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Environmental Justice and Health Inequalities

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ABSTRACT

Environmental justice (EJ) emphasizes the equitable distribution of environmental benefits and burdens, ensuring that all communities, regardless of race, ethnicity, or socioeconomic status, can live in a healthy environment. This review examines the complex interplay between environmental hazards and health inequalities, highlighting how low-income, minority, and Indigenous populations disproportionately bear environmental risks such as air and water pollution, hazardous waste exposure, and climate-related stressors. Drawing on historical, global, and local case studies, it explores mechanisms linking environmental exposures to adverse health outcomes, including social determinants of health, regulatory gaps, and community vulnerability. The review also emphasizes methodological approaches for assessing environmental inequities, including spatial mapping, epidemiological analysis, and community-based participatory research. Policy interventions, co-benefits of equitable strategies, and community empowerment emerge as critical levers to reduce disparities and promote health equity. This synthesis underscores the urgent need for inclusive, evidence-informed policies that integrate fairness, procedural justice, and local engagement to mitigate environmental health inequities worldwide.

Keywords: Environmental Justice, Health Inequalities, Social Determinants of Health, Vulnerable Populations, and Policy Interventions.

INTRODUCTION

Environmental justice is broadly defined as the fair treatment of all races, ethnicities, and income groups in the development, implementation, and enforcement of environmental laws and policies. Environmental justice promotes the right of all people to live in a clean and healthy environment, free from environmental pollution and degradation. Environmental justice encompasses policies and laws that address disproportionate exposure to environmental hazards such as toxic chemical releases and hazardous waste treatment, storage, and disposal. Public health researchers increasingly assert that environmental exposures and hazards have a disproportionate impact on the health of low-income and minority populations [1]. Environmental justice addresses the unequal share of adverse health effects resulting from disproportionate distributions of environmental hazards in the race and space of social systems [13]. In turn, adverse health outcomes or risks involved in public health, such as injury or disease, are considered determinants of health equity and inequality. Public health researchers focus on exposures and hazards that can be evaluated against defined metrics and measurable criteria, variations in these exposures, and the social, economic, and political drivers of these inequalities. Based on these foundational insights, it is possible to characterize environmental justice as a contributor to health inequity or inequality in public health, with the former emphasizing socioeconomic status and the latter emphasizing deterministic risk factors [2]. Environmental justice is implicated in public health equity through theories, policies, and regulations. Environmental hazards encompass a broad range of exposure domains, climatic conditions or climate change, environmental pollution or degradation, food or nutrition, environmental science and technology, land use, nature or biodiversity, and water [4]. Environmental policies and regulations lack appropriate social considerations, building an imbalance in public health equity, health dispersion, or aversion [7].

Conceptual Foundations of Environmental Justice

The environmental justice (EJ) framework arose in the United States in 1982 in part in response to the siting of a toxic waste facility in a majority-Black neighborhood in North Carolina and has developed since then along multiple theoretical strands [2]. Definitions of EJ vary considerably, with most encompassing principles of

distributive and procedural justice, recognition, and capabilities [3]. Distributive justice concerns the fair allocation of environmental burdens and benefits; procedural justice encompasses the extent to which all individuals are afforded the opportunity to participate in environmental decision-making; recognition addresses the need for acknowledgement of particular identity-based interests and community histories; and capabilities refers to the focus on enhancing the available choice set of individuals [7]. In seeking a just distribution of environmental exposure and associated health risk, the present work primarily engages with the concepts of distributive justice and procedural justice [3].

Health Inequalities: Definitions and Metrics

Epidemiological research distinguishes between health inequalities, defined as systematic, avoidable, and unjust differences in health across social groups, and health inequities, defined as a particular subset of unequal health differences that are associated with social disadvantage. The terms are often used interchangeably, however, particularly in policy circles, where the designation of an issue as a health inequality often emphasizes the moral case for intervention, whereas the label of health inequality tends to denote a more analytical perspective. The preference for the term health inequality here is also intended to invoke the distinction from health equity—a situation in which health is distributed equally rather than a process by which to achieve and sustain such a state 1.

