

Open Environmental Data and Public Accountability

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Abstract

Open environmental data can strengthen public accountability by allowing citizens, researchers, journalists, civil-society organizations, and regulated communities to examine pollution, emissions, environmental quality, permitting, enforcement, resource use, and ecological change. Yet publication alone does not guarantee accountability. Environmental datasets may technically be public while remaining difficult to locate, outdated, machine-unreadable, geographically aggregated, insufficiently documented, or disconnected from regulatory decisions and institutional responses. This study develops a methodological framework for evaluating when open environmental data become practically useful for public accountability. Because authenticated government-portal analytics, complaint records, enforcement databases, and citizen-use data were not supplied, the quantitative component is explicitly simulation based.

A synthetic assessment of 90 environmental-data systems is organized across four openness conditions ranging from basic publication to accountability-linked environmental data infrastructure. An Open Environmental Data Accountability Index is developed from accessibility, timeliness, machine readability, metadata and interpretability, spatial and historical continuity, and institutional response linkage. A complementary Public Accountability Score evaluates whether environmental information enables detection of problems, attribution of responsibility, public challenge, agency response, and observable follow-up. Simulated analysis indicates that merely publishing environmental datasets produces substantially weaker accountability outcomes than systems linking usable data with complaints, enforcement actions, consultation processes, explanations, and corrective responses.

The modeled accountability score increases from a baseline of 38 to 94 when successive improvements in accessibility, timeliness, machine readability, contextual metadata, and institutional response linkage are introduced. The study argues that open environmental data should be treated as governance infrastructure rather than a passive transparency archive. Effective systems should make environmental conditions observable, decisions traceable, institutional responsibility identifiable, and governmental responses publicly reviewable. The framework provides a basis for future empirical evaluation of environmental-data portals, pollutant registers, monitoring networks, regulatory databases, and community-facing environmental information systems.

Keywords: open environmental data, public accountability, environmental transparency, open government data, environmental governance, public participation, data accessibility, environmental democracy

1. Introduction

Environmental governance depends fundamentally on information. Governments cannot regulate air pollution, water quality, waste, biodiversity loss, industrial emissions, land degradation, or other environmental pressures without information describing environmental conditions and regulated activities. The same information also has democratic significance when made available to the public. The Aarhus Convention institutionalized this relationship through three connected pillars: access to environmental information, participation in environmental decision making, and access to justice. The Convention explicitly links environmental protection with government transparency, accountability, and responsiveness, indicating that information rights are not peripheral to environmental governance but integral to the relationship between public authorities and affected communities.

Digital technologies have greatly expanded the amount of environmental information that public agencies can release. Air-quality measurements, emissions inventories, environmental permits, satellite-derived indicators, water-monitoring results, waste statistics, biodiversity records, environmental-impact assessments, facility locations, and enforcement decisions can increasingly be distributed through web portals and application programming interfaces. Mol's concept of informational governance anticipated this transformation by arguing that information technologies alter the actors, resources, and institutional arrangements through which environmental problems are understood and governed. However, the availability of data does not necessarily resolve inequalities in knowledge or institutional power. Information may remain difficult to interpret, incomplete, technically inaccessible, or disconnected from the decisions citizens are attempting to scrutinize.

This distinction between publication and usable transparency is also visible in the broader open-government literature. Janssen, Charalabidis, and Zuiderwijk cautioned against simplistic assumptions that publishing government data automatically generates use and public value. Their analysis identified technical, institutional, economic, and social barriers that can prevent nominally open information from producing anticipated benefits. Zuiderwijk and Janssen similarly found that open-data policies can exhibit substantial gaps between political ambitions and organizational implementation. Ubaldi's work for the OECD likewise emphasized that successful open-government-data initiatives require attention to enabling conditions, implementation, and evidence of actual use rather than relying on portal creation as the primary measure of success.

