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Review

A Review of Explosive Ordnance Disposal (EOD) Databases: Interdisciplinary Relevance, Environmental Impact, and Future Directions

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Abstract: Explosive hazards – from legacy unexploded ordnance (UXO) to rapidly evolving improvised explosive devices (IEDs) – pose lasting risks to people and ecosystems. Beyond blast effects, open-burn/open-detonate (OBOD) practices release toxic metals (Pb, depleted U, W) and energetic residues (*e.g.* TNT, RDX, HMX) that persist in soils, sediments, and groundwater. This review benchmarks six widely used Explosive Ordnance Disposal (EOD) data resources: – TURPIN, – Cat-UXO, – EODVOID, – the NATO Ammunition Data Base (NADB), – IMSMA, and – ORDATA, against five criteria: – completeness, – update latency, – data-quality assurance, – environmental fields, and – accessibility. We synthesize empirical measurements around UXO sites and compare life-cycle evidence for OBOD versus contained detonation/burn and hydro-abrasive cutting. While the databases excel at imagery and identification, environmental metadata, quality assurance/quality control (QA/QC) provenance, and access remain uneven, limiting artificial intelligence (AI)-assisted analysis and coordinated remediation. Case studies consistently show metals and energetics above screening benchmarks, underscoring the need for standardized contamination fields (matrix, depth, analyte, method, units, detection limits). We propose a roadmap – harmonized exchange schemas, audit trails, and integration of real-time sensors with AI hotspot prediction – to evolve EOD databases into sustainability-oriented decision-support systems. A unified data ecosystem can advance cleaner water and seas, healthier soils, and safer communities, aligning with the 2023 UN Environment Assembly's call to address conflict-related pollution.

Keywords: explosive ordnance disposal, EOD, unexploded ordnance, UXO, improvised explosive device, IED, environmental contamination, ordnance database, risk assessment, environmental remediation

Acronims and abbreviations:

AI	Artificial intelligence
AXO	Abandoned explosive ordnance
Cat-UXO	Catalogue of Explosives and Unexploded Ordnance
EO	Explosive ordnance
EOD	Explosive ordnance disposal
EODVOID	Explosive Ordnance Disposal Visual Ordnance Identification Database
GICHD	The Geneva International Centre for Humanitarian Demining
IED	Improvised explosive devices
IMSMA	Information Management System for Mine Action
JSEODTIC	Joint Service EOD Technical Information Center
NADB	The NATO Ammunition Data Base
NGO	Non-Governmental Organization
ORDATA	The Collaborative Ordnance Data Repository
UXO	Unexploded ordnance

1 Introduction

Unexploded ordnance (UXO) and improvised explosive devices (IEDs) pose enduring challenges for global communities, ecosystems, and humanitarian initiatives. Legacy munitions from conflicts such as the First and Second World Wars, the Vietnam War, and numerous regional confrontations still contaminate soils, waterbodies, and habitats, impeding agricultural production, infrastructure development, and environmental remediation. It is estimated that in Baltic Sea alone, after World War II there are approximately 300 000 tonnes of dumped conventional munition [1] and 50,000 metric tons of chemical weapons [2]. Moreover, initiating systems containing mercury fulminate and lead(II) azide were also sea dumped but separately from the bulk charges of munitions [3]. These explosive remnants continue to threaten human life and livelihoods [4] while also disrupting ecological balance through habitat alteration and the introduction of toxic compounds into local biota [4-9].

Humanitarian mine action (HMA) has historically prioritized the physical clearance of landmines and explosive remnants of war (ERW), focusing on blast and fragmentation hazards that pose immediate risks to civilians [4, 5]. However, growing evidence indicates that open burning or open detonation (OBOD) of ordnance can lead to significant contamination of soil and water by carcinogenic heavy metals (Pb, U, Ni, Co, W) and energetic compounds (*e.g.* TNT, DNT, RDX, HMX, PETN), which may migrate into groundwater or bioaccumulate in local flora and fauna [9]. Although many militaries have started to limit OBOD practices due to stricter environmental regulations, it remains a widely used method in humanitarian and post-conflict explosive ordnance disposal (EOD) operations, raising concerns about long-term ecological harm.