Health Inequalities: Definitions and Metrics

Health outcome disparities persist across numerous dimensions, including geography, socio-economic status, education, occupation, race/ethnicity, disability, and migration status. In addition to health inequities, the environmental justice literature has increasingly emphasized health distribution patterns [3]. Accordingly, environmental injustice provides a critical lens through which to explore the unequal distribution of health outcomes, the structural factors that shape these distributions, and the policies needed to address them [2]. Disparity refers to a substantive difference in health outcomes among populations. Equity denotes how fairly or justly health outcomes, burdens, and resources are shared among populations [1]. Health outcomes can utilize different metrics, including prevalence, incidence, and length of life, quality of life, and disability-adjusted life years (DALYs) [4]. The health inequality literature most commonly employs gap, rate ratio, and population-at-risk (PAR) gap metrics. Burden estimates, years of life lost (YLL), and accelerated aging jointly quantify severity or demand for care in the context of health distribution [1, 3].

Historical and Global Perspectives on Environmental Injustice

The struggle for environmental justice arises from human history, whose prerequisite is consciousness of social justice. Colonial and neocolonial struggles for justice to the land are fundamentally an environmental struggle when these social justice struggles arise [2]. Historical and geographical variations in the struggle for environmental justice are conditioned by different regimes associated with the forces and means of reproduction, institutionalized practices of power, and groups appropriately struggling for justice to the land [4]. The emergence of petroleum and expansion of consumption in settler states engendered new socioecological regimes that imposed severe environmental injustices on subjugated settler-indigenous groups, obstructing redress to both the land and society [5]. These injustices mobilized widespread collective action amid a struggle for redress, aggravating class struggles between mainstream forms of society and organized society in settler states. Globalization and the neoliberal repudiation of socially constitutive activities exacerbate environmental injustices differently in postcolonial and settler states [8].

Pathways Linking Environment and Health: Mechanisms and Evidence

Environmental health is considered by many public health experts to be critical for epidemiological analyses of disease causation [5]. Eliminate the environmental exposures, and virtually there are all chronic diseases will be prominently in need of epidemiological analyses. Furthermore, several public health experts at the World Health Organisation have referred to some extra notes in their respective disciplines on Hanlon's classic textbook, and the importance of preserving the health of the natural environment is that "environmental health is probably the most important form of public health"[5]. The zero population growth debate in the 1960s attracted the attention of epidemiologists, medical experts, mathematicians, and public policy-makers as a potential global crisis of unprecedented trend and character. In fact, epidemiological knowledge has ultimately lagged behind the enhancements of population wealth, mobility, urbanisation, and industrialisation on average [2].

Exposure Disparities and Vulnerable Populations

Pollution-related health risks are unequally distributed across social groups, with minority and low-income populations sometimes subjected to greater hazards than other communities with similar or lower incomes. Location and land use strongly determine exposure to air and industrial pollution, solid waste and hazardous waste disposal, lead in housing, and other elements of the physical environment that affect health[6]. Although race and ethnicity are associated with health disparities, social class influences access to health care and life chances and mediates some of the effects of race [4]. For example, even controlling for income, people of color face elevated exposures to dangerous chemicals and larger illness burdens linked to the release of these chemicals.

Vulnerable populations include poor, minority, and immigrant children, people with age-related disabilities, the elderly, some occupational groups, and certain rural residents. Rural communities have been found to have poor air quality, water quality, and structural conditions typical of third-world cities and to be disproportionately affected by pollution from agricultural chemicals [4].

