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Military Contamination and Regimes of Scientific Recognition: A Conceptual Framework

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Abstract

This article develops a conceptual framework for analyzing military contamination as a long-term, distributed, and frequently under-recognized process. The central problem is not the moral classification of individual scientists, but the institutional and cognitive organization of scientific knowledge in contexts where state, military, and industrial action produces environmental harm. The article introduces the concept of a regime of scientific recognition, understood as a historically situated configuration of rules, practices, evidentiary thresholds, institutional dependencies, and forms of responsibility through which a scientific community determines what counts as contamination, which data are relevant, how fragmented evidence is connected, how uncertainty is interpreted, and what practical consequences follow from incomplete knowledge. Three ideal-typical regimes are distinguished: accompanying science, warning science, and critical reconstruction. Accompanying science accepts a military or state objective as already given and produces knowledge that enables, regulates, or normalizes action. Warning science treats incomplete but converging evidence of potential harm as a sufficient basis for precautionary restriction or reconsideration. Critical reconstruction investigates not only the harm itself, but also the historical and institutional conditions that made the harm fragmented, delayed, or difficult to recognize. The article argues that military contamination must be studied not only through environmental science, toxicology, medicine, and geography, but also through the sociology of scientific knowledge, the history of expertise, political ecology, and theories of institutional responsibility. Scientific communities are not passive recipients of external pressure. They actively reproduce regimes of recognition through disciplinary boundaries, professional norms, career incentives, institutional hierarchies, and definitions of legitimate scientific conduct. The framework proposed here contributes to the study of environmental harm by shifting attention from isolated pollutants and effects to the organization of

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knowledge through which long-term contaminating processes become visible or remain institutionally invisible.

Keywords: military contamination; scientific recognition; scientific community; accompanying science; warning science; critical reconstruction; environmental harm; uncertainty; burden of proof; precaution; sociology of knowledge; political ecology; scientific responsibility.

Key Points

1. **Military contamination should be conceptualized not only as material environmental damage, but also as a problem of scientific recognition.** The article argues that military contamination cannot be adequately understood solely in terms of toxic substances, polluted soils, contaminated water, destroyed infrastructure, ecosystem degradation, or long-term health consequences. These material processes are essential, but they do not exhaust the problem. Military contamination may exist physically before it is recognized scientifically, administratively, legally, or politically. The central analytical question is therefore how military contamination becomes visible as an object of scientific knowledge, and why it often remains fragmented, delayed, or insufficiently recognized.
2. **The article introduces the concept of a regime of scientific recognition.** The principal theoretical contribution of the article is the concept of a regime of scientific recognition. This concept refers to a historically situated institutional and cognitive configuration through which scientific communities determine what counts as contamination, which forms of evidence are considered relevant, how dispersed data are connected, how uncertainty is interpreted, where the burden of proof is placed, and what practical consequences follow from incomplete knowledge. The concept makes it possible to analyze not only the production of scientific data, but also the institutional conditions under which such data are transformed, or fail to be transformed, into recognized knowledge of harm.
3. **Three ideal-typical regimes are distinguished: accompanying science, warning science, and critical reconstruction.** The article differentiates between three ideal-typical regimes of scientific recognition. Accompanying science accepts a military, state, or industrial objective as already given and produces knowledge that enables, regulates, or normalizes action. Warning science treats incomplete but converging evidence of possible harm as a sufficient basis for precautionary restriction, disclosure, monitoring, or reconsideration. Critical reconstruction investigates not only the harm itself, but also the historical and institutional conditions that made the harm fragmented, delayed, disputed, or difficult to prove. These regimes are not moral classifications of individual scientists, but analytical categories describing different institutional relations between knowledge, uncertainty, and action.