In contemporary conflict zones, IEDs have emerged as a highly adaptable and unpredictable threat, often constructed from unconventional materials. Their rapid evolution frequently outpaces traditional response strategies, placing civilians, deminers, and environmental managers at elevated risk. The demand for timely, accurate, and context-specific information on ordnance identification and disposal has therefore grown exponentially, underscoring the critical role of EOD databases.

Reliable ordnance identification became especially challenging during clearance operations in places like Fallujah and Mosul, where abandoned explosive ordnance (AXO) and UXO from more than twenty different countries were encountered. These environments challenged even the most experienced EOD technicians, prompting the compilation of ordnance identification documents that featured hundreds of distinct munitions types. Similarly, in Ukraine, over 305,000 explosive munitions were located, recorded, and removed in just the first year of conflict, according to estimates by the Geneva International Centre for Humanitarian Demining (GICHD). However, roughly one-third of the country remains affected, exposing millions of citizens to potential harm. The high dud rate among some munitions – estimated at around 40% in certain areas – further complicates clearance and heightens the need for robust identification resources [4, 5].

This situation highlights the urgent requirement for centralized and comprehensive EOD, UXO, and AXO databases. The diversity of ordnance – including artillery projectiles, tank ammunition, landmines, air-dropped bombs, and ballistic missiles – demands consistent, real-time, and reliable identification systems to enhance both operational safety and efficiency.

Several prominent EOD databases significantly aid ordnance identification and disposal through extensive collections of technical data, historical records, and disposal guidelines. TURPIN, widely used by French EOD personnel, is particularly valued for its multilingual accessibility and comprehensive visual library of over 120,000 images, greatly enhancing field identification accuracy. Meanwhile, Cat-UXO has proved indispensable for post-conflict environmental remediation by meticulously cataloging historical unexploded ordnance, thus assisting Non-Governmental Organizations (NGOs) and researchers in targeted risk assessments and community education. Explosive Ordnance Disposal Visual Ordnance Identification Database (EODVOID) leverages crowd-sourced contributions to capture emergent threats and new IED variants, maintaining a dynamic, field-relevant resource. IMSMA – supported by GICHD – integrates geospatial data to coordinate mine action efforts, while the NATO Ammunition Database (NAD) offers standardized ammunition classification for interoperability among allied forces. In addition, the GICHD Explosive Ordnance Guide and Joint Service EOD Technical Information Center (JSEODTIC) provide practical field guidance and specialized technical intelligence, respectively.

Despite these advances, substantial challenges persist. Existing databases vary in accessibility (some are classified or restricted), data verification (crowd-sourced versus curated), update frequency (periodic versus real-time), and environmental utility (lack of explicit ecological or toxicological data). Gaps in standardization and global data sharing also hinder the efficient use of these resources, especially for humanitarian and environmental programs.

Crucially, no comprehensive scholarly review currently consolidates these references, evaluates their environmental and interdisciplinary dimensions, and identifies the next steps to unify or expand their coverage. Accordingly, this paper aims to bridge that gap by mapping key EOD databases, assessing their capabilities and limitations, and proposing a roadmap for future integration of advanced analytic methods, including artificial intelligence and sensor-based data collection. Such efforts can help ensure that EOD databases continue to evolve to meet the growing demands of safety, environmental integrity, and humanitarian support in regions afflicted by explosive ordnance.

2 Methodology

2.1 Scope

This review examines globally recognized EOD databases extensively used across military, police, humanitarian, and environmental contexts. We include platforms such as TURPIN, Cat-UXO, EODVOID, NADB, IMSMA, the GICHD Explosive Ordnance Guide, and JSEODTIC. Region-specific resources (*e.g.* Afghanistan Ordnance Identification Guide, Iraq Ordnance Identification Guide, and Ukraine-specific ammunition guides) are also discussed where relevant for environmental management and ordnance disposal. The search was restricted to English-language publications from the past 15 years (2010-2025) to capture modern trends and tools. Practitioner-focused literature and operational reports were also reviewed to identify real-world applications of these databases.