Social Determinants of Health and Environmental Risks

Socioeconomic status (SES) strongly influences exposure and susceptibility to environmental risks and is considered a key determinant of health [6]. Innovative approaches addressing social vulnerability, such as the Environmental Justice Index, explore SES in connection with distance to pollution sources, aiming to capture the cumulation of environmental burdens; upward trends in health inequalities during the COVID-19 pandemic further underscore the importance of SES factors [4]. Other conceptual frameworks integrate housing, education, and occupation with environmental burdens/outcomes, recognizing their importance for health and considering potential interaction effects with pollution [2]. Moreover, these socio-economic positions (SEPs) can buffer individual and community responses to environmental hazards.

Policy Environments and Regulatory Gaps

Environmental justice and health inequities remain a pressing concern in BIPOC and socio-economically disadvantaged communities worldwide. Environmental hazards such as air pollution, heavy metals, and microbial contamination have adverse health effects ranging from anxiety to cardiovascular disease [2]. However, policy interventions designed to remediate these burdens have, at times, increased exposure disproportionately among vulnerable populations [3]. The regulatory landscape enacting and enforcing measures on a range of hazardous substances, including pesticides, heavy metals, polychlorinated biphenyls (PCBs), and volatiles, often fails to encompass the multitude of co-occurring toxicants facing certain communities [6]. Contaminated sites for remediation, such as landfills, industrial facilities, air pollution sources, and hazardous-waste sites, have also been sited in, and continue to negatively affect, BIPOC, low-income, and economically deprived communities [3]. Essential environmental and health-promotion policies targeting population groups such as children, the elderly, pregnant women, or persons with disabilities have also not considered the additional burden borne by some of these groups due to disproportionate environmental contamination [9]. Yet beyond environmental hazards, environmental amelioration policies, particularly in urbanized settings, may further compound the health burden of already over-exposed vulnerable populations with widespread and difficult-to-assess chemical interventions such as lead-paint abatement or the use of PCBs as construction materials [4]. New insights suggest that efforts framed primarily in terms of environmental quality or more directly as environmental-justice initiatives may promote "solution-sharing" across considerable socio-economic divides, addressing growing social and economic inequality that is arguably the most pressing health concern globally [6].

Methodologies for Assessing Environmental Justice and Health Outcomes

A variety of methodologies have been proposed to assess environmental (in)justice and associated health outcomes, employing diverse geographies, timeframes, analyses, and meso- and macro-level datasets[2]. Existing frameworks and case studies in both the risk and justification branches of the field provide foundational yet flexible structures for future studies of these interwoven topics [3]. In controlling exposure estimates, modelling assumptions, and construction of health metrics applied to address environmental equity, an especially wide range of choices can be made, many of which depend heavily on specific stakeholder perspectives. Systematic comparison and mechanistic scrutiny of existing assessments, both in urban and rural environments, can highlight conflicting assumptions, view-integrated alternatives, and documentation of the influence of diverse exposure and health-aggravating factors that often shape equity patterns at these scales [3, 2].

Spatial Analysis and Equity Mapping

Environmental health hazards may be spatially characterized to investigate inequity. Geographic information systems (GIS) provide tools to create exposure surfaces that suggest locations affected by such hazards [5]. Thematic maps, called "Hotspot" analyses, visually display concentration or proximity to potential hazards and guide inferences about inequitable distribution [8]. Health and environmental data might jointly characterize inequity in vulnerability to climate change, permitting equity-focused visualization of both problems and potential benefits of mitigation. Though GIS analyses have clear advantages, uncertainty accompanies exposure estimates, and predictive validity towards actual risk remains poorly explored [5].