4. **The central problem is often not the absence of knowledge, but the fragmentation of knowledge.** The article emphasizes that military contamination frequently remains under-recognized despite the existence of substantial partial knowledge. Laboratory measurements, toxicological findings, field observations, medical complaints, ecological anomalies, technical reports, and archival materials may all exist, yet remain disconnected from one another. A pollutant may be studied separately from an ecosystem, an ecosystem separately from public health, public health separately from military decision-making, and military decision-making separately from legal responsibility. In such cases, scientific precision at the level of individual fragments may coexist with a failure to recognize the contaminating process as a whole.
5. **Uncertainty and the burden of proof are central mechanisms in the scientific and institutional recognition of military contamination.** The article argues that uncertainty is not a neutral scientific condition. Its practical meaning depends on the regime of recognition within which it is interpreted. In one regime, insufficient evidence may justify the continuation of military or industrial action until harm is conclusively demonstrated. In another, the same uncertainty may justify precaution, especially where potential harm is persistent, irreversible, cumulative, or difficult to monitor retrospectively. The article therefore insists on distinguishing between different standards of proof: causal attribution, legal responsibility, compensation, policy restriction, and precautionary action cannot require identical evidentiary thresholds. In cases of long-term military contamination, the burden of precaution should fall primarily on those who initiate, authorize, or benefit from potentially harmful action, rather than on exposed populations, future researchers, or later courts.

Introduction

This text has been prepared for a conference devoted to military pollution, soils, and water resources (1). From a certain perspective, it may be regarded as a preliminary working paper. It is addressed to colleagues studying various aspects of military pollution, soil conditions, freshwater systems, and land use (2-6). We would like to avoid reproducing conventional and often unproductive approaches to the study of military pollution. Too much still remains beyond the attention of experts. Scholars often remain silent about many issues or address them inconsistently. In this sense, the text is an attempt to make sense of the subject and to move beyond the implicit expert traps that have taken shape within the scientific community.

This text will be continued. The continuation will clarify the logic of what is defined here as a regime of critical reconstruction. The text is intended for discussion.

Military contamination is commonly approached as a problem of material damage: toxic substances, polluted soils, contaminated water, destroyed infrastructure, damaged ecosystems, and long-term health effects. Such an approach is necessary, but

insufficient. Military contamination is not only a physical, chemical, ecological, or medical process. It is also a problem of recognition. Harm may exist materially before it exists scientifically, administratively, legally, or politically. It may be measured in fragments without being recognized as a coherent process. It may be known in parts while remaining invisible as a total transformation of the environment.

The central question of this article is therefore not simply what military contamination is, but how it becomes scientifically recognizable. Why do scientific communities often produce large quantities of data without transforming these data into an integrated understanding of harm? Why are substances, samples, toxicological effects, medical complaints, damaged territories, destroyed infrastructures, and long-term ecological consequences frequently treated as separate objects rather than as elements of a single contaminating process? Why does scientific uncertainty so often function as a reason for continuing action rather than as a reason for precaution? Why does knowledge sometimes become evidence only after harm has already become irreversible?

These questions require a shift in analytical perspective. The problem cannot be adequately explained by dividing scientists into honest and dishonest individuals. Individual moral responsibility matters, but it does not explain the stability, recurrence, and institutional durability of scientific behavior in situations of military and environmental harm. The more important issue is the standard of scientific work: the institutional conditions, disciplinary habits, evidentiary thresholds, administrative expectations, and professional incentives that shape how scientific communities recognize or fail to recognize a process of contamination.

This article proposes the concept of a regime of scientific recognition as a tool for analyzing this problem. A regime of scientific recognition is not a scientific method and not a theory held by individual researchers. It is a historically situated institutional-cognitive configuration that determines what a scientific community is able to see as an object of knowledge, which forms of evidence it accepts as relevant, how it connects fragmented data, what degree of proof it requires, how it interprets uncertainty, where it places the burden of proof, and what practical action follows from incomplete knowledge.

The article distinguishes three ideal-typical regimes: accompanying science, warning science, and critical reconstruction. These regimes are not separate sciences in a methodological sense. They may use the same laboratories, samples, archives, toxicological models, environmental measurements, statistical procedures, and expert vocabularies. Their difference lies not primarily in method, but in institutional function, temporal horizon, interpretation of uncertainty, and relation to action.

Accompanying science accepts the state, military, or industrial objective as already given and produces knowledge that makes action technically possible, administratively manageable, and normatively defensible. Warning science treats incomplete but converging signs of danger as sufficient grounds for precautionary restriction or reconsideration. Critical reconstruction investigates how harm became fragmented,

delayed, disputed, or difficult to prove, and how the organization of knowledge contributed to this invisibility.