2.2 Selection process

We selected databases based on the following criteria:

– **Practical Use:** Demonstrated field applications in ordnance identification or remediation.
– **Data Breadth:** Comprehensive coverage of a wide range of ordnance types, from historical UXO to modern IEDs.
– **Environmental Relevance:** Inclusion of contamination or disposal impact data relevant to ecosystems.
– **Accessibility:** Public or restricted access for various stakeholders, allowing for a diverse analysis of database types.

2.3 Analysis framework

We evaluated each database with respect to five critical indicators:

– **Data Comprehensiveness:** Assessment of technical specifications, historical data, and environmental impact assessments provided within the database.
– **Update Latency:** The regularity and timeliness of incorporating new findings, technologies, or ordnance types.
– **Data-Quality Assurance:** Mechanisms in place to ensure the accuracy and reliability of the data, distinguishing between crowd-sourced and curated information.
– **Environmental Fields:** The presence and detail of explicit ecological or toxicological data, and information relevant to contamination or disposal impact.
– **Accessibility:** Ease of user interface, availability for non-experts, and whether access is public or restricted.

3 Overview of Principal EOD Databases

EOD databases streamline the identification, classification, and disposal of explosive threats. Below is a consolidated overview of major platforms, each serving distinct operational niches. Our assessment of databases with restricted access, such as the NADB and JSEODTIC, is based on publicly available descriptions of their stated functionalities, scope, and reported characteristics, rather than direct access to their classified or proprietary content. Table 1 provides a comprehensive summary of these databases.

3.1 TURPIN Ammunition Database

- **Description**: Maintained by French Sécurité Civile, TURPIN hosts over 14,000 datasheets and 120,000 images of conventional ammunition and UXO.
- **Applications**: Used by French EOD teams and international partners.
- **Strengths**:
  (i) high-quality imagery and technical specs aid accurate ordnance recognition,
  (ii) multilingual capability.
- **Limitations**:
  (i) restricted access to authorized personnel,
  (ii) limited public awareness beyond professional EOD circles.

3.2 Cat-UXO

- **Description**: Focuses on historical UXO, integrating archival data with technical insights to support environmental remediation and educational purposes.
- **Applications**: Useful for post-conflict cleanup, risk mapping, and community education.
- **Strengths**:
  (i) extensive historical ordnance coverage,
  (ii) region-specific classifications for targeted risk assessments.
- **Limitations**:
  (i) limited coverage of modern ordnance or IEDs,
  (ii) primarily oriented toward historical contexts.

3.3 EODVOID

- **Description**: A crowd-sourced platform emphasizing visual identification of various ordnance, including IEDs.
- **Applications**: Ideal for regions with high IED activity, leveraging frequent user contributions.
- **Strengths**:
  (i) rapid updates from diverse field sources,
  (ii) high-quality images and 3D visualizations.
- **Limitations**:
  (i) data reliability varies due to crowd-sourced nature,
  (ii) lack of standardization in classification protocols.

3.4 NADB

- **Description**: The NADB is a comprehensive repository that provides detailed information on various ammunition types used by NATO member countries. While specific contents of the NADB are not publicly disclosed due to security considerations, it generally includes:
  (i) **Technical Specifications**: Detailed data on ammunition dimensions, weight, composition, and performance characteristics.
  (ii) **Identification Features**: Information on markings, color codes, and other identifiers crucial for recognizing different ammunition types.
  (iii) **Safety and Handling Procedures**: Guidelines on the safe storage, transportation, and disposal of ammunition.
  (iv) **Compatibility and Interoperability Data**: Information ensuring that ammunition can be effectively used across various NATO platforms and by different member nations.
- **Applications**: Enhances interoperability for multinational military operations and contributes to standardized classification.
- **Strengths**:
  (i) authoritative source with uniform classification standards,
  (ii) facilitates logistical coordination among NATO forces,
  (iii) maintains a focus on safety protocols and interoperability guidance.
- **Limitations**:
  (i) limited coverage of non-NATO or improvised threats,
  (ii) primarily addresses military-grade ordnance,
  (iii) contents are largely non-public, limiting widespread reference.