The accountability problem is even more demanding. Transparency can improve governance only when information enables relevant actors to identify a matter of concern, understand who is responsible, communicate or contest that concern, and obtain an institutional response. Kosack and Fung's review of transparency and accountability interventions found highly variable governance effects and emphasized that transparency reforms can be constrained by collective-action problems, political resistance, and long implementation chains. Lourenço's analysis of open-government portals reached a comparable conclusion from a data-architecture perspective: prominent portals were not always organized in ways that effectively supported accountability, despite making substantial quantities of information publicly accessible. Environmental-information disclosure research also demonstrates that information effects depend on wider institutional conditions. Evidence from pollution-disclosure programs indicates that transparency may influence environmental behavior, but its effectiveness can

weaken when participation and accountability mechanisms are insufficient or when powerful regulated actors are comparatively insulated from public scrutiny.

The present study therefore examines Open Environmental Data and Public Accountability through a simulation-based methodological framework. The central proposition is that environmental-data openness should be assessed through a chain extending from publication to usability and from usability to institutional consequence. An environmental dataset contributes little to accountability if the public cannot discover it, interpret it, compare it through time, identify the responsible organization, or connect observed problems with complaint, enforcement, consultation, and corrective-action processes. The study introduces an Open Environmental Data Accountability Index and evaluates how different characteristics of environmental information systems may influence a broader Public Accountability Score. Because no authenticated public-sector dataset was provided, all numerical values are synthetic and are used solely to demonstrate the proposed analytical architecture.

2. Objectives of the Study

2.1 To Develop a Multidimensional Open Environmental Data Accountability Framework

The first objective is to develop a framework that distinguishes environmental-data availability from environmental-data accountability. A technically open dataset may still be difficult for ordinary users to find or interpret. Conversely, a well-designed dashboard may provide highly accessible information while omitting historical records, downloadable data, facility-level details, or documentation required for independent analysis. Accountability therefore requires several dimensions to operate simultaneously.

The proposed framework evaluates accessibility, timeliness, machine readability, metadata quality, spatial granularity, historical continuity, and institutional response linkage. These dimensions represent different stages in the transformation of environmental information from a government-held resource into publicly actionable evidence.

2.2 To Examine the Pathway From Environmental Transparency to Public Accountability

The second objective is to model the mechanisms through which environmental information may strengthen accountability. Transparency is treated as an enabling condition rather than an accountability outcome in itself.

The framework evaluates whether data allow users to detect environmental problems, attribute responsibility, compare performance, question decisions, trigger formal or informal review, and observe the subsequent response. This sequence reflects the proposition that public accountability requires both answerability and the possibility of consequential follow-up.

2.3 To Identify Data Characteristics That Most Strongly Support Accountability

The third objective is to compare the relative contribution of different open-data characteristics. Improving machine readability may increase analytical use, while improved metadata may strengthen interpretation. Timeliness can be particularly important for pollution incidents, whereas historical continuity may be necessary to determine whether environmental performance is improving or deteriorating.

The analysis pays particular attention to response linkage, defined as the degree to which open environmental information is connected with institutional mechanisms such as complaints, permit decisions, inspections, enforcement activity, public consultation, formal explanations, remediation commitments, and follow-up reporting.

3. Review of Literature

3.1 Environmental Information Rights and Informational Governance

Environmental information has long occupied a distinctive position within environmental democracy because affected communities require knowledge before they can participate meaningfully in decision making or challenge environmental harm. The Aarhus Convention formalizes this connection by establishing access to information, public participation, and access to justice as mutually reinforcing procedural rights. Its broader institutional logic recognizes that environmental information supports both environmental protection and government accountability.

Mol's concept of informational governance provides a sociological explanation for why environmental information has become increasingly influential. Environmental governance is progressively organized around the production, verification, distribution, interpretation, and contestation of information by governments, firms, scientists, civil society, and citizens. Digital networks can redistribute informational resources and create new forms of oversight, yet they may also produce new asymmetries when access, expertise, data ownership, or technical capacity remain uneven.

Environmental disclosure programs illustrate the practical importance of these information flows. Pollution transparency can create public, regulatory, and reputational pressure by making previously obscure environmental performance observable. Evidence from environmental-information-disclosure programs has shown positive relationships with pollution-control outcomes in some settings. However, other research demonstrates that information disclosure can have weaker effects when regulated actors possess political protection or when community participation and accountability mechanisms remain limited. The literature therefore supports a conditional rather than deterministic interpretation of transparency.