The immediate context for this article is preparation for a conference on military contamination, soils, and water resources. It is addressed to colleagues working on different aspects of war-related environmental harm, including soils, freshwater systems, land use, public health, and the reconstruction of damaged landscapes. Its purpose is not to repeat established expert vocabularies, but to clarify the analytical conditions under which military contamination can be recognized as a long-term process rather than as a set of separate technical problems.

This article is intended as the first step in a broader research programme. A subsequent text will develop in greater detail the logic of what is here defined as the regime of critical reconstruction. The present article therefore does not attempt to contain the whole programme. Its aim is more limited: to formulate a stable conceptual vocabulary for analyzing military contamination as a problem of scientific recognition.

The argument developed here is theoretical and conceptual. It does not provide a completed empirical history of any single case. Rather, it offers a framework for future empirical research into military contamination, scientific responsibility, and the production of non-recognition. Its central claim is that the study of military contamination must include not only the analysis of pollutants, exposure pathways, and health consequences, but also the analysis of the scientific regimes through which such consequences become recognized, denied, fragmented, postponed, or reconstructed.

RESULTS

Military contamination as a long-term process

Military contamination should be understood broadly. It includes direct and indirect environmental consequences of military activity: chemical agents, fuel spills, heavy metals, explosives, combustion products, destroyed industrial facilities, damaged water systems, fires, toxic emissions, unexploded ordnance, contaminated sediments, altered hydrological regimes, soil degradation, damaged agricultural systems, disrupted sanitation, and long-term medical consequences. Military contamination also includes secondary and indirect processes that may not initially appear as contamination in a narrow chemical sense, but are nevertheless produced by military activity.

This broad understanding is necessary because war does not only destroy objects. It transforms environments. A military operation may alter the chemical composition of soils, contaminate water systems, damage industrial infrastructure, create new exposure pathways, displace populations, destroy monitoring systems, interrupt medical care, and make future reconstruction of exposure extremely difficult. The resulting harm is not always visible as a single event. It may appear gradually, unevenly, and through dispersed indicators.

Military contamination is therefore temporally complex. The time of military action is often short: an operation, an attack, a campaign, a tactical decision, or a logistical necessity. The time of environmental consequence is longer: years, decades, and sometimes generations. Soil, water, sediments, food chains, bodies, and infrastructures do not follow the temporal logic of military command. What appears as a temporary operational measure may become a durable environmental condition.

This temporal mismatch is central. Military institutions often operate under urgency, secrecy, hierarchy, and exceptional justification. Environmental systems operate through accumulation, persistence, dispersion, transformation, and delayed effects. Scientific communities are among the few institutions theoretically capable of connecting these temporalities. Yet they are often embedded in the short time of the task: measure a substance, assess a dose, evaluate a local risk, produce a report, provide an expert opinion, or regulate a limited exposure pathway.

For this reason, military contamination should not be treated only as an impact on the environment. That formulation suggests that the environment is an external object upon which human activity acts. A stronger formulation is needed. Military activity produces environments. It creates the future conditions in which human and non-human life will exist. War may end politically, but the environment produced by war continues to exist chemically, biologically, hydrologically, medically, and socially.

The problem of scientific non-recognition

The problem addressed in this article is not the simple absence of knowledge. In many cases, scientific knowledge about harm exists in partial form. There may be experimental data, toxicological findings, field observations, measurements, medical complaints, archival records, technical reports, or ecological anomalies. Yet these fragments may fail to become a recognized process.

This distinction is crucial. A society may possess data without possessing recognition. Recognition requires more than information. It requires the connection of information into an object that demands interpretation, decision, and responsibility. In the case of military contamination, recognition requires the transformation of dispersed indicators into an understanding of a long-term process.

Scientific non-recognition may occur through fragmentation. A pollutant is studied separately from an ecosystem; an ecosystem separately from public health; public health separately from military decision-making; military decision-making separately from legal responsibility; legal responsibility separately from archival secrecy; archival secrecy separately from the future difficulty of proof. Each fragment may be studied rigorously, but the process as a whole remains weakly recognized.