Epidemiological Approaches to Environmental Exposures

Cohort, case-control, and cross-sectional designs remain three epidemiological study designs relevant to environmental exposures [4]. Cohort studies, including prospective principal studies and retrospective ones, ideally establish temporality and, depending on sample size and relatively short latency periods, may allow for examination of latency effects. Such designs have been extensively applied to air pollution, lead, and many other contaminants. Case-control studies lend themselves particularly to rare outcomes, while with large populations, cross-sectional analysis of wide-ranging diseases can provide a crude indication of environmental health

relationships [1]. Depending on tractable resources and the local epidemiological context, any of these approaches can contribute useful information. For environmental epidemiology, exposure assessment is the defining challenge, owing to variability in both space and time, leading to ambiguity in agent and dose characterization [8]. Exposure metrics such as distance to a pumping station, facility emissions, environmental sensor data, construction activity, satellite imagery, land-use data, and community self-reporting have been applied, accompanied by simulation modeling when needed[7]. Neither individual nor proxy exposure measurements straightforwardly capture real exposure; the inclusion of formal spatiotemporal models can enhance interpretability. Measurement error is a perennial concern for many fields, since systematic misreporting and technical artifacts can generate apparent associations that vary with health outcome or population sub-group; indeed, powerful multivariate classification techniques may even yield apparently justifiable pro-discrimination policies or unethical interventions [8]. Similarly, attention to effect modification through both fixed and random parameters is important, as confounding between exposure-response associations can arise from mutually confounding environmental and social factors [8]. In the absence of actual data, mere observation of a historical phenomenon among plants and animals is not a reliable basis for causal inference. Point estimates of probabilities can be subject to far more extensive apparent redundancy than clear statements of complete or partial sampling distributions [1].

Ethical Frameworks and Community-Based Participatory Research

Environmental justice is framed as an ethical issue that questions the fairness of the distribution of environmental burdens and the procedural mechanisms available for redress. The ethical frameworks that can be applied to this issue include utilitarianism, deontological ethics, virtue ethics, and the ethics of care [4]. The first three of these ethical approaches would justify an environmentally inadequate distribution of health-promoting goods such as clean air, safe drinking water, and the absence of environmental toxins, if at least on average the net health benefits from these same goods met a certain level [9]. The ethics of care, on the other hand, recognizes that the material conditions and capabilities that support human health are not distributed uniformly. It demands a precautionary approach to the environmental health issue. Community members reflect a similar sensitivity to fair distribution issues [6]. Participatory action research (PAR) approaches suitable for environmental justice health studies promote greater engagement around equity issues. When research is undertaken with, rather than on, community members, it acknowledges their expertise, builds trust, and assists with data ownership and interpretation. PAR approaches seek to locate and empower an effective "voice" within the community to communicate salient distributions and transport equity issues. Community members specify how problem criteria should be stated as a research question [5]. These questions are often formulated in terms of transport equity and impacts across social and spatial dimensions, with a focus on vulnerable subpopulations [7]. Community-based participatory research (CBPR) has emerged as a framework to facilitate the involvement of individuals and groups that are often overlooked in the research process, especially those who bear the disproportionate burden of environmental problems [6]. Successful implementation of CBPR involves early connections with a community or group facing an environmental concern, identification of the issue of greatest importance to them, and continued focus on processes and benefits that the community perceives to be valuable. The success of public policies, practices, and interventions focused on the environment, health, and equity can be markedly enhanced by weaving community perspectives into scientific assessments of patterns and linkages [8]. Such a partnership approach emphasizes the key principles of co-defining the problem, co-developing the solution, co-implementing the intervention, and co-evaluating the outcomes across the environmental, health, and equity domains [7]. Accordingly, numerous organizations at different levels are collaborating on participatory health studies to understand environmental burdens and health impacts across diverse contexts.