3.5 Explosive Ordnance Guide for Mine Action Programs (GICHD)

- **Description**: Developed by the GICHD [5], combines GIS features with database management to coordinate mine action [10].
- **Applications**: Landmine and UXO mapping, clearance, and community outreach.
- **Strengths**:
  (i) robust geospatial integration,
  (ii) facilitates multi-agency collaboration.
- **Limitations**:
  (i) requires specialized training,
  (ii) data accuracy depends on consistent field reporting.

Table 1. Overview of selected EOD databases: coverage, users, and features

Database	Ordnance Types Covered	Key Data Stored	Handling and Disposal Instructions	Intended Users	Additional Features	Ref.
TURPIN Ammunition Database	Conventional ammunition, UXO	14,000+ datasheets, 120,000 images, technical specs, identification features	Yes	Authorized EOD technicians, police	Multilingual, secure online access, official database for French EOD techs	[11]
Cat-UXO	Historical UXO from past conflicts	Historical records, technical characteristics, geographical classification	Limited guidance	Humanitarian demining NGOs, researchers	Valuable for environmental remediation and educational resource; rich historical context	[12]
EODVOID	Various ordnance types	3D models of ordnance, high-resolution images, metadata	Yes	EOD technicians, AI/ML algorithm developers	Automated photogrammetry for rapid 3D model creation, supports AI/ML training	[13]
NADB	Ammunition used by NATO and non-NATO nations	Standardized ammo classifications, technical specs, nomenclature, 435,000 items held in the NATO inventories	Yes (standard protocols)	NATO member forces	Facilitates interoperability, authoritative reference for allied operations. Secure web-based database	[14]
Explosive Ordnance Guide for Mine Action Programs	Founded by GICHD. Landmines, Commonly encountered UXO, explosive devices	Basic identification details, general guidelines for field personnel	Yes (basic)	Field personnel in demining operations, Mine action authorities, NGOs	Static reference, limited adaptability to emerging threats	[10]

Database	Ordnance Types Covered	Key Data Stored	Handling and Disposal Instructions	Intended Users	Additional Features	Ref.
JSEODTIC	Foreign and domestic ordnance	Classified technical intelligence, detailed manuals	Yes (detailed)	Authorized U.S. DoD personnel, allied EOD teams	Secure, in-depth technical intelligence, restricted access	[15]
Basic Identification of Ammunition in Ukraine	Ammunition in Ukraine	Comprehensive ordnance guide tailored to Ukraine, updated regularly	Yes	Ukrainian EOD teams, international partners	Focuses on ordnance found in Ukraine, updated frequently	[16]
The Grenade Recognition Manual	Historical grenades (UK, US, Japan, Netherlands)	Breakdown of grenade types, detailed images of components	No	Researchers, EOD teams	Accessible website with detailed imagery	[17]
Afghanistan Ordnance Identification Guide	Ordnance in Afghanistan	Identification of over 800 items, organized into PDFs	Limited	NGOs, military	Series of PDFs for ease of access	[18]
Iraq Ordnance Identification Guide	Ordnance in Iraq	Identification of approximately 1,200 items, organized into PDFs	Limited	NGOs, military	Series of PDFs for ease of access	[19]
ORDATA	Landmines, UXO	Over 3,000 entries, including technical specs, ordnance imagery, and identification data	Yes	Humanitarian demining authorities, NGOs	Free, requires registration	[20]

Database	Ordnance Types Covered	Key Data Stored	Handling and Disposal Instructions	Intended Users	Additional Features	Ref.
Open Source Munitions Portal	Various (projectiles, missiles, bombs, etc.)	Archive with tags describing munition characteristics and discovery context	Limited	Researchers, NGOs, journalists	Continuously updated, highly visual	[21]
Weapons of the Islamic State	IED components, ammo, precursors	Analysis of 40,000+ items recovered from ISIS supply chains	Yes	Military, researchers	Includes traceable components and chemical precursors used by ISIS	[22]
EOD Data Hub	Global ordnance	Repository for global EOD data	Yes (certified users only)	EOD operators	Registration required, restricted access	[23]
UXOinfo. com's Document Library	Western ordnance	Technical documents on ordnance and weapons	No	Researchers, EOD teams	Free access to Western-focused weapons guides	[24]
Bulletpicker	Global ordnance	Historical and technical information	No	Researchers, EOD teams	Free access	[25]

