may actually be an advantage to specify disaggregation of EJ areas and their prominence rather than acting more procedurally and never changing the system. These applications also do not offer an immediate overview of a larger area (e.g., a state) and comparisons require the user to select multiple adjacent locations. While this seems like a limitation, the utility of this tool should not rest solely on policy audiences and should endeavor to include public participation of over-burdened EJ communities.

Another limitation may be that SD indicators are only available at the aggregate level (Census tract or block group). Therefore, applications adopting this approach may lead to overemphasis on EB (e.g., sources of pollution and their location) and lack information on SD (the EPA's EJSCREEN is an exception as it proportionally adjusts SD data). Because of this, it can be difficult for users to evaluate the dual nature (SD and EB) of EJ, both in terms of policymakers and communities. However, again, this limitation has been addressed (EJSCREEN) and can be ameliorated partially.

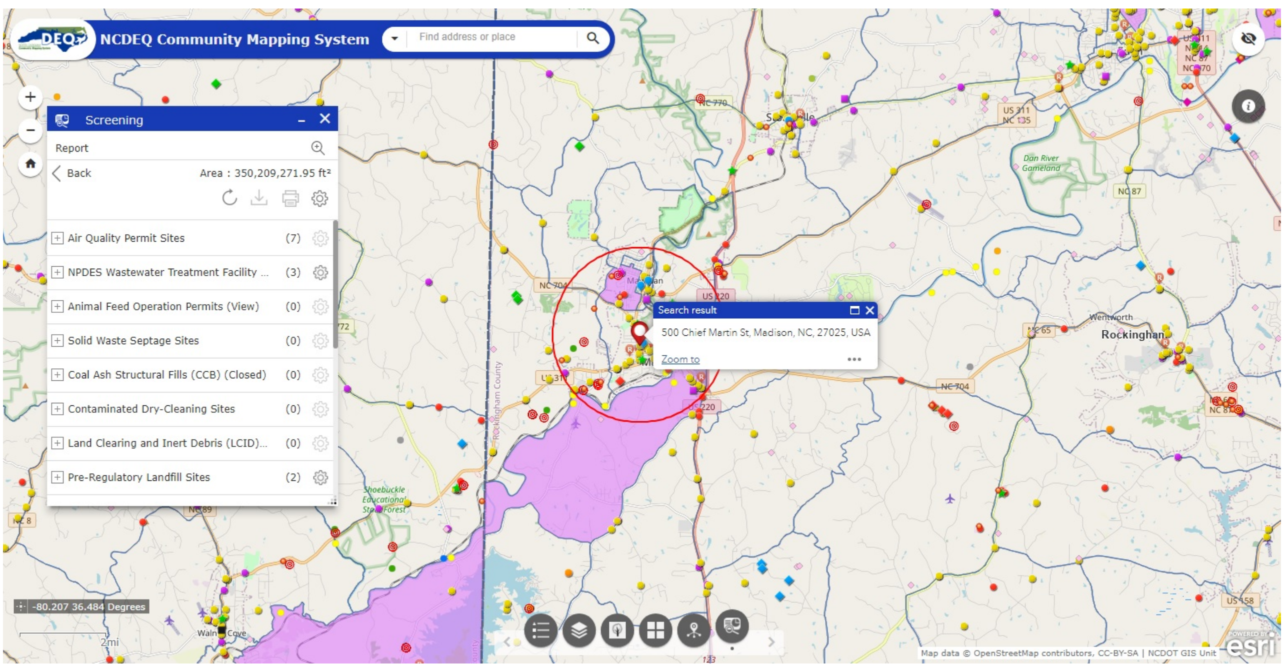

Figure 3. Screenshot of the North Carolina's Community Mapping System as of June 10th 2022.

Finally, a location proximity approach uses the number of pollution sources and hazards (e.g., permit requiring facilities, brownfields, superfunds, and cleanup sites) located in the user-selected area to measure EB. It's designed to assume all environmental hazards and pollution sources equally contribute to the area's EB, even if this might not be true (e.g., some facilities might release more hazardous substances than others). Residents lack the expertise to assess each hazard and pollution source individually and to evaluate their cumulative impact. Moreover, this measurement approach differs from those generally adopted by policymakers who rely on pollution thresholds established by the EPA (e.g., PM levels) for policy decisions. **Table 1** shows that only a few states exclusively adopt one or the other approach, with several dashboards combining features of both. For instance, several areal unit dashboards provide tools to draw a customized area on the map even if they don't count the number of environmental hazards (e.g., New Mexico; EPASCREEN).

