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LEVERAGING ENVIRONMENTAL FORENSIC EXPERTISE FOR EFFICIENT POLLUTION LIABILITY ALLOCATION

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1. INTRODUCTION

The pollution of a site necessitates investigations to identify the polluters responsible and a fair liability allocation process that makes the polluters pay for the damage they have caused to the environment. The role of an environmental forensic expert in the investigative phase – determining the source of pollution and assigning responsibility – is well established. However, the possibility of involving them in the liability allocation process that relies on investigation findings remains largely unexplored. This situation perhaps stems from the perceived risks involved in such a practice, where the investigating agency itself handles liability allocation. One major concern is the potential for a conflict of interest. If the forensic expert(s) have a stake in the outcome, they may be tempted to protect their reputation or shield certain individuals from blame, leading to biased conclusions. These situations can also result in a lack of objectivity, where investigators unconsciously or deliberately favor specific parties due to prior relationships or other influences. Moreover, public trust in the investigation process may erode if the experts are seen as biased or self-serving. A lack of external oversight can also lead to cover-ups, where the investigators downplay their own mistakes or those of related entities to avoid accountability. Such practices can create legal challenges, as affected parties may dispute the findings in court, leading to prolonged legal battles and potential invalidation of the investigation's conclusions. In addition to acceptability and integrity issues, the experts may lack the necessary expertise – mainly the legal – to fairly allocate liability, leading to errors and inefficiencies in the process.

In spite of these risks, there are many advantages that prompt one to explore how the expertise of a forensic scientist can be used for liability allocation. One of the main advantages of allowing the experts to allocate liability is efficiency and speed. Since the investigator already possesses relevant evidence and knowledge of the case, it can make quicker decisions without the delays that often arise when transferring responsibility to another entity. The specialized expertise in investigations ensures a more accurate and informed approach to liability allocation. This method is also cost-effective, as it reduces the need for external consultants or legal bodies, saving both time and resources.

Furthermore, consistency in findings is another significant benefit. When the same experts investigate and assign liability, there is a streamlined approach, minimizing discrepancies or conflicting conclusions that might arise from involving multiple entities. The experts' comprehensive understanding of the case reduces the chances of misinterpretation, ensuring a more contextually informed decision. In addition, keeping the process within one agency eliminates bureaucratic delays that could arise from transferring liability allocation to a different organization. Lastly, direct accountability can serve as a positive factor—when an agency is responsible for both investigation and liability allocation, it may be more committed to ensuring a thorough and fair process. However, leveraging these advantages effectively poses a challenge, as it must be done without compromising the integrity of the liability allocation process. Here, we suggest ways to get the task accomplished.

2. LIABILITY ALLOCATION AS A TWO-STAGE PROCESS TO MAKE USE OF FORENSIC EXPERTISE

Along with the integrity issues, a major challenge in forensic experts undertaking liability allocation is their possible lack of legal expertise required in the process. Yet another key issue is the inability to ensure consistency in the allocation process due to a lack of standard procedures. Priya et al. (2023[a]) had considered these issues and came up with a two-stage liability allocation process to address them.

Priya et al. (2020), after analyzing various court cases, research literature, and statutory documents on pollution liability allocation, identified a set of factors relevant to determining liability. These factors are pollutant characteristics, its volume, toxicity, environmental impact, the migratory potential of pollutants, the extent of approved deviations from standards, each party's level of culpability, the degree to which a party benefited from disposal, financial capa-

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bility, period of occupancy, scale of operations, economic benefits, cooperation with remediation agencies, knowledge of contamination, strength of evidence, agreements between parties, mindset, and economic status. After identifying these factors, they categorized them as technical and non-technical. This classification aimed to facilitate a two-stage liability allocation process: the first stage of technical liability allocation, followed by the final stage of legal liability allocation, which incorporated additional non-technical factors relevant to the case (Figure 1).

To ensure an objective distinction between technical liability and legal liability, they provided formal definitions for these. Technical liability was defined as 'the liability that is proportional to the quantified share of each party in those attributes of pollution/pollutant(s) which can be measured using scientific techniques'. Legal liability, on the other hand, was defined as 'the liability of each party for pollution as decided by an authority authorized to carry out such responsibility allocation in the obeisance of any rules and regulations relevant to the case and applicable to the jurisdiction where the decision is made'. Technical liability is determined solely based on technical factors.