Fragmentation is not inherently illegitimate. Scientific work requires specialization, methods, disciplines, instruments, and controlled objects. No scientific community can study everything at once. However, fragmentation becomes problematic when it prevents recognition of the process that gives meaning to the fragments. In such

situations, scientific rigor in parts may coexist with cognitive failure at the level of the whole.

The phrase ‘there is insufficient evidence’ is especially important in this context. It may be scientifically cautious and methodologically justified. But insufficient evidence for what? Insufficient for final causal proof? Insufficient for legal compensation? Insufficient for policy restriction? Insufficient for continuation of military action? These are not the same questions. A regime of recognition determines which question is being answered.

In cases of long-term military contamination, the absence of complete proof may be interpreted in two opposed ways. It may mean that action may continue until harm is conclusively demonstrated. Or it may mean that action must be restricted because the potential harm is severe, persistent, and difficult to reverse. The difference between these interpretations is not only methodological. It is institutional, political, and ethical.

Regimes of scientific recognition

A regime of scientific recognition can be defined as a historically specific institutional and cognitive configuration through which a scientific community determines whether dispersed data about the environmental consequences of military activity are recognized as a coherent contaminating process and whether such recognition becomes a basis for scientific, administrative, legal, or political action.

This definition contains several analytical components.

First, the subject of recognition is not science in general, but a concrete scientific community situated in a specific historical, political, disciplinary, and institutional environment. Scientific communities differ according to state form, funding structure, degree of autonomy, relation to military institutions, public accountability, disciplinary culture, generational structure, and tolerance of dissent.

Second, the object of recognition is not fixed. In a weak regime, the object may be an isolated substance, dose, sample, territory, disease, military episode, or administrative file. In a stronger regime, the object becomes a long-term process of environmental transformation produced by military activity.

Third, the regime determines admissible data. Laboratory measurements, animal experiments, soil samples, water samples, sediment analysis, epidemiological findings, medical records, field observations, testimonies, satellite imagery, military records, industrial documents, and archival materials may be treated as relevant or irrelevant depending on the regime.

Fourth, the regime determines the logic of aggregation. Are fragments treated separately, or are they interpreted as signs of a larger process? Does the system require independent proof of each fragment, or does it recognize the significance of converging indicators?

Fifth, the regime establishes the threshold of proof. It determines how much evidence is required before harm is recognized and before action must change.

Sixth, the regime interprets uncertainty. Uncertainty may justify continuation, precaution, or retrospective investigation into why knowledge remained incomplete.

Seventh, the regime distributes the burden of proof. The burden may be placed on victims, future researchers, courts, the state, the military, producers, or those who initiate the action.

Eighth, the regime connects knowledge to action. Scientific knowledge may accompany action, warn against it, or reconstruct its hidden consequences after the fact.

The concept of regime therefore makes it possible to analyze not only what scientific communities know, but also how they organize the relation between knowledge, uncertainty, and action.

Three ideal-typical regimes

The proposed typology distinguishes three ideal-typical regimes of scientific recognition: accompanying science, warning science, and critical reconstruction. These regimes should not be understood as chronological stages. There is no necessary sequence in which accompanying science is followed by warning science and then by critical reconstruction. In some cases, warning science may emerge early. In others, it may remain marginal or be institutionally suppressed. Critical reconstruction may appear only after political transformation, archival access, litigation, ecological disaster, or generational change.

The regimes may overlap. The same document may originally function as accompanying science, later be read as warning evidence, and later still become material for critical reconstruction. The same scientist may move from one regime to another, or remain within one regime throughout a career. The typology is therefore analytical, not moralistic. It is not a classification of good and bad individuals. It is a classification of institutional-cognitive relations between knowledge, uncertainty, and action.

The three regimes may be compared as follows:

Parameter	Accompanying science	Warning science	Critical reconstruction
Main question	How can action be technically managed?	Are there sufficient warning signs to restrict or stop action?	Why was the process not recognized earlier?
Relation to objective	The military or state objective is accepted as given.	The objective may be questioned under conditions of serious risk.	The history of the objective and its consequences is analyzed.