Overall, a location proximity approach, we argue, is much better suited to assess overburdened EJ communities because it does not rely on predefined abstract boundaries, nor does it use a single fixed unit of reference to prioritize areas of intervention. Moreover, most areal unit applications use ordinal measures, such as percentiles, and multidimensional indexes, which are intelligible to understand for many residents. By contrast, a location proximity approach uses more intuitive measures (e.g., the number of environmental hazards in each area) to assess a meaningful EB. However, both approaches apply a unidimensional definition of EJ by overemphasizing either EB or SD data, challenging the identification of overburdened communities as defined by EO 14008[8].

3. Community-Policy Participatory Partnerships: A New Model to Impact EJ Policy

Community Participatory Partnerships are found among citizen science initiatives dating back over 30 years in the United States, with a high number of these awareness-raising and training projects situated in ecological and environmental sciences [15]. Importantly, these projects are typically constrained in four important ways. First, these research studies have not mediated the tension in the field on what constitutes citizen science and community-based science [16]. Second, there is a lack of knowledge concerning how these projects sustain vital networks between communities, academics, scientists, and policy-makers [15]. Third, these partnerships also situate issues of environmental injustice and the political negotiations of environmental policy as less important features when engaging historically marginalized communities [17]. Finally, these projects do not have high participant rates from Black and Brown communities [18], which can lead to devaluing the rich knowledge from the communities served [19]. These four considerations underline the need to build infrastructure where policymakers, community organizers, academics, and scientists discuss these EJ is-

[8]https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad

sues and are respected for their contributions toward Environmental Justice. This is why we built such a Partnership in Chicago with local grass-roots community organizations, as well as with the Alderpeople that are charged to serve them in SW Chicago. Additionally, illuminated by a recent EJ application to exposure science through *Nature* supports infusing communities for EJ:

> Researchers should meet with community members and stakeholders to learn more about the community, involve them in the research process, collectively determine the environmental exposure issues of highest concern for the community, and develop sustainable interventions and implementation strategies to address them … involving the community in the research project, from start to finish, will facilitate community learning about exposure science and how it relates to the health of all those involved. It will also provide researchers with better knowledge of human behaviors, activities, and risk perceptions that may impact exposures, and improve researcher competency in assessing exposures … [and] it is not enough to document the continued exposure and environmental health disparities in structurally marginalized communities [20]. (p.9)

In sum, we know that historically marginalized communities do not garner interest from broader EJ initiatives. Therefore, we sought to not just build a partnership, but engage in learning about cumulative environmental burdens present in our partners' locale in ways that make sense for them. Without this extension to serve the local community needs and learning, as well as the Aldermanic learning of these issues, our partners would still not be able to scientifically identify their local contexts as areas where they have the agency and right to determine what is permitted.

Our research context, Chicago, has been continuously shaped and shifted over time. The historical and contemporary disproportionate exposure of Black and Brown communities to high-pollution and a litany of environmental hazards does not occur by chance. Like all cities, Chicago is governed by spatial rules and these rules are reflective of the desires and power structure of the nation. Cities generally reflect the social order by situating citizens in material conditions that we can see (e.g., buildings, security cameras, green spaces), hear (e.g., sirens, birds singing), smell (e.g., a freshly cut lawn, fresh bagels) and be otherwise affected by (e.g., pollution). In cities, people with differential power over others install, benefit from, and use markers of identity and spatial acts of oppression (e.g., racism) to create meanings and experiences that benefit them[21]. In Chicago, this means that race and racism combine to ensure that wealthy and white populations have disproportionate access to less burdened environments with better birth and health outcomes.

Historically, some have focused on racist policies that have spatialized white advantage through political acts of oppression (e.g., mortgage-insurance redlining, segregation) to create racialized places. In this work, we are focused on the ways that these contexts also create fodder for issues that persist in Chicago around Environmental Burdens (EB) derived from EPA/HUD/DOJ datasets and Socioeconomic Disparities (SD) from the Illinois State Board of Education's Yearly Report Cards that provide data on all schools in Illinois. Historically, the populations subject to these issues are not the focus of EJ initiatives. To understand how people are affected by, understand, and act on EJ issues in Chicago, scientists need to understand places as saturated in histories and inequities. Through C-PPPs, we can build the infrastructure to sustain systemic policy EJ changes.