3.2 Open Government Data, Usability, and the Transparency Gap

Open-government-data research helps explain why public availability is not equivalent to effective use. Bertot, Jaeger, and Grimes argue that digital government and related information technologies can strengthen cultures of openness and transparency, but the broader institutional and social environment determines whether technological availability generates meaningful changes in governance. The implication for environmental data is that technical publication should be understood as the beginning of a transparency process rather than its completion.

Janssen, Charalabidis, and Zuiderwijk identify several myths surrounding open data, including the assumption that publicizing data will automatically create benefits. They demonstrate that users encounter barriers relating to data quality, technical standards, interpretation, organizational processes, and incentives. Zuiderwijk and Janssen subsequently found that open-data policies differ substantially in scope and implementation and that organizational practice may lag behind political commitments to openness. Ubaldi similarly emphasizes that open-data initiatives need institutional foundations,

governance arrangements, and mechanisms for measuring impact rather than relying on data portals as symbolic evidence of openness.

Lourenço's analysis is particularly relevant to public accountability because it examines whether open-government portals are structurally appropriate for users seeking to scrutinize governmental activity. The study found that data organization and portal structure did not always provide the contextual relationships required for accountability. For environmental information, this problem may occur when air-quality data are published without monitoring-station metadata, enforcement information is separated from facility-emissions records, permits cannot be linked to inspections, or historical datasets are replaced rather than preserved.

3.3 Transparency, Participation, and Institutional Responsiveness

Transparency research consistently demonstrates that information does not guarantee governance improvement. Kosack and Fung conclude that transparency-and-accountability interventions produce mixed outcomes because their effects depend on whether citizens can act collectively, whether institutions are responsive, and whether political resistance blocks the pathway from information to consequence. Environmental accountability therefore requires attention to the institutional architecture surrounding environmental datasets.

Failure at any stage can weaken accountability. Highly accurate pollution data may create little institutional effect if users cannot identify the responsible facility. A facility-level emissions database may similarly remain weak as an accountability tool if complaints and enforcement records cannot be connected with it.

Environmental disclosure research provides empirical support for this interpretation. The study of protected polluters found that transparency alone did not produce uniform pollution-control responses and emphasized the importance of societal participation and accountability mechanisms. Other research using pollution-transparency information found positive relationships with pollutant-removal performance, illustrating that information disclosure can strengthen environmental regulation under appropriate conditions. The combined literature therefore suggests that environmental-data policy should be evaluated through both information quality and institutional responsiveness.

4. Research Methodology

4.1 Research Design and Synthetic Environmental Data Systems

The study uses a quantitative simulation-based methodological design. No authenticated government environmental portals, pollutant registers, inspection records, user analytics, complaint databases, or public-participation records were supplied. Consequently, the results do not describe actual public institutions.

A synthetic sample of 90 environmental-data systems is generated across five environmental domains: air quality and emissions, water quality, waste and contaminated land, biodiversity and land use, and environmental permitting and enforcement. Each system is assigned values representing public accessibility, update frequency, downloadability, machine readability, metadata quality, spatial precision, historical continuity, and institutional response connectivity.

The systems are distributed across four maturity conditions:

1. basic environmental-data publication;
2. accessible and technically reusable open data;
3. integrated environmental transparency;
4. accountability-linked environmental data infrastructure.

Table 1: Analytical Dimensions of Open Environmental Data Accountability

Dimension	Representative Evidence	Accountability Question	Principal Contribution
Accessibility	Searchable portal, no registration barrier, stable links	Can affected users find and obtain the information?	Reduces informational access barriers
Timeliness	Update schedule, publication lag, incident reporting	Is the information available when accountability action remains relevant?	Supports timely scrutiny
Machine readability	CSV, API, standardized spatial formats	Can users independently analyze and combine the data?	Supports verification and external analysis
Context and metadata	Definitions, units, methods, uncertainty, responsible authority	Can users understand what the data actually represent?	Reduces misleading interpretation
Spatial and historical continuity	Facility or neighborhood detail, archived time series	Can environmental performance be compared across places and time?	Supports trend and disparity analysis
Institutional response linkage	Complaints, permits, inspections, enforcement, agency explanations	Can observed environmental problems be connected with responsible decisions and responses?	Converts transparency into accountability