Environmental Justice in Urban and Rural Contexts

Health inequalities attributable to environmental risk factors arise in various settings across and within countries. Statistical evidence linking specific exposures to specific health outcomes motivates an examination of the spatial patterns of risk and health indicators [6]. Three geographically and thematically diverse case studies illustrate the complexity of these relationships and the diverse frameworks for analysis, policy action, and community engagement [2]. Air pollution, a well-established risk factor for several diseases, is increasingly recognized as a major environmental health inequity [6]. Urban air quality and population health in the United States illustrate how long-standing exposure contrasts and vulnerable groups can highlight environmental injustice opportunities for the most populous cities to take on global sustainability and health [8]. The Health Effects Institute Exposure 3 model, based on the predictor-building approach for the full U.S. data set and the most extensive transport model for Los Angeles, shows that per capita populations, especially in the central parts of the megalopolis, are both exposed to high concentrations and affected by diseases whose incidence is significantly enhanced by these concentrations. These locations are home to predominantly Hispanic and Black populations [12]. At both the city and the county level, pollutants that account for the largest fractions of the total burden include: particulate matter, nitrogen dioxide, ozone, lead, benzene, and carbon, imposing an annual loss of approximately 100 Healthy

Life Years (HLY) or 14,300,000 years of life lost across residents. A robust focus of the Los Angeles and U.S. CDA health agenda on initiatives that would reduce these pollutants is thus warranted. Community members consider process industries such as painting and coating or production of perfume and colognes; while the public sectors still represent the largest number of affected locations, the distances separating sensitive-population facilities from residents are larger, and much fewer of these locations are sited in non-minority Community Areas[1]. The California Environmental Protection Agency continues to monitor Air Quality in the state's air basins to ensure compliance with regulations and maintain improvements in public health [3]. The Healthy Communities Initiative, established in 2000 and jointly funded by the California State and Los Angeles County, supports community-based efforts that empower local residents. The South Coast Air Quality Management District, in partnership with the California Air Resources Board, launched a Supplemental Environment Program to develop an air pollution reduction plan for the South Coast Air Basin. Brownfields community workshops and real-time youth air monitoring seek to address air quality issues [2]. Indigenous communities in Canada face socio-cultural and environmental pressures that violate their land, culture, identity, and health. Historical colonization and neoliberal globalization violate Indigenous Peoples' right to govern, manage, and take control over traditional land and resources, including water [3]. Among other environmental pollutants, the sludge from pulp and paper mills contaminates lakes and cultural resources essential for the livelihood of certain Indigenous communities [2]. Toxic algae blooms render drinking water unsafe for human consumption and limit traditional fishing and gathering practices, resulting in loss of livelihood. Recognizing the relevance of drinking water and community empowerment, some Indigenous First Nations engaged in discussions with federal, provincial, and local governments to seek a collaborative approach for source water protection [4]. Following these efforts, the provinces established a First Nations Safe Drinking Water Initiative. The FNSDWI program is collaborative and aims to develop source-water protection as a priority in First Nations communities [13]. Siting of hazardous waste facilities in the vicinity of socially marginalized communities disproportionately exposes these communities to hazardous waste materials [7]. An analytical framework termed the Environmental Justice Siting Indicators considers siting processes as a multi-step institutional cycle through which wastes enter, during which siting cannot be entirely avoided; after which remediation is often longer than anticipated; and potentially results in the highest burden of hazardous waste. Access to the Institutional Cycle is shown to be uneven [7]. Comparison of the relative degree of social marginality of communities adjacent to permitted hazardous-waste sites in the Birmingham North region of Alabama with other locations regulated by several other State and Federal agencies. Beginning in the early 1970s, and according to the publicly available records of the State Agency, one facility was permitted that received such wastes from outside the Birmingham North community, and a second facility, subsequently dissolved, was permitted within the Birmingham North community [6]. While tactical consideration of regulatory access has enabled some of the remaining locations to be kept free of permitted hazardous-waste facilities, control over the Siting Institution Cycle has been unilaterally transferred from the publicly elected Government to a single non-elected Agency, where in complex multi-agency environments, the Siting Mechanism is left accessible at least one other institutional site[8].