4. Methodology

The PHD[9] addresses the abovementioned unidimensional limitations and provides a new scalable but localized decision support tool across stakeholders. Our research approach was inspired by "cumulative impacts" recently identified by the U.S. EPA [22] [text highlighted by the authors]:

> Communities that have multiple industrial and energy facilities and are saturated with legacy pollution want to see EPA […] **taking cumulative impacts and risks into account**, even if they cannot be measured with precision. Permitting and rulemaking have typically not reflected the reality of overburdened communities, which means that **it is often easier to site an eighth facility in a community that already has seven than in a community that has none**.

Thanks to PHD, residents we work with can easily assess whether adding a new facility in these communities' local contexts is acceptable according to the EJ principle of equitable distribution (*i.e.*, Is the community's cumulative EB too high?) and to what extent the new facility impact socioeconomically disadvantaged groups (*i.e.*, Is the new facility located to a sensitive location?).

Leveraging a community-based participatory design (CBPD) to develop the PHD was instrumental to identify the EB for the local community and identify iteratively refined design parameters for the EJ visualization interface (see **Figure 4** below for this CBPD model). This approach relied on meetings with community members and stakeholders concerned with knowing which polluters are near their homes, schools, and places of work. **Figure 4** below provides a visual overview of the interactive relationship between the local community, the data, and the dashboard. The PHD development process shows the intersection of "information flow and interaction spheres" and the "public discourse spheres," while aiming to connect the community to the visualization interface.

Based on local community, disciplinary experts, and aldermanic input, we selected five sources of hazards to display in the PHD as summarized in **Table 2**. Asphalt plants and rail yards, particularly, emerged as concerns for these predominantly Black and Latinx local communities. These data are usually absent

[9]The PHD can be accessed at the following link: https://univofillinois.maps.arcgis.com/apps/instant/nearby/index.html?appid=486f6e438ecf4b048deebc8dafd9f2c1&sliderDistance=1.1

from state-level dashboards and demonstrate the value of a CBPD approach. In Figure 4, the cumulative EB is measured by the number of potential pollution sources in the defined areas. In this example, within a 1.5 km radius from the selected location, there are 5 asphalt plants, 5 toxic chemicals emitted by TRI, and 1 brownfield. Adding another asphalt plant or TRI facility might easily overburden the community given the number of already existing facilities.

The PHD dashboard was built using the customizable ESRI ArcGIS "Nearby" app template, which is used to generate maps and information reports with its interface optimized for both desktop and mobile browsers. An advantage for using this template was its ease of use for communities from different cities so they can create similar interfaces without resorting to Computer Science programming solutions. The Nearby app allows the user to enter a location using one of three options by clicking on the map, entering an address, or using their current location. Then, the user specifies the search radius. The application displays all results in the search radius by default and provides estimates of their distance from the center.

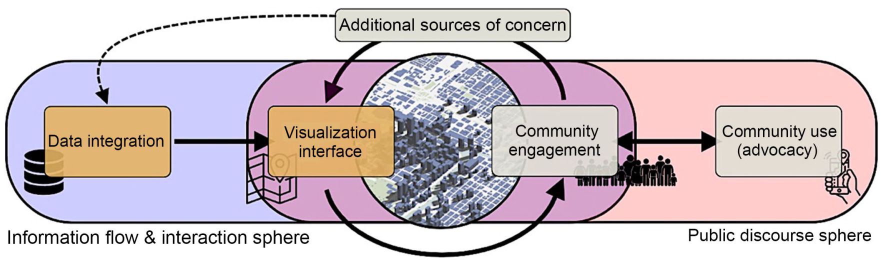

Figure 4. Schematic of the community based participatory design approach.

Table 2. Hazard sources in the PHD.