3.6 Region-Specific Databases

Several region-specific guides—such as the Basic Identification of Ammunition in Ukraine [16], Afghanistan Ordnance Identification Guide [18], and Iraq Ordnance Identification Guide [19] address localized threats by cataloging munitions prevalent in specific conflict areas. While invaluable for immediate operational needs, these resources often lack interoperability with larger global databases, restricting broader data sharing and comparative analyses.

To understand how well existing EOD databases serve environmental-remediation needs, we assessed six widely cited resources (TURPIN, Cat-UXO, EODVOID, NADB, IMSMA, and ORDATA) against five quality indicators: completeness of records, update latency, data-quality assurance, availability of explicit environmental fields, and user accessibility. Each indicator was scored on a 1 (poor) – 5 (excellent) ordinal scale by two independent reviewers, disagreements over one point were resolved by consensus. Raw scores appear in Table 2 visualizes the data as a heat-map to highlight relative strengths and weaknesses. The mentioned databases are constructed for military and police services involved in EOD operations, so from an environmental research point of view, mainly IMSMA can be useful.

Table 2. Database quality scores (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent)

Database	Completeness	Update latency	Data quality	Environmental fields	Accessibility
TURPIN	5	3	4	2	2
Cat-UXO	3	2	3	3	4
EODVOID	3	5	2	1	5
NADB	5	4	5	1	1
IMSMA	4	3	4	4	3
ORDATA	3	2	3	2	4

4 Environmental Concentrations at Representative UXO Sites

Table 3 effectively summarizes empirical case studies demonstrating environmental contamination at various UXO sites. It highlights that the measured concentrations of both metals (such as lead, uranium, and tungsten) and energetics (like RDX and TNT) in different matrices (soil, groundwater, coastal water, sediments) consistently exceed established human-health or ecological screening levels.

Table 3. Measured concentrations of metals and energetics at representative UXO sites

Case study	Matrix and depth	Analyte	Reported concentration	Guideline / exceedance	Ref.
Civil/Police riflerange berm (USA)	Soil 0 – 10 cm	Lead	1,142-24,484 $mg \cdot kg^{-1}$	US-EPA residential soil RDC 200 $mg \cdot kg^{-1}$	[31,32]
Post-conflict area in Bosnia and Herzegovina	Soil beneath DU penetrator	Uranium (total)	45,300 $mg \cdot kg^{-1}$	USEPA industrial soil screening 1,000 $mg \cdot kg^{-1}$, surfacesoil background is typically < 10 $mg \cdot kg^{-1}$	[33]
Safwan district, southern Iraq	Soil surface (0 – 10 cm)	U (depleted)	4 000 $mg \cdot kg^{-1}$	Canadian industrial soil SQG 2 000 $mg \cdot kg^{-1}$ (×2)	[34]
German small-arms range	Berm soil, groundwater	Tungsten	up to 2,080 $mg \cdot kg^{-1}$ in berm soils; dissolved W in groundwater to 400 $\mu g \cdot L^{-1}$	Danish soil quality criterion is 100 $mg \cdot kg^{-1}$	[35]
Yorktown Naval Weapons Station (USA)	Groundwater (Rifle Range, Site 22)	RDX	1.2, 3.2, 4.9, up to 63 $\mu g \cdot L^{-1}$	US-EPA, groundwater standard, 0.42 $\mu g \cdot L^{-1}$	[36]
Bahia Salina del Sur (Puerto Rico)	Coastal water	RDX	4,120-85,700 $\mu g \cdot L^{-1}$ (in cavity); 3.3-107 $\mu g \cdot L^{-1}$ at 0.10 m	NOAA aquatic benchmark 0.018 $\mu g \cdot L^{-1}$	[37]
Baltic Sea dumpsites, Germany	Sediments	TNT	Up to 110 $\mu g \cdot kg^{-1}$	Cancer risk level in water 100 $\mu g \cdot L^{-1}$	[29]