To make the distinction between technical liability and legal liability clear, consider a case where forensic investigations reveal that parties A and B contributed to contamination at a site with pollutant P. Technical liability allocation would involve distributing remediation liability in proportion to each party's quantified share of P. This task is best performed by a forensic expert, who possesses the technical expertise needed for accurate assessment. However, if a contract exists between A and B – one that A claims absolves it of liability but is disputed by B – technical liability allocation alone would not be sufficient to finalize the process. In such cases, a judicial body or other authorized entity must evaluate the validity and applicability of the agreement. Nevertheless, the forensic expert's technical liability assessment would serve as the foundation for the final allocation.

The technical factors suggested to be used for allocating the clean-up liability are:

1. **Spread of chemicals in the environmental medium**: The chemicals get dispersed in the environmental medium once it is released. The more the spread of chemicals in the medium, the more will be the difficulty in remediating the site. Mobility of chemicals were used as a determinant for liability allocation by U.S courts (Graves et al. 2000). Duration of discharge and the time of release also affects the spread of contaminants in the medium. Direct quantification of the spread of contaminants can be done by calculating the volume of the contaminated medium. Indirect methods of quantification include using different coefficients like octanol-water partition coefficient (K_{ow}), the soil absorption coefficient (K_{oc}), etc.
2. **Quantity of pollutants**: Quantity of chemicals was used as a principal criteria for liability allocation by many countries of the world. Other things being similar, remediation cost is generally proportional to the quantity of pollutants. In cases where the volume of contaminated medium is the same, the cost for clean-up would differ based on the quantity of chemicals. Different environmental forensic techniques, like chemical fingerprinting, transport modeling, etc., can be used for determining the quantity of pollutants.
3. **Remediability of chemicals**: The term refers to the ease with which a contaminant can be separated from an environmental medium as a part of remediation efforts. The remediability of chemicals decides the remediation expenses. Remediability of chemicals depends on the properties of chemicals as well as the contaminated medium. Remediability of chemicals also decides the remediation technology that can be adopted at a site for clean-up. The chemicals released combine with the environmental medium to form a matrix. The stronger the matrix, the more difficult the remediation.
   Priya et al. (2023[b]) suggested using 'Remediability Score (RS)' for quantifying remediability. RS is determined on a scale of 0-100. The lower the RS, the greater will be the remediability of the site. The factors determining RS were decided based on the factors that the United States Environmental Protection Agency (USEPA) uses for soil screening and groundwater remediation technologies (FRTR 2025). These factors are:

   - Complexity of technology: The complexity of the technology influences the selection of remediation technology. When many technologies are available for a site, the one with lesser complexity is always preferred.
   - Resource requirement of the technology: When two technologies are found suitable for a site, the one that requires fewer resources and efforts will be selected for remediation.
   - Stage of development in the technology: Remediation technologies with above-average developmental status are always preferred for remediation.
   - Confidence in the technology: When multiple remediation technologies are available for a site, the technologies that are most reliable are considered for the remediation of the site.
   - Efficiency of the technology in terms of contaminant reduction in the environmental matrix: The technology that reduces the contamination level to

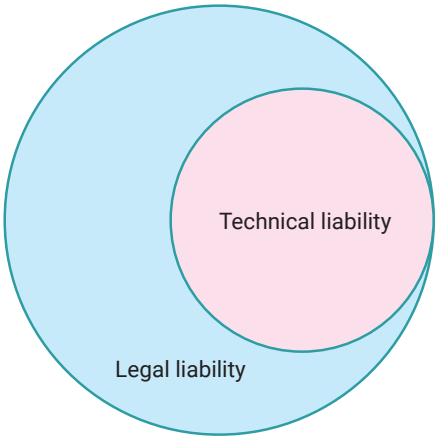

FIGURE 1: Technical vs. legal liability of pollution.

meet the regulatory objectives is always preferred over other technologies.
- Efficiency of the technology in terms of long-term effectiveness: The long-term effectiveness of the technology is considered while selecting the most suitable technology.
- Disturbance caused to the soil: The technology which causes the least disturbance to soil is selected as the most suitable technology, mainly in cases when the site is undergoing any development.
- Time requirement: The technology which requires less time is always preferred over other technologies. Contaminated sites need to be remediated quickly to avoid further spreading of contaminants.

4. **Persistence of chemicals**: The duration for which a chemical remains in the medium is given by persistence. Persistence of chemicals is expressed in terms of the half-life of chemicals. The higher the persistence of the chemicals, the higher will be the costs associated with clean-up. The half-lives of chemicals are available in different databases like National Pesticide Information Centre, European Chemicals Agency (ECHA), etc.