Hazard sources	Description	Data source
Toxic Release Inventory (TRI) reporting facilities	Location of TRI sites and background information about the toxic emissions (*i.e.*, quantity, carcinogenicity, etc.)	USEPA TRI Basic Plus Database
Rail yards	Railroad hubs are a major source of particulate matter pollution and represent a structural legacy.	US Department of Transportation on-line data portal
Asphalt plants	Communities were concerned by the numerous facilities producing and processing asphalt within residential zones. These facilities were de-listed from the TRI section 313 reporting program in 2002. They are still regulated by state and federal agencies and require a permitting.	Data provided by the Southwest Environmental Alliance.
Brownfields	Location of brownfields	US EPA's "Cleanups In My Community" (CIMC) data set
Landscape burden	EB caused by the mere presence of industrial zones. State government tools do not show this major structural EB source because city governments control these data.	City of Chicago's shape files

Another aspect of our designed PHD is to emphasize the most sensitive and relatively immobile population living in these communities: kindergarten (age 5 to 6) to 8th-grade schoolchildren (henceforth K-8). In recognition of their increased vulnerability to pollution, the 1997 Executive Order (EO) 13045 [23], charges each Federal agency to: 1) make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children; and 2) ensure that policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. The PHD supports this valuable identification of those most vulnerable to environmental hazards in ways that are not yet taken up.

The PHD maps all Chicago public schools with an attendance boundary and provides summary demographic information for each school within the selected zone of concern (*i.e.*, number of students, percent minorities, and percent below poverty level). As shown in **Figure 5**, through these such visualizations, the cumulative EB has an identifiable potential impact endpoint: Schools. This emphasis aims to materialize the broader EPA policy goal that "no group of [children], should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental and commercial operations or policies."[10] The PHD also aligns itself with the "child-centered" approach to cumulative assessments promoted by the World Health Organization [24].

School demographic characteristics additionally offer a way to provide SD information, which are not available at such level of granularity based on census track rigidity. Schools, again, reflect a "location's" demographic characteristics, especially for elementary-aged children who are often locally situated in very high proximity to their school. They can also show the impact of EB on a sensitive population who is likely exposed to nearby hazards for a relatively long period of time (*i.e.*, 8 hours/day for 8 years). Unlike the aerial unit and the proximity to location approaches, the PHD integrates both EB and SD data at the community level by using schools as a reference point.

5. Findings

Our PHD is a new tool to redesign EJ GIS applications targeted to localized policymaking. It draws from a location proximity approach but expands it in two major ways. First, it overcomes the lack of granularity of SD data at the community level by using school as reference point for community characteristics. This method, in turn, highlights the impact of EJ policies on a particularly sensitive population, namely children. Second, it relies on community inputs to measure the cumulative EB. Thanks to our CBPD, the PHD includes data on asphalt plants and industrial corridors that are missing from state-level dashboards but very relevant for city policymaking. Moreover, the PHD is reproducible among other areas; it was created using the ESRI ArcGIS "Nearby" app template which can be easily employed by other community groups with a minimal level of GIS expertise.

[10]"Environmental Justice".