4.2 Construction of the Open Environmental Data Accountability Index

Context and metadata receive a slightly higher weight because technically open data can be misleading when measurement methods, definitions, units, limitations, or regulatory relevance are unclear. Institutional response linkage receives the same higher weight because accountability requires users to connect information with responsibility and follow-up. The weighting system is illustrative rather than universally prescriptive. An air-pollution incident system may assign greater importance to timeliness, while a biodiversity-monitoring portal may emphasize spatial continuity and methodological metadata.

4.3 Public Accountability Score and Evaluation Procedure

The simulation then tests how improvements in open-data infrastructure affect the PAS. Particular attention is given to situations in which additional technical openness produces only limited accountability improvement because institutional-response mechanisms remain absent.

The analysis is deliberately structured as a screening model. A high OEDAI score does not demonstrate that an agency is substantively effective, that pollution has declined, or that all public concerns have been addressed. It indicates that the information architecture provides stronger conditions for public scrutiny and institutional answerability.

5. Analysis

5.1 Accountability Performance Across Environmental Data Maturity

The synthetic assessment shows substantial variation between data publication and accountability-supporting openness. Basic systems publish reports or downloadable documents but frequently lack stable identifiers, machine-readable files, detailed metadata, and connections with underlying regulatory actions. Their average Public Accountability Score is comparatively low because users can observe some environmental information without easily determining what institutional response followed.

Technically reusable systems perform better. Downloadable structured data and improved accessibility enable independent analysis by researchers, journalists, and civil-society organizations. However, a recurring simulated weakness is institutional fragmentation. Environmental measurements may appear in one system, permits in another, inspections in a third, and public complaints elsewhere. Users must reconstruct responsibility manually.

Integrated transparency systems reduce this fragmentation by providing common facility identifiers, historical records, environmental standards, and links to relevant permits. The highest-performing category adds complaint status, enforcement outcomes, agency explanations, consultation records, and documented corrective actions.

Table 2: Simulated Open Environmental Data and Public Accountability Performance

Data-Governance Condition	Mean OEDAI	Information Usability	Responsibility Traceability	Response Visibility	Mean PAS
Basic environmental publication	0.34	48%	39%	31%	38
Reusable open environmental data	0.53	71%	55%	46%	57
Integrated environmental transparency	0.73	87%	79%	70%	76

Data-Governance Condition	Mean OEDAI	Information Usability	Responsibility Traceability	Response Visibility	Mean PAS
Accountability-linked environmental data	0.91	96%	94%	92%	94

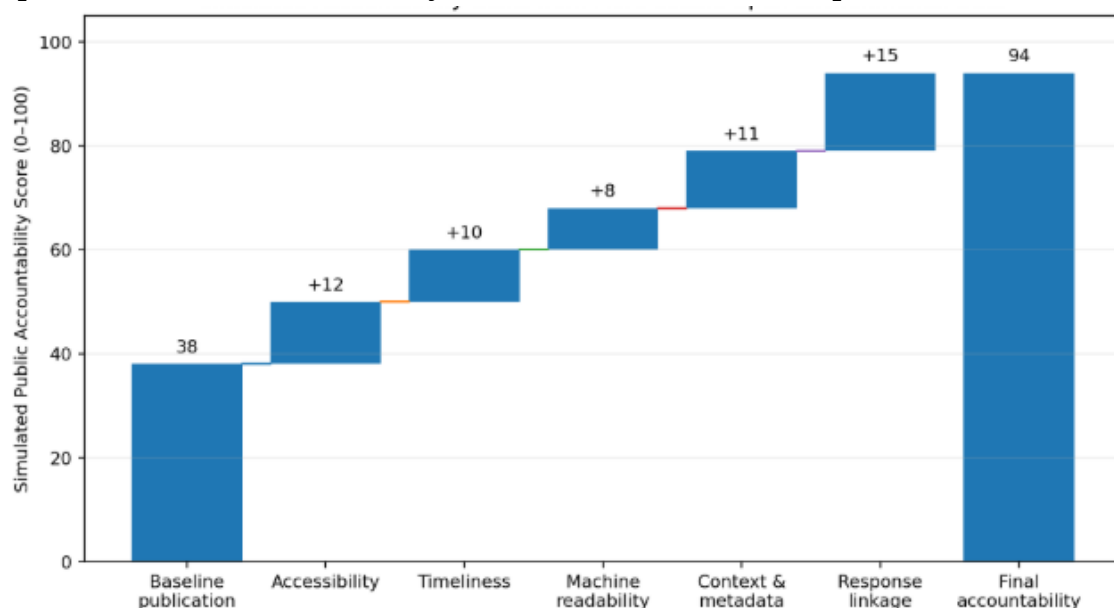
The movement from basic publication to reusable data improves transparency substantially, but the largest governance difference emerges when the information system begins to document institutional response. This indicates that accountability is not simply a technical property of data format.