Object	Fragment: substance, dose, sample, local effect, norm.	Configuration of warning signs.	Long-term process and the organization of knowledge about it.
Uncertainty	Reason to continue until harm is conclusively proven.	Reason for precaution when harm may be serious or irreversible.	Object of investigation: why was knowledge incomplete?
Burden of proof	Often shifted to victims, future science, or later courts.	Shifted toward those who initiate action.	Placed on the system that acted without adequate knowledge or monitoring.
Practical output	Continuation, regulation, technical optimization.	Restriction, monitoring, disclosure, suspension, revision.	Reconstruction, accountability, institutional learning, prevention.

Accompanying science

Accompanying science is the regime in which scientific knowledge accepts an external objective as already established. The objective may be military, industrial, state-administrative, or technological. Science is then asked not whether the objective should be pursued, but how it can be pursued more effectively, safely, measurably, or defensibly.

This regime does not necessarily involve fraud, corruption, or intentional harm. Accompanying science may be methodologically careful and technically competent. Its limitation lies in the structure of the question. It asks how to measure, regulate, optimize, reduce local risk, or provide expert assessment within a framework that has already defined the action as permissible.

Accompanying science is indispensable to modern state action. It produces measurements, classifications, tables, thresholds, protocols, expert reports, regulatory categories, and technical language. It allows dangerous activities to be administered rationally rather than conducted blindly. Yet this rationalization has an ambivalent function. It may reduce harm, but it may also normalize the continuation of harmful action.

The central mechanism of accompanying science is the conversion of methodological caution into administrative permission. A scientific statement such as ‘causality has not been conclusively established’ may be methodologically correct. However, when embedded in an administrative system oriented toward continuation, it may be interpreted as ‘there is no sufficient reason to stop’. A statement that ‘further research is required’ may become a practical delay. A statement that ‘available data are incomplete’ may become a justification for maintaining the current course of action.

This does not require assuming direct bad faith. The problem lies in the institutional coupling between scientific caution and administrative action. When the default position is continuation, uncertainty works in favor of those who act. In long-term

contamination, this is especially dangerous because conclusive proof may appear only after the damage has occurred.

Accompanying science also offers professional comfort. It allows scientists to remain within narrow competence: a sample, a model, a substance, a report, a method, a laboratory, a discipline. Responsibility is localized. The scientist may claim responsibility for the correctness of a fragment, but not for the total environment produced by the larger system of action. In this way, fragmentation becomes not only a cognitive form, but also a form of institutional irresponsibility.

Warning science

Warning science differs from accompanying science not primarily in method, but in the meaning it assigns to incomplete knowledge. It may use the same data, samples, toxicological findings, environmental measurements, and statistical tools. However, it interprets converging signs of danger as a possible basis for action before complete certainty is available.

In warning science, uncertainty does not automatically justify continuation. If the potential harm is large, persistent, irreversible, transboundary, intergenerational, or difficult to monitor after the fact, then incomplete knowledge may justify restriction, suspension, disclosure, monitoring, or reconsideration. The question shifts from 'has harm been conclusively proven?' to 'are there sufficient reasons to believe that continuing may produce serious and poorly reversible harm?'

This regime is closely related to precaution, but it should not be reduced to a simple normative slogan. Warning science does not reject evidence. It changes the practical threshold at which evidence becomes relevant for action. The greater the potential irreversibility of harm, the lower the legitimacy of continuing under uncertainty.

The central conflict between accompanying science and warning science is therefore not a conflict between rationality and emotion. It is a conflict between two rationalities of incomplete knowledge. One treats uncertainty as a reason not to stop. The other treats uncertainty, under conditions of possible severe harm, as a reason not to continue.

Warning science requires institutional conditions that allow scientific concern to become visible. These include professional autonomy, channels of public communication, competing expert communities, protection for dissent, and a culture in which responsibility extends beyond narrow technical correctness. In authoritarian or highly militarized contexts, warning science may be marginalized before it becomes public. In more open systems, it may coexist and conflict with accompanying science.