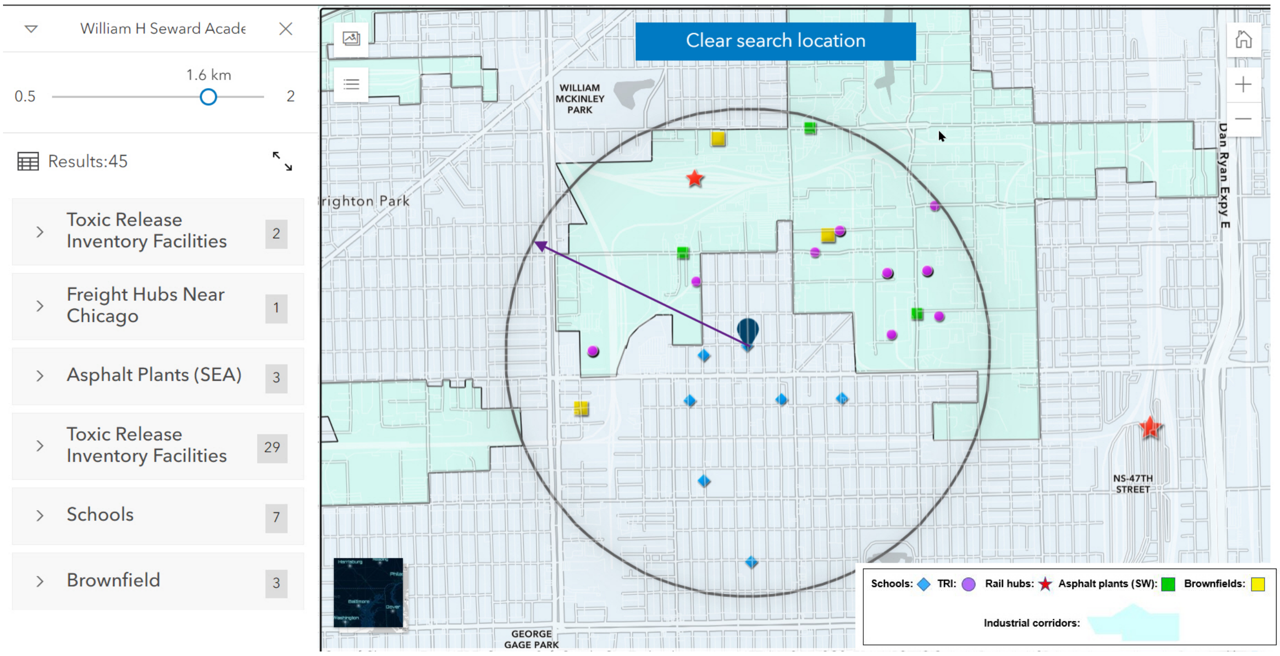

Figure 5. PHD Dashboard Example with 1-mile proximity boundaries of William H Seward Academy.

The policy-value impact of this work is shown below by a quote from our partnering Alderman in the city of Chicago whose neighborhoods are highly underserved in environmental justice policy:

> "The dashboard was most useful in detecting environmental issues early on, establishing real community engagement, and facilitating more interactions with the community."

Utilizing this PHD, we focused on the most sensitive populations in the area (*i.e.*, K-8 students). We note that the Chicago Department of Public Health (CDPH) is taking this community into account for siting a facility in Southeast Chicago where, using PHD, we have identified multiple hazards: "The proposed facility boundary is approximately 1250 feet from the nearest residences and approximately 1600 feet from George Washington High School and Rowan Park." [25] Our approach is to create a list of the overall hazardous sources to assess whether adding one more source is acceptable under the EJ principle of people (in this case children) sharing proportionately environmental consequences. Our dashboard provides such visualizations of these major sources. In Figure 5, we showcase our PHD and design features integrated from community-led requests.

Our PHD shows the new facility would be situated in a 3.14 square mile area that now contains:

1) Eight (8) Chicago public schools with 3359 children.
2) One (1) asphalt plant (Reliable Ogden LLC).
3) One (1) brownfield.
4) Seven (7) TRI facilities (e.g., H KRAMER & CO) that emit 18 toxic chemi-

cals, including the carcinogens trichloroethylene, tetrachloroethylene, methyl isobutyl ketone, nickel, lead, and di(2-ethylhexyl) phthalate.

Geographically, these eight schools are wedged between two industrial corridors (*i.e.*, landscape burden). Three of the schools are less than 1-mile from the I-55 and I-90 expressways. These corridors are a major source of heavy truck traffic, serving the numerous industrial and storage facilities as well as being the operational location of diesel-powered material handling equipment known for their diesel particulate matter and oxides of nitrogen emissions. To assess the impact of adding a new facility in an EJ community, we examined the existing burden on the nearby schools. The John Greenleaf Whittier Elementary School is selected to demonstrate this approach. This School is approximately 1575 feet from the proposed facility—a distance that would take the average person about five minutes to walk—if they could walk in a straight line. **Table 3**'s information is based on the pre-COVID 2016-17 Chicago Public Schools database and provides demographics and distance for the four closest schools. By taking the adjacent schools as the reference point for a preliminary screening assessment, our proximity approach aligns itself with the "child-centered approach to cumulative risk assessment" promoted by the World Health Organization. [26]

Within a 1-mile radius of the Whittier school the following hazmat sources are found:

1) Five (5) TRI reporting facilities emitting 16 toxic chemicals, including the carcinogens trichloroethylene, tetrachloroethylene, methyl isobutyl ketone, nickel, lead, and di(2-ethylhexyl) phthalate.