Urban Air Quality and Population Health

Environmental justice and health inequalities remain prominent social concerns throughout the world. Environmental pollutants directly impact human health, with vulnerable populations, especially the poor, children, and people with functional restrictions, experiencing the greatest share of exposure and health burden. Urban air quality constitutes a classic example of the complex interplay, as large cities abound in motorized traffic, energy generation facilities, and industrial sources that increase outdoor pollution [6]. These pollution sources also coexist with social vulnerability, exposing certain subpopulations to substantially more air pollutants. Consequently, exposure information about specific demographic groups reveals which groups are economically and socially disadvantaged and identifies pertinent exposure-reduction measures [5]. The development of exposure estimates for urban indoor air quality, outdoor air quality, and noise shows substantial differences in exposure levels among different groups [7]. The distribution of the exposure of low-income and low-education persons, as well as members of certain racial and ethnic minorities (namely, African Americans, Latinos, and indigenous community members), varies markedly from that of other groups. Numerous health studies clearly show a direct connection among air pollution exposure, economic and social disadvantage, and adverse health effects, including increases in mortality and morbidity due to general disease and specifically due to respiratory and cardiovascular diseases [8]. The public health community has recognized the environmental justice issue since the late 1990s, with the U.S. Department of Health and Human Services producing a series of reports on the subject during the late 1990s to the early 2000s [8]. Present-day efforts focus on environmental–health gaps across community characteristics, including access to safe and clean drinking water, inadequate sewerage facilities, and control of urban land–use types that tend to increase health risks, to address exposure gaps that remain open and have been aggravated by ongoing urbanization and rapid economic expansion [7].

Water Contamination and Indigenous Communities

Indigenous peoples in Canada continue to be the most affected by the prevalence of contaminated drinking water and untreated wastewater. Water is a sacred element among indigenous people [8]. In Sibbold's analysis of water contamination in First Nations communities in Canada, hazardous forms of contamination are identified, such as the presence of heavy metals and coliform bacteria. Development activities targeting Mista-Shipu (Grand River) Indigenous land in Labrador threaten the traditional homelands of the Innu and Innuit and challenge the availability of freshwater in the territory. Culvert installations on highways constructed without consultation have impeded the exercise of the Innu's right to hunt and fish within their territory [9]. Cultural conflicts and differing technical considerations have been noted among the Irish peoples, notably in respect of the clarification of groundwater guidelines on unbound sites by the Irish Environmental Protection Agency. The Mista-Shipu and two outstation sites were selected for study in order to highlight the valuable work being done by Flat Bay Indian Band to restore and protect water [11]. Although environmental justice lacks a universally accepted definition, the approach encompasses distributional, procedural, and recognition principles [2]. Consideration of the link between water, culture, and justice has also emerged in Australian cases involving Indigenous water rights [7]. Contaminated water can affect cultural and spiritual practices and lead to increased psycho-social stress, respiratory, dermatological, gastrointestinal, and reproductive illnesses, and negative birth and early development outcomes among First Nations on or off reserve [9]. Protecting water from pollution is fundamental to environmental justice. In the case of First Nations in Canada, upstream water pollution influences downstream communities such as those in the Flat Bay Indian Band territory in Newfoundland and Labrador, where the Mista-Shipu Indigenous land and the Mista-Shipu and Flat Bay rivers (traditional fishing, trapping, and family gathering sites) are located [4]. Environmental justice encompasses distributional, procedural, and recognition principles, and addressing the Flat Bay Indian Band situation requires attention to these issues. As settler States continue to undermine Indigenous peoples' rights, freshwater contamination constitutes a threat to social, cultural, and economic sustainability [2].