Since technical factors are independent of the specific case, standardized guidelines for technical liability allocation can be developed. Existing guidelines, such as those provided by INTERPOL, focus on investigative procedures and the enforcement aspects of environmental crimes (INTERPOL, 2014). However, they do not offer guidance on determining liability, as legal liability falls under the jurisdiction of individual countries' legal systems. Separating technical liability from legal liability would allow organizations like INTERPOL to establish guidelines specifically for technical liability allocation.

Priya et al. (2023[a]) have proposed an objective procedure for technical liability allocation based on the factors presented above and demonstrated its application with an example. Even if the suggested factors require refinement, their proposal provides a foundational model for technical liability allocation guidelines and presents a viable approach to integrating forensic expertise into pollution liability allocation.

3. ENSURING INTEGRITY OF THE ALLOCATION PROCESS

Ensuring integrity in pollution liability allocation is as crucial as in any other liability allocation process. A reliable and transparent system prevents wrongful attribution of liability and ensures that responsibility is assigned accurately and equitably. It also aligns with legal and regulatory requirements, reducing the risk of disputes, appeals, or reversals. Maintaining integrity enhances credibility and trust among stakeholders, including the involved parties and the general public. Additionally, it minimizes the risk of bias, manipulation, or undue influence from personal, corporate, or political interests. Proper liability allocation ensures that remediation costs are fairly distributed, promoting responsible environmental practices and preventing long-term economic and ecological harm.

To ensure fairness in the allocation process, liability allocation (the technical liability part) by investigating forensic expert(s) should be permitted only when the investigation is done by independent forensic experts. These experts must operate without any obligation to the parties involved in the case, ensuring impartiality in their assessments. However, to maintain the integrity of the process, the cost of such investigations should be covered by a public fund. This fund can later be recuperated through contributions from the guilty parties, with a portion of the damages collected being allocated to replenish the fund. This approach guarantees that financial constraints do not hinder an impartial investigation, and liability is assigned based on scientific evidence rather than the financial capacity of the parties involved. For example, in the United States, the EPA's National Enforcement Investigations Center (NEIC) conducts federally funded environmental forensic analyses to support enforcement actions. When violations are identified, the EPA may seek to recover the costs of these investigations from the responsible parties, including companies found to be non-compliant with environmental laws. Involving such independent agencies in liability allocation improves efficiency while preserving the integrity of the process.

In cases where forensic experts are hired by the disputing parties, they should not be involved in liability allocation. Instead, another independent authority – similar to the National Green Tribunal (NGT) of India, which comprises both forensic and legal experts – should be responsible for allocating liability. The advantage of this approach is that the cost of the investigation is borne by the involved parties rather than relying on public funds, even if for a limited period. However, this method presents the risk that affluent parties may engage highly paid experts to manipulate the technical evidence and escape accountability. To counter this, it is essential to have a competent panel of forensic experts within the allocating authority. A well-qualified and impartial team can ensure that scientific and legal evaluations are conducted with the highest level of accuracy and fairness, preventing financial disparities from influencing the outcome. Table 1 summarizes the options for involving environmental forensic experts in pollution liability allocation.

In the era of artificial intelligence, advanced forensic techniques like machine learning models can be used to reduce the influence of human bias and enhance integrity. For instance, AI-assisted satellite imagery tools were used independently to verify the destruction in the Amazon forest, where the corporate companies had provided misinformation. AI-driven validation is key to preventing bias in environmental liability cases.

4. CONCLUDING REMARKS

Involving environmental forensic experts in pollution liability allocation can enhance the efficiency and accuracy of the process. However, challenges such as their limited legal knowledge, the absence of objective guidelines, and potential integrity concerns must be addressed. A structured, two-stage approach – beginning with technical liability allocation by independent forensic experts, followed

TABLE 1: Options of involving forensic experts in liability allocation.

Case	Determinants of liability	Liability allocation	Role of forensic experts
Independent forensic expert(s) carry out investigation at the contaminated site and carry out liability allocation based on the criteria for technical liability allocation	No factors other than technical	Complete	Investigation and liability allocation as independent experts
	No factors other than technical, but party/parties challenge investigation/allocation	Liability allocation by judicial authority, taking inputs from the independent forensic experts	
	Presence of decisive non-technical factors		
Forensic experts hired by parties carry out investigations at site and investigation results are presented by experts before allocating authority	Technical factors and/or non-technical factors	Authority consisting of independent forensic experts and legal experts carry out allocation based on the investigation results/additional details sought/collected	Different groups of forensic experts involved at investigation stage and allocation stage

by final allocation considering legal and non-technical factors – can provide a balanced solution. Establishing clear, standardized guidelines for technical liability allocation will further ensure consistency and reliability. By adopting this approach, forensic expertise can be effectively leveraged while maintaining fairness and transparency in pollution liability allocation.

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