2) One (1) railyard (Union Pacific Railroad—Global I terminal).

3) One (1) asphalt plant (Reliable Ogden LLC).

4) One (1) brownfield.

5) The landscape burden of being close to the industrial corridors to the north and south.

At 565 feet from Whittier is a TRI reporting site emitting tetrachloroethylene, trichloroethylene, and methyl isobutyl ketone—all known carcinogens. **Because existing permits for these facilities lack cumulative impact measurement, the consequences/degree of environmental burden resulting from proximity to these multiple hazmat sources for the children living and going to school here cannot be fully known.** The other schools in the zone share similar burdens, clearly demonstrating the high disparity in the distribution of potential environmental consequences across the city: many schools in northeast section of Chicago have no such hazmat sources near them. The EJ status of the schools in the Southwest section of the city raises serious issues that cannot be overlooked, which go beyond the emission levels of any existing or planned facility. The City has already recognized the need to implement a cumulative impact framework of assessment to protect these children. This recognition leads directly to a decision pathway already envisioned by City leaders: implementation of a new cumulative impact ordinance for EJ communities:

Table 3. Four K-8 schools closest to the facility.

School	Students	Low Income	Hispanic	Distance (ft)
John Greenleaf Whittier	299	92.1%	99.1%	1575
Peter Cooper Elementary Dual Language Academy	459	88.7%	96.9%	3051
Irma C Ruiz	699	89%	96.3%	3215
Orozco Fine Arts & Sciences	541	89.6%	96.1%	4035

Source: 2016-17 Chicago Public Schools database—School Profile Information SY1617 Distances are derived.

> The City shares the US EPA's commitment to environmental justice and public health, and we look forward to partnering with them to conduct a fair, thorough and timely health impact analysis… At the same time, Mayor Lori Lightfoot directed the City's Chief Sustainability Officer and the Department of Public Health to propose a new cumulative impact ordinance for consideration by the City Council before the end of this year, broadening its authority over air quality considerations, especially in Chicago's more industrialized neighborhoods. [27]

Given the EJ status of the nearby schools in "industrialized neighborhoods," the best approach for siting new facilities is the cumulative impact ordinance that the City of Chicago is planning to implement. The importance of cumulative exposures is not something new. The concept has been well established since the Food Quality Protection Act (FQPA) of 1996, which required the US EPA to make cumulative assessments of the risks posed by exposures to pesticides. This law raised the awareness of such risks and led to the advancement and differentiation of cumulative risk and impact assessment methodologies. The US EPA details this approach and established "A Framework for Assessing Health Risks of Environmental Exposures to Children". Eight states such as California, have been using cumulative impact methodologies to assess the EJ status of communities since the early 2000s. Recently, the New Jersey State passed the EJ law (C.13:1D-159 to 161; September 18, 2020) that requires permit applications to have an environmental justice impact statement for the nearby overburdened communities. At a city level, the City of Newark, NJ made history when the City Council passed a first-in-the-nation Environmental Justice and Cumulative Impacts Ordinance in July 2016. Our PHD helps identify and disaggregate these sites.

Indeed, concurrent use by community members who live in areas that are cumulatively burdened by environmental hazards has shown the impact of the PHD on how communities inform policy. A leading community member in the fight against environmental injustice in Chicago's Southwest side argues: "The dashboards were a bridge from the community to the politicians. They facilitated the communication between us." This is imperative for the utility of data visualizations like the PHD in that, as Charles Lee reminds us above, there is no use for visualizations without community guidance and infusion with politicians making sense with the community. This community member goes on to support the PHD's utility in their own goals to seek EJ in their community: "Every alderman that we sat with, we told them to use the dashboard to create a radius of one mile around their office to see all the polluters and the nearby schools." Here we see an explicit connection that the community wants: How close are these EJ hazards to schools? To their youth? To their elders?

This utility of the PHD was not left upon only identification; rather, the community members took up this visualization to negotiate the historical prevalence of hazard in their community, as well as discuss with their fellow community members and politicians about their overburdened EJ status. This was done explicitly by drawing on the proximity-based design features infused in the PHD. Below is a transcript of a Community Member with us asking "Were you able to perceive any change in the community based on the dashboards?" to tease out the PHD's importance and use:

00:40:47 Community Member

> I'm able to perceive change in the community based on these dashboards by specifying an address and seeing how many polluters are around.