Critical reconstruction

Critical reconstruction is the regime in which the object of inquiry becomes both the harm itself and the history of its non-recognition. It asks why a real contaminating process was broken into isolated fragments, why data were not collected or connected,

why monitoring was inadequate, why causal chains later became difficult to prove, and how institutional ignorance was produced.

This regime is especially important in cases where harm is recognized late. After years or decades, it may be argued that exposure cannot be reconstructed, causal relations are uncertain, groups are heterogeneous, medical data are incomplete, environmental baselines are missing, and the original conditions cannot be known. These claims may be technically true. But critical reconstruction asks why this is so. Who acted without adequate monitoring? Who controlled the data? Who defined the relevant indicators? Who decided that warning signs were insufficient? Who benefited from the later impossibility of proof?

The key point is that lack of knowledge is not always innocent. It may be produced by the system that initiated or permitted the action. If a state, military institution, or industrial actor undertakes an activity capable of producing long-term harm without establishing adequate monitoring, the resulting uncertainty cannot be treated as neutral. It is part of the institutional history of the harm.

Critical reconstruction therefore has a dual object: the environmental process and the scientific-administrative order that failed to recognize it. It does not merely expose wrongdoing. It reconstructs the conditions under which harm became knowable in fragments but not actionable as a whole.

Scientific communities and institutional responsibility

The concept of regimes of recognition requires a non-naive understanding of scientific communities. A scientific community is not a universal, passive, and homogeneous body of experts. It is historically formed, institutionally organized, culturally situated, and internally stratified. It has hierarchies, career mechanisms, funding dependencies, disciplinary boundaries, symbolic authorities, and norms of legitimate speech.

Scientific communities may be pressured by states, military institutions, or industries. But they may also actively reproduce the very regimes that limit recognition. They may defend narrow expertise, reward technical service, marginalize interdisciplinary criticism, suppress uncomfortable questions, and classify broader responsibility as political rather than scientific. They may treat reflexive inquiry into their own role as external to real science.

This point is essential. The regime of recognition is not imposed only from outside. It is reproduced through the scientific community itself: through what questions are considered legitimate, what evidence is considered sufficient, what forms of responsibility are considered professional, and what kinds of intervention are considered inappropriate.

Different political systems create different possibilities for regime conflict. In liberal-democratic contexts, accompanying science, warning science, and critical reconstruction may coexist within the same state and even within the same field. This does not guarantee that warning science will prevail, but it creates conditions for

contestation. In authoritarian or totalitarian contexts, public warning may be treated as disloyalty, and critical reconstruction may be postponed until political change or archival opening. In post-authoritarian contexts, accompanying science may survive the state that formed it and adapt to new political conditions.

The scientific community must therefore be studied not only as a producer of knowledge, but also as a producer of non-recognition.

Fragmentation and the burden of proof

Fragmentation becomes especially consequential when combined with the distribution of the burden of proof. If each fragment must be proven separately, and if the burden of proof is placed on victims, exposed populations, future researchers, or later courts, then the system structurally favors continuation. Harm becomes recognized only after it has accumulated sufficiently to overcome institutional skepticism.

In long-term contamination, this creates a profound asymmetry. Those who initiate action often control the timing, data, monitoring, classification, and access to information. Those who suffer consequences may encounter the process only later, when exposure is difficult to reconstruct. If baseline data were not collected, if samples were not preserved, if medical monitoring was inadequate, and if archives remain inaccessible, then uncertainty becomes a retrospective protection for the initiators of action.

A scientifically responsible regime cannot treat this uncertainty as neutral. The burden of proof should not automatically fall on those who experience delayed consequences. Where action is capable of producing long-term, poorly reversible harm, the burden of precaution should fall on those who initiate or authorize the action.

This does not mean abandoning standards of proof. It means distinguishing between different contexts of proof. The standard required for final causal attribution, criminal responsibility, compensation, policy restriction, and precautionary action cannot be identical. A regime of recognition becomes dangerous when it silently applies the most demanding standard of proof to the earliest moment of preventive action.

Toward a catalogue of precedents

The proposed framework requires empirical development through a catalogue of precedents. Such a catalogue should not merely list cases of military pollution. It should reconstruct the relation between action, knowledge, uncertainty, decision, and responsibility.