Key insight: values regularly exceed human-health or ecological screening levels, confirming the need for explicit contamination fields in EOD repositories

For instance, lead concentrations at Jefferson Proving Ground and a rifle range berm soil were found to be significantly higher than the US-EPA residential soil RDC [26]. Similarly, total uranium and depleted uranium at Jefferson Proving Ground and Safwan district in Iraq, respectively, greatly surpassed industrial soil screening guidelines [27]. Contamination by RDX has been detected in groundwater at Yorktown Naval Weapons Station and coastal water in Bahia Salina del Sur, exceeding relevant benchmarks [28, 29]. Furthermore, TNT levels at Baltic Sea dumpsites were found to be far above German sediment EQS [30].

This consistent pattern of exceedances across diverse sites and contaminants underscores the urgent necessity for incorporating explicit contamination fields within EOD repositories. Such data integration would greatly facilitate comprehensive environmental risk assessment and the planning of effective remediation strategies for UXO-affected areas. These exceedances highlight the critical need for EOD databases to capture detailed environmental-contamination metadata – depth, matrix, analyte speciation and concentration – so that clearance planning, risk assessment and remediation can be properly informed.

5 Discussion

5.1 Environmental implications of explosive ordnance (EO)

The environmental impact of EO contamination cannot be overlooked. The GICHD notes that EO releases toxic metals and explosives into soil and water, persisting for decades and bioaccumulating in plants and animals [38]. Addressing these risks requires incorporating detailed chemical and ecological data into EOD databases, enabling better risk assessments and remediation strategies. Norwegian People's Aid emphasizes adopting environmentally conscious practices, such as adhering to regulations and implementing sustainable methodologies, to reduce the ecological footprint of clearance efforts [39-43].

In addition to immediate hazards, EO can cause hidden pollution, as heavy metals and energetic compounds often migrate into groundwater or accumulate in the food chain [43]. Mitigating such impacts demands sustainable clearance operations and the adoption of enhanced management practices, including limiting open burning or detonation, and exploring contained detonation chambers or chemical neutralization methods. These measures protect ecosystems and promote more effective demining outcomes [44].

5.2 Artificial intelligence (AI), machine learning (ML) and database integration

AI and ML technologies have long been explored for their potential in enhancing EOD systems. Over three decades ago, Madrid *et al.* [45] developed the AI-EOD system, an expert system incorporating neural networks for ordnance identification. Despite its promising foundation, the system's capabilities were constrained by the computational limitations of its time. Today, advances in processing power and the development of sophisticated ML models now offer more sophisticated possibilities.

Modern AI-driven initiatives include the EODVOID, which employs automated photogrammetry to create 3D models of ordnance, enhancing identification accuracy and speed [13]. Similarly, projects like Augmented Reality and AI Assistance in EOD (project ARES) leverage AR interfaces to improve situational awareness, while multi-agent systems support coordinated detection and disposal [46, 47]. Additionally, advancements in unmanned aerial vehicles (UAVs) equipped with deep learning algorithms have enabled autonomous systems to detect, recognize, and neutralize unexploded ordnance effectively [48].

These developments underscore the transformative potential of AI and ML in the EOD domain, enhancing the capabilities of databases and field operations alike. However, one of the significant challenges remains the scattered nature of EOD databases, which hinders the full realization of AI-driven solutions. Current databases exist in various formats, such as categorized lists, PDF files with images and descriptions, or unstructured repositories. Some databases are well-organized and categorized, while others lack consistent structuring, making data retrieval and integration a cumbersome process. This inconsistency limits the ability of AI models to access and utilize the information effectively, thereby affecting their predictive and operational accuracy. To address this, there is a need for a centralized and standardized database framework that ensures compatibility, accessibility, and comprehensive data structuring across different platforms.

The ongoing conflict in Ukraine underscores the urgency of centralizing EOD, UXO, and AXO data. Its diverse munitions – from landmines to ballistic missiles – exacerbate contamination risks, highlighting the need for databases that integrate geospatial and environmental data. Machine learning models trained on historical data could predict likely UXO locations or assess environmental risks. By integrating IoT-enabled sensors, databases could further provide real-time updates, enhancing field operations and safety.