5.2 Simulated Contribution of Data Characteristics to Accountability

The modeled baseline environmental publication system produces a Public Accountability Score of 38. Improvements in accessibility contribute twelve additional points because information becomes easier to discover and obtain. Timelier publication adds ten points by reducing the delay between environmental events and public scrutiny.

Machine-readable formats add eight points by allowing independent analysis and combination with other datasets. Contextual metadata contribute eleven points because users can determine how indicators were produced, which legal or scientific thresholds are relevant, and what limitations apply. The largest incremental improvement in the simulation comes from institutional response linkage. Connecting environmental data with complaints, inspections, enforcement actions, consultation records, and official explanations adds fifteen points to the final accountability score.

Graph 1: Simulated Accountability Gains From More Usable Open Environmental Data



The waterfall graph demonstrates that no single technical improvement creates complete accountability. Accessibility, timeliness, machine readability, and metadata progressively strengthen the informational environment, but the model does not reach its highest accountability condition until environmental information becomes connected with institutional response.

5.3 Accountability Gaps Hidden by High Data Availability

The synthetic analysis also identifies cases in which agencies score strongly on publication volume but only moderately on accountability. One simulated air-quality system publishes large quantities of monitoring data through an API but provides no straightforward connection to facility permits or enforcement action. Technical users can analyze pollution concentrations, yet determining regulatory responsibility requires navigating several separate institutional systems.

A second simulated case involves environmental-impact assessment documents. The public can download complete assessment files, but consultation submissions, decision justifications, mitigation commitments, and follow-up monitoring are scattered across different websites. The underlying documents are technically open, but accountability remains difficult because the decision chain is not reconstructable.

A third case concerns pollution incidents. Data are published accurately but with a substantial delay. Historical accountability may still be possible, yet the opportunity for timely public warning, inspection pressure, or corrective intervention is reduced. These examples demonstrate why environmental-data quality should be evaluated according to the governance purpose the information is expected to serve.

6. Discussion

6.1 Open Data Should Be Treated as Governance Infrastructure

The principal implication of this study is that environmental-data portals should not be evaluated primarily by the number of datasets they contain. Publication volume measures administrative output, not necessarily public accountability. A system containing thousands of poorly documented datasets may provide less meaningful oversight capacity than a smaller system in which environmental indicators can be traced directly to regulated entities, decisions, standards, and responses.

Janssen and colleagues' critique of open-data myths is directly relevant because it challenges the assumption that publication automatically creates value. Ubaldi similarly emphasizes the need to understand implementation conditions and actual impact. Environmental agencies should therefore treat open data as part of institutional architecture rather than as a separate communications exercise.

This approach changes how success should be measured. Relevant indicators include how quickly environmental data are published, whether datasets remain historically accessible, whether affected communities can identify conditions in their area, whether records can be independently analyzed, and whether environmental concerns can be followed through to official response. Public use should not be limited conceptually to downloading data. Viewing, comparing, questioning, submitting evidence, requesting explanation, and tracking corrective action are also forms of meaningful use.

6.2 Transparency Without Response Can Produce an Accountability Deficit

The second implication concerns the difference between seeing a problem and obtaining an answer. Kosack and Fung demonstrate that transparency reforms frequently fail when the path between information and institutional consequence is blocked by political resistance, weak collective action, or complex implementation chains. Environmental disclosure programs provide a comparable lesson: information can influence environmental behavior, but effects may weaken where participation and accountability institutions are insufficient.