Each precedent should be analyzed through a consistent set of questions:

1. What military or state action was undertaken?

2. What objective justified the action?

3. What environment was produced by the action?

4. Which substances, infrastructures, ecosystems, populations, and exposure pathways were involved?

5. What data existed before, during, and after the action?

6. Who collected the data?

7. Who controlled access to the data?

8. Which data were treated as relevant or irrelevant?

9. Were warning signs present?

10. How were warning signs interpreted?

11. How was knowledge fragmented by discipline, agency, territory, type of harm, or legal category?

12. Who bore the burden of proof?

13. Was monitoring adequate?

14. Were samples preserved?

15. When did critical reconstruction become possible?

16. What institutional practices made harm difficult to recognize?

17. What would a different regime of recognition have required?

Such a catalogue would make it possible to compare cases not only by pollutant or territory, but by regime of recognition. The key comparative question would be: under what institutional and cognitive conditions does scientific knowledge prevent harm, and under what conditions does it merely accompany harm until it becomes irreversible?

Discussion: scientific rigor and delayed harm

The framework proposed here does not reject scientific rigor. On the contrary, it requires it. The problem is not that science is too rigorous, but that the practical meaning of rigor changes depending on the type of danger. In cases of immediate, local, reversible, and easily measurable harm, strict causal proof may be achievable before major damage occurs. In cases of long-term, distributed, mixed, and delayed harm, waiting for conclusive proof may mean waiting until prevention is no longer possible.

Scientific rationality is powerful because it separates variables, controls conditions, tests hypotheses, requires evidence, and avoids premature conclusions. Yet these same virtues may become limitations when the object is a long-term environmental process. Real contamination often involves interaction rather than isolation, accumulation rather than single events, delayed effects rather than immediate symptoms, and probabilistic patterns rather than simple causal chains.

The challenge is therefore to develop a form of scientific responsibility appropriate to slow and distributed harm. Such responsibility requires the ability to recognize configurations of evidence, not only isolated proof. It requires attention to temporal scale, not only immediate effect. It requires reflection on the organization of knowledge, not only the accuracy of individual measurements.

In this sense, military contamination is not only an environmental problem. It is a test of scientific regimes. It reveals whether a scientific community can connect fragments, interpret uncertainty responsibly, resist the automatic priority of state action, and recognize the future environment being produced by present decisions.

Conclusions

1. Military contamination often remains insufficiently recognized not because knowledge is entirely absent, but because knowledge is organized in fragmented, disciplinary, administrative, and temporally limited ways. Scientific communities may produce data without producing recognition. They may describe substances, samples, and effects without identifying the long-term process that connects them.

2. The concept of a regime of scientific recognition makes it possible to analyze this problem systematically. It directs attention to the conditions under which dispersed data become a recognized process, and to the institutional mechanisms through which uncertainty is interpreted as permission, warning, or evidence of prior failure.

3. Three regimes have been distinguished. Accompanying science accepts the objective of action and provides the knowledge needed to implement, regulate, or normalize it. Warning science treats incomplete but converging evidence as a basis for precaution. Critical reconstruction investigates how harm became fragmented, delayed, or difficult to prove.

4. The main danger arises when the regime of permission becomes normal. If action continues until harm is conclusively proven, then in cases of long-term contamination proof may arrive only after environmental damage has already occurred. In such cases, science may be able to describe harm, but not prevent it.

5. The task is therefore not to weaken science, but to strengthen its responsibility. Scientific rigor should not mean paralysis before serious warning signs. Methodological caution should not become administrative permission for dangerous action. Incomplete knowledge should not automatically work in favor of those who initiate military or industrial interventions.

6. Where action is capable of producing long-lasting, poorly reversible, biologically dangerous environments, incomplete knowledge should trigger precaution, monitoring, disclosure, preservation of samples, revision of objectives, and, where necessary, critical reconstruction. Otherwise, scientific communities risk becoming technically competent participants in the production of environments whose consequences they will recognize only after recognition has come too late.

Conflict of Interest

The authors declare no conflict of interest.

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