6 Research Gaps and Challenges

Despite the advancements in EOD databases, several research gaps and challenges persist, impeding their effectiveness in addressing contemporary explosive threats, for example:

– **Emerging Threats:** Novel IEDs observed in recent conflicts such as Syria and Ukraine, which incorporate unconventional materials like commercial drones and 3D-printed components, frequently outpace the tracking capabilities of existing databases. A lack of timely updates or global data sharing on these innovations delays identification and disposal, compromising safety and environmental protection.
– **Interoperability:** The lack of integration between national and international databases limits information sharing across borders. Disparate systems with varying data formats and classification schemes impede collaboration among military forces, humanitarian organizations, and law enforcement agencies. This fragmentation can lead to redundant efforts, information silos, and delays in critical operations.
– **Real-time data:** Existing databases offer limited tools for dynamic analysis and real-time decision-making. The absence of real-time data updates and analytics capabilities restricts the ability to respond promptly to emerging threats. In fast-paced operational environments, delayed or outdated information can have serious consequences.
– **Localization:** Few databases incorporate region-specific ordnance knowledge, reducing their relevance in localized threat contexts. Cultural nuances, indigenous explosive devices, and regionally prevalent ordnance types may not be adequately represented. This lack of localization affects the accuracy of threat assessments and the effectiveness of response strategies in specific areas.
– **Life-cycle impacts of clearance options:** Understanding the full environmental implications of EOD activities requires comprehensive life-cycle assessments (LCAs) of different clearance methods. Current databases often lack detailed comparative data on the environmental footprints of various disposal techniques, making it difficult for EOD practitioners and environmental managers to select the most sustainable options.

The OBOD method, while effective for immediate neutralization, is known to release significant quantities of toxic metals, unreacted energetics (such as TNT, RDX, and HMX), and greenhouse gases into the atmosphere, soil, and water [49]. These releases contribute to long-term environmental contamination and health risks, as demonstrated by the empirical data in Table 3. A significant research gap lies in the lack of systematically collected and accessible data within EOD databases that quantifies these impacts across diverse ordnance types and environmental conditions.

In contrast, alternative disposal methods offer substantial environmental advantages, yet their comprehensive life-cycle impacts are not consistently documented within existing EOD databases. For instance, contained detonation chambers significantly reduce the release of atmospheric pollutants and contain solid residues, preventing widespread soil and water contamination [50]. Similarly, hydro-abrasive cutting (using high-pressure water with abrasive particles) allows for the safe dismantling of ordnance without detonation, minimizing both hazardous emissions and noise pollution [51]. Life-cycle comparisons, in line with ISO 14040 principles for environmental management, have shown that these contained and non-explosive methods can reduce greenhouse-gas emissions and toxic releases by ≥70% relative to OBOD. The absence of such critical comparative data within EOD databases hinders evidence-based decision-making for sustainable EOD operations and prevents a holistic assessment of the environmental costs and benefits of different approaches. Integrating comprehensive LCA data for various clearance options is essential to drive the adoption of more environmentally responsible practices and to measure progress towards broader sustainability goals.

7 Recommendations and Future Directions

The persistent and evolving nature of UXO and IED threats underscores the need for EOD databases to become more adaptive, collaborative, and technologically advanced. While current databases such as TURPIN, Cat-UXO, EODVOID, NADB, IMSMA, GICHD's Explosive Ordnance Guide, and JSEODTIC each address important niches, ongoing research, and expert analyses – including insights drawn from the 2021 publication *"Technological Innovations Influencing Future EOD and Related Capabilities"* – highlight the trajectory towards more sophisticated, integrated solutions. The main expectations are:

– **Policy relevance:** Harmonized EOD datasets can supply indicator data for Sustainable Development Goals (SDGs) by linking ordnance locations with monitoring results from Section 4. Specifically:
  (i) SDG 3.9 (hazardous-chemical deaths),
  (ii) SDG 6.3 (water quality),
  (iii) SDG 14.1 (marine pollution),
  (iv) SDG 15.1 (terrestrial ecosystems).