00:41:12 Community Member

> You could talk about pollution, but not in the same way when you can underline it and pinpoint it and say this is what we have in our community.

00:41:22 Community Member

> We can say we have 8 out of the 20 asphalt plants in the city.

00:41:27 Community Member

> We have 6 out of the eight rail yards in the City of Chicago.

This interview response showcases how this specific community member was able to interpret and engage with the platform in ways that they previously stated they could not with IL EPA GIS maps. Namely, this same community member said previously: "The IL EPA's platform was very confusing. Because of this I asked the Alderman and UIC team to help me identify carcinogens in my community after going door-to-door and seeing countless community members with cancer."

We have also identified areas of improvement. While the current PHD selects five hazard sources, additional sources deemed important among local communities can be added. These sources could include the length of identified industrial roads, proximity of selected sites to their closest industrial zone boundary, superfund sites, air-permitted facilities, locations of noise (e.g., airports), and the traffic pollution that comes to and from railyards and their adjoining storage facilities. Other sensitive population indicators may also be added, such as location of day care centers and assisted living facilities. These additions will require a more elaborate data analysis and integration phase, which has not taken place yet for the PHD. In turn, future work is needed to understand the best visualization strategies to display SD and EB data. Currently, data distribution is aggregated to a single value that is displayed on a map in line with the interaction modes allowed by the PHD. We are focusing on comparing the effectiveness of diverse visualizations, from techniques that rely on aggregations to ones that visualize the underlying distribution [28]. These will inform future designs.

6. Conclusions and Implications

Overall, our PHD dashboard's value through integrating SD and EB data at a more localized level has been realized in various ways that shed light on implications of this work. Driven by several community meetings, Chicago Aldermen made requests specifically to our multidisciplinary UIC team to submit a formal report to the US EPA Region V on proposed operational permitting of an industrial facility operating on the city's southwest side – their home and their community. The report's findings substantiated claims from residents for a disproportionate share of EB in comparison to other communities in Chicago. According to the PHD, the proposed facility would increase the EB of a local school that is already exposed to five TRI reporting facilities, one railyard, one asphalt plant, and one brownfield, and near industrial corridors to both the north and the south [29]. Following meetings with federal, state, and city environmental agencies, EPA Region V issued a 114 letter to the facility requesting additional information under the Clean Air Act. These events corroborated the impact of the PHD as an understandable decision support tool that assists community groups to work with their elected officials to visualize the incremental impact that one more facility is likely to create by focusing on the cumulative EB for the community in general, and their elementary schoolchildren more specifically, while also recognizing the need to improve the current state of the over-burdened environmental hazards statuses in their community.

The PHD demonstrates the value that lies in partnering with local communities to drive policy decisions that impact them, as well, which aligns with our argument that EJ is best served through a community-based participatory design model. Additionally, this "two-way" street that is often described in EJ [30] and Partnership [31] literature should not be an afterthought when it comes to the fair treatment and meaningful involvement of those most impacted by structurally racist policy and procedural bureaucracy. Indeed, a recent *Nature* publication models this iterative design and engagement process with communities and supports its use based on the current literature [20]. And where they provide a hypothetical model of this interaction between community-policy partnering that builds public participation, our work presented above provides an empirical, albeit preliminary, sequence of events that draw on the importance to support the emancipatory possibility that comes with supporting local communities to advocate beyond procedural justice toward actual Environmental Justice by systematic design [32]. Beyond very important implications for communities themselves, the PHD is an example of what a more humanizing academic enterprise can do to affect local change while broadening citizen participation in science and policy making. It is not lost on us that while we provided the technical apparatus, it was communities that reshaped the tool itself and their voices that helped to clarify the reality of overburdened communities in Chicago. If anything, this *making present* [33] [34] of the social and political terrain that these Asian, Black, and Latinx communities face in regard to EJ highlights to us that there is more work to do to build on these findings and support this model in scalable ways outside of Chicago. In the end, our narrative to support environmentally-just communities self-determining the future of their locales is a story that is often repeated and never systematically enacted for justice. We argue the approach we presented here is an alternative to this zero-sum approach and helps all stakeholders to import their individual voices and collective experiences into the political process.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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