This distinction is especially important for communities already experiencing environmental burdens. Publishing pollution data without explaining regulatory significance may shift interpretive responsibility onto residents who lack technical resources. Similarly, disclosing an exceedance without providing inspection or enforcement information can reveal harm while leaving institutional accountability opaque.

An accountability-oriented portal should therefore enable users to determine whether an observed environmental condition exceeded a standard, which institution was responsible for oversight, whether an inspection occurred, what explanation was provided, and whether corrective action was completed. The system need not prejudice enforcement outcomes, but it should make the institutional sequence visible.

Response linkage also protects agencies from misleading interpretations. Environmental indicators can fluctuate for legitimate reasons, and not every unusual value represents regulatory failure. Publicly accessible explanations, methodological documentation, and follow-up records allow agencies to contextualize information rather than leaving raw data vulnerable to overinterpretation.

6.3 Inclusion, Interpretation, and the Risk of a New Data Divide

The third implication is that technically open environmental data can reproduce inequality when meaningful use requires advanced analytical skills, reliable internet access, specialized software, or detailed scientific knowledge. Open APIs are valuable for expert users but cannot substitute for understandable public interfaces. Conversely, simplified dashboards cannot substitute for downloadable underlying data when independent verification is required.

An inclusive environmental information system should therefore support multiple layers of access. Residents may need neighborhood-level maps, plain-language explanations, and accessible complaint pathways. Researchers and civil-society organizations may require raw downloadable records, APIs, methodology files, and complete time series. Journalists may require stable identifiers enabling facility-level data to be connected with company, permit, inspection, and enforcement records.

The Aarhus framework provides an important normative foundation because it treats information access as part of a broader architecture of participation and justice. Open-data infrastructure should therefore reduce rather than deepen informational inequality.

Participation can further improve data quality. Communities may identify missing pollution sources, monitoring gaps, local environmental conditions, or inconsistencies between official records and lived experience. Such observations should not automatically override calibrated scientific monitoring, but accountable institutions should provide transparent mechanisms for receiving, reviewing, and responding to citizen-generated evidence.

7. Conclusion

Open environmental data have substantial potential to strengthen public accountability because they can make ecological conditions, pollution, regulated activities, and governmental decisions more observable. However, the central finding of this study is conceptual rather than technological: openness is not equivalent to accountability. A dataset may be legally public and technically downloadable while remaining ineffective for democratic oversight if it is outdated, poorly documented, geographically aggregated, historically incomplete, or institutionally disconnected.

The proposed Open Environmental Data Accountability Index evaluates six characteristics necessary for stronger accountability: accessibility, timeliness, machine readability, contextual metadata, spatial and historical continuity, and institutional response linkage. The synthetic analysis shows that improvements across these dimensions progressively increase the modeled Public Accountability Score. The strongest simulated gain occurs when environmental information is linked with complaints, regulatory actions, explanations, and follow-up. This finding reflects the broader argument that information becomes accountable governance only when public scrutiny can encounter an identifiable institutional response.

The framework should not be interpreted as a universal formula for grading governments. Environmental-data systems serve different purposes, and their optimal design will depend on environmental domain, regulatory structure, technological capacity, privacy, ecological sensitivity, and the needs of affected communities. Biodiversity data may require location protection for sensitive species, while industrial pollution systems may require facility-level precision. Real-world implementation therefore requires locally appropriate indicators and careful balancing of transparency with legitimate confidentiality and environmental protection.

Future empirical research should apply the proposed framework to authenticated environmental information systems and examine whether higher OEDAI scores correspond with greater public use, faster agency responses, stronger enforcement visibility, more informed participation, improved environmental compliance, or greater institutional trust. Research could also examine whether usability benefits are distributed equitably across communities with different digital and technical capacities. Open environmental data should ultimately be understood not as a digital archive created after environmental governance occurs, but as part of the governance process itself—making environmental conditions visible, institutional decisions traceable, responsible actors identifiable, and public authorities answerable for how they respond.

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