Hazardous Waste Sites and Social Marginality

The siting of hazardous waste facilities is inextricably linked to broader processes of urban decline, structural disadvantage, and community dislocation across metropolitan regions, while also intersecting with issues of environmental quality in particular neighbourhoods [10]. Rigid borders that demarcate the inner city from more affluent suburban areas often obscure the extent to which urban communities located outside of gentrifying areas remain marginalised, both socially and environmentally. Yet, siting processes targeting vulnerable communities do not proceed unchallenged [3]. Collective resistance efforts mobilise to protect these neighbourhoods from hazardous developments, and the demand for an environmental agenda sensitive to the social and cultural dimensions of specific areas emerges. Ultimately, siting decisions are conditioned by a community's social, political, and economic differentiation relative to the broader metropolis [7]. Thus, a site analysis predictive of community impact requires not only an understanding of unique local characteristics but also an appreciation for the particular positioning of an area within the wider metropolitan mosaic [4]. In the siting of hazardous waste facilities, socially precarious communities are still often excluded from local political deliberations. Some siting procedures include politically expressive measures that constitute a fundamental prerequisite for ascertaining which communities possess sufficient agency to participate in regulatory review processes. Departmental responses to such expressive measures have demonstrated a marked unwillingness to consider publicly articulated appeals for environmental justice [10].

Policy Interventions and Public Health Impacts

Environmental injustices arise when individuals or communities who already face socioeconomic or other disadvantages also endure a disproportionate share of harmful environmental risks [3]. Such disadvantaged groups include but are not limited to racial and ethnic minorities, low-income households, elderly people, children, the disabled, and certain Indigenous populations [7]. Disparities in exposure often correspond closely with social vulnerability. Environmental stressors are not evenly distributed across populations, and some groups are often more likely to be located close to or exposed to certain harmful environmental conditions, leading to a less than equal chance for basic socio-economic and environmental sustainability[5]. From an environmental justice perspective, it is critical to address whether the current generation is leaving the natural world in a decent condition for future generations and whether some groups are disproportionately exposed to toxic waste or other environmental burdens and thus bereft even of climate stability and environmental sustainability prospects [10]. Environmental burdens are often unequally distributed across populations [12]. Consequently, attention has recently shifted to indirectly exposed groups, which include those who experience specific vulnerabilities besides direct exposure. As previously illustrated, numerous factors contribute to vulnerabilities, including socio-economic status (SES), race, ethnicity, age, gender, education, geographic location, mobility or migration behavior, health status, occupation, industry, land ownership or tenure, Constitutional water rights, and governance mode [6].

Eco-health indicators are different from welfare or climate sustainability indicators; eco-health determines the change of human health in response to ecological stabilisation rather than the impact of human health-typed material-resource structures or social-mode regulations on environmental sustainability [8]. Regulatory systems can facilitate or impede science-policy effectiveness. For instance, the five non-state environmental governance standards identified earlier are significant in the context of climate stabilisation, eco-recovery regulation, eco-environmental priority-prevention, policy-support structure, and multi-pillar institutional modelling. The shifting focus of environmental burdens poses the challenge of incorporating indirectly exposed populations into policy-making, modelling, decision-making, and assessment processes [4].

Regulatory Reforms and Environmental Justice Metrics

Policies designed to reduce environmental health risks and improve population health will have the greatest impact if they also help reduce the disparities in risk and health across population subgroups [9]. Some groups, particularly minority and low-income communities, already face disproportionately high exposures to a range of environmental hazards and, thus, experience higher rates of associated diseases and health losses [10]. The same groups are often located near hazardous waste sites and other sources of environmental pollution. In formulating new policies within this context, it is important first to identify readily accessible metrics that can be used to quantify the level of environmental injustice in potential regulatory alternatives [7]. Second, to facilitate ongoing monitoring of policies' performance with respect to environmental justice, the availability of a well-defined, health-related metric would provide a practical means of tracking changes in relative risk among population groups. Finally, the identification of additional metrics that can complement existing regulatory analyses would provide policymakers with yet another avenue for evaluating potential actions [11]. The concept of environmental justice links matters of fairness with environmental conditions and, in particular, with the differential distribution of environmental risks among population subgroups defined along demographic lines such as minority status, poverty, or immigrant population [3]. Such groups are often the targets of proposed regulatory interventions, yet the equity implications of government actions taken to reduce environmental health risks rarely receive formal attention [6]. The limited incorporation of equity into regulatory analyses stems partly from the belief that fair and unfair distributions of risk constitute normative or philosophical issues rather than analytical questions amenable to measurement and quantitative exploration [12].