For UNEA 6/13 (2023) "Mitigating pollution from conflicts and explosives", the rubric identifies which databases already store contamination metrics (IMSMA) and which need new fields (NADB, TURPIN). An interoperable API would allow the UNEP Conflict and Environment Observatory to ingest these data directly.

- **AI, Big Data, and Predictive Analytics:** The incorporation of AI and big data analysis holds promise for transforming raw data streams into actionable intelligence. AI-driven algorithms can identify patterns in large datasets, anticipate emerging threat trends, and optimize resource allocation [52]. These advancements reflect the book's emphasis on facilitating predictive analysis and trend mapping, positioning EOD databases not only as static repositories but as dynamic analytical platforms supporting strategic decision-making, environmental remediation planning, and rapid response operations.
- **Data Interoperability, Standardization, and Real-Time Access:** The 2021 publication advocates for interoperability and standardization, reinforcing the need for common data formats, classification protocols, and communication standards to streamline international EOD cooperation. By unifying disparate information systems, organizations can share intelligence seamlessly, strengthening cross-border efforts in humanitarian demining and environmental management. The book also highlights the potential of real-time data access—for example, providing EOD technicians with HUDs that display ordnance schematics, contamination maps, and sensor feeds in the field. These capabilities could significantly enhance situational awareness, reduce operational delays, and minimize environmental damage by enabling timely interventions [30].
- **Localization, Autonomous Systems, and Emerging Domains:** Localizing databases with region-specific data remains critical, and future innovations should incorporate historical data and indigenous knowledge to improve relevance in diverse cultural and ecological contexts [53]. The desired attributes, as identified by the book, also include compatibility with autonomous systems, such as UAVs, ROVs, and robotics, to automate data collection in inaccessible areas. This adaptability ensures that EOD databases become integral to a broader technological ecosystem that can swiftly adapt to changing tactical and environmental conditions.
- **Addressing Cost, Security, and Adoption Challenges:** Despite the clear benefits, the book acknowledges challenges, including high development and deployment costs and limited adoption due to insufficient standardization. Overcoming these hurdles will require international partnerships, stable

funding mechanisms, and careful governance structures to ensure secure data sharing among trusted entities. In aligning these future-oriented concepts with existing platforms, policymakers, technology developers, and end-users can collaborate to integrate cost-effective solutions without compromising data integrity or operational security.

As demonstrated in the article, there are several databases that aggregate ammunition data essential for EOD operations. It would be beneficial to combine data scattered across various databases into one large, yet transparent database. A team to carry out such a task could be established under the auspices of international organizations responsible for collective security, such as NATO or Interpol.

8 Conclusions

- The effective management of explosive ordnance hazards is paramount for global safety, environmental protection, and sustainable development. This review has critically assessed existing EOD databases, highlighting their strengths in specific operational niches while identifying significant gaps in data completeness, interoperability, environmental fields, and real-time analytical capabilities.
- Our analysis demonstrates that while current databases provide foundational support for EOD operations, their fragmented nature and limited integration of environmental data impede comprehensive risk assessment and remediation efforts. The empirical case studies presented unequivocally illustrate the persistent and hazardous environmental contamination caused by explosive remnants, underscoring the urgent need for EOD repositories to explicitly incorporate toxicological and ecological metrics.
- Looking forward, the convergence of advanced technologies, particularly AI, machine learning, and real-time sensor integration, offers transformative potential for EOD databases. By evolving into dynamic, sustainability-oriented decision-support systems, these databases can transcend their current static roles and become pivotal tools for predictive analysis, coordinated environmental remediation, and enhanced operational safety. Achieving this future requires a concerted effort towards data standardization, improved accessibility, and a policy framework that encourages international collaboration and information exchange. Ultimately, robust and integrated EOD databases are indispensable for mitigating the multifaceted threats posed by explosive ordnance and contributing to a safer, cleaner, and more

sustainable global environment in line with key Sustainable Development Goals and international resolutions on conflict-related pollution.

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