Community Engagement and Empowerment

Community engagement represents a multifaceted strategy rooted in participatory and empowerment principles, encompassing the co-development of interventions, co-evaluation, and the establishment of formal accountability mechanisms [13]. Such engagement disseminates information about health and exposure, raises public awareness concerning potential risks, gathers local knowledge, elevates community concerns, and cultivates acceptance of scientific and engineering solutions [11]. While these efforts are critical elements of effective outreach and education, they must nevertheless be complemented by active community involvement in research design, methodology, implementation, analysis, and reporting [7, 11].

Economic and Health Co-benefits of Equitable Policies

The co-benefits of health and economic gains from addressing climate change using equitable policies exceed the costs by a ratio of at least 3:1 in almost all regions, whereas the economics of climate action that does not address equity show economic and health costs exceeding the benefits in many regions[12]. The cost-benefit trade-offs of equitable approaches compare favorably to the trade-offs of inequitable approaches, thus rendering the equitable approaches highly attractive. CEA and CBA can also reduce inequities when equity considerations are explicitly included in their formulations [11]. Equity-enhancing climate policies can magnify health, economic, and equity benefits compared to climate policies not designed for equity, produce specific equity benefits in disadvantaged communities, and reduce the overall costs of transition to a two-degree future[13]. Extending analytical scopes to include equity when addressing energy and climate also creates new political opportunities by rallying constituents not previously involved in climate issues [12-15].

Future Directions, Gaps, and Research Agendas

The intersection of environmental justice and health inequalities presents critical gaps and research needs essential to advancing knowledge and promoting policy change. Candidate questions include the following: [1]. What accounts for variation in demographic groups' relative exposure to environmental hazards, and what role do environmental risk, economic status, and additional social factors exert upon health? [2]. Do environmental policies that explicitly and accurately consider the distribution of health impacts across different social groups result in greater fairness than those that neglect equity-related dimensions? What frameworks and metrics operationalize equity? [3]. Which elements of the built environment produce optimal health benefits and minimal adverse health consequences for historically marginalized communities? [4]. How do climate change and emissions reduction policies differentially affect health benefits, and what co-benefits arise from fairness-oriented interventions? [5]. How do macroeconomic trajectories shape environmental profiles? What environmental

policies simultaneously bolster economic growth and enhance a just distribution of benefits across affected populations? [6]. Where, how, and in what manner do exposure-distribution disparities arise across socioeconomic and other axes of social differentiation? Areas warranting further exploration encompass specific pathways connecting environmental and health inequities, methodologies for evaluating environmental justice dimensions (e.g., exposure proximity) and related health outcomes, the consequences of governmental institutional configurations for health, the geographical diffusion of health policy initiatives, and the influence of policy reconfigurations on environmental conditions and health profiles [16-19].

CONCLUSION

Environmental justice and health inequalities are deeply intertwined, reflecting both structural and environmental factors that shape population health. Vulnerable populations, including racial and ethnic minorities, low-income communities, Indigenous groups, and children experience disproportionate exposure to environmental hazards, resulting in elevated rates of disease, mortality, and diminished quality of life. Historical, socio-economic, and policy contexts exacerbate these disparities, while traditional regulatory frameworks often fail to account for equity considerations. Evidence from urban, rural, and Indigenous settings highlights the importance of integrating procedural justice, distributive fairness, and community engagement in environmental health policies. Approaches such as participatory research, equity-focused interventions, and spatial analysis tools provide pathways to identify and reduce exposure disparities. Equitable policies not only improve public health outcomes but also generate economic and social co-benefits, reinforcing the moral and practical imperative to prioritize justice in environmental governance. Achieving meaningful progress requires continued interdisciplinary research, inclusive policy-making, and sustained community empowerment to ensure that all populations have the right to a clean, safe, and health-promoting environment.

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