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TECHNOLOGICAL APPROACHES TO THE REUSE OF DEMOLITION WASTE IN ROAD CONSTRUCTION AND THEIR ENVIRONMENTAL BENEFITS

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Abstract. The study examines reviews modern technological approaches to the reuse of construction and demolition waste in road construction, specifically the application to produce asphalt and concrete materials. It analyzes methods of mechanical and chemical processing, recycling technologies, and their integration into the structural layers of pavement. Particular attention is paid to the environmental benefits of such solutions: waste reduction, decreased consumption of natural resources, and lower emissions of greenhouse gases and pollutants. The research highlights practical aspects of using reclaimed materials and assesses their technical performance in comparison with virgin materials. The findings confirm the effectiveness of implementing waste reuse technologies for the sustainable development of transport infrastructure.

Keywords: construction and demolition waste, reuse, recycling, road construction, asphalt and concrete materials, environmental efficiency, sustainable development, processing technologies, waste reduction.

1. Introduction

The war in Ukraine has caused large-scale destruction of transport, residential, and industrial infrastructure, resulting in the generation of vast quantities of construction and demolition waste. In the context of destroyed cities and roads, these materials are not only a disposal challenge but also a potential resource for infrastructure reconstruction. Accumulated demolition waste, including concrete, asphalt, bricks, and other structural materials, can be reused in road construction, enabling the alignment of environmental safety with economic efficiency while accelerating recovery efforts (Ghisellini et al., 2019; Ferriz-Papi et al., 2024).

In most cases, secondary (recycled) materials are conventionally used as components for the production of new material mixtures, primarily as partial substitutes for virgin aggregates (Arulrajah et al., 2017; Borghi et al., 2018). Modern technological approaches to waste reuse mainly involve mechanical crushing, sorting, and chemical stabilization, followed by incorporation into construction mixtures or selected structural layers of road pavements. However, such approaches are often limited to individual technological solutions and do not comprehensively address the broader challenges of large-scale waste utilization. As a result, despite the environmental and economic benefits associated with recycling demolition waste – such as landfill volume reduction, decreased consumption of natural resources, and mitigation of environmental impacts – the problem of its systematic and efficient application in transport infrastructure remains insufficiently resolved.

The scientific novelty of this study lies in the development of an algorithmic framework for the reuse of demolition waste in road construction under post-conflict conditions, where the scope of application is initially determined by the type of demolition material and further refined based on its physical and mechanical properties. This framework integrates principles of selective demolition, on-site processing technologies, and material-specific performance criteria to guide the optimal selection of reuse pathways for different pavement layers. In addition, it allows for the assessment of environmental benefits through a Life Cycle Assessment (LCA)-based approach (Borghi et al., 2018), providing a structured tool for both sustainable waste management and resilient infrastructure recovery.

Unlike previous studies that addressed individual material streams or isolated recycling technologies, this approach provides a structured decision-making tool that supports resilient and resource-efficient strategies for the post-war reconstruction of transport infrastructure.

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The aim of this study is to is to provide a systematic analysis of modern technological approaches to the reuse of demolition waste accumulated due to military actions in Ukraine, as well as to assess its environmental benefits and potential for practical application in road construction. To achieve this aim, the study focuses on reviewing and classifying current recycling technologies, evaluating their ecological and economic advantages, and developing recommendations for their practical implementation in transport infrastructure. The results of this work provide a basis for formulating conclusions and guidelines for effective post-conflict infrastructure recovery and sustainable waste management.

2. Materials and methods

The large-scale destruction caused by the war in Ukraine has resulted in more than 100 000 000 tonnes of Construction and Demolition Waste (CDW), equivalent to over 250 000 000 m^3 of debris generated from damaged buildings and infrastructure (World Bank, 2023; Kyiv School of Economics, 2024). Simultaneously, within the framework of the circular economy concept, these materials should be viewed not as an environmental burden, but as a valuable secondary resource. Reusing demolition waste in the recovery of transport infrastructure allows for both shorter reconstruction timelines and a reduced environmental footprint associated with the extraction of virgin materials.

As of early 2025, more than 200 000 000 m^2 of residential and public buildings in Ukraine have been destroyed or damaged, generating an unprecedented amount of construction debris that would typically take decades to accumulate under normal conditions (Kyiv School of Economics, 2024). Concrete, brick, metal, wood, glass, and plastic are all potential secondary raw materials for new infrastructure projects. However, the lack of proper logistics and processing infrastructure poses a risk of turning these ruins into massive environmental problems.

In the context of post-war reconstruction, a substantial share of materials generated from damaged and demolished buildings-estimated at 50–70% by mass-can potentially be salvaged and reused following appropriate processing and quality control (World Bank, 2023; United Nations Environment Programme, 2023).

The methodology includes:

- *Careful dismantling* of structures to extract reusable elements such as steel beams, timber components, bricks, etc.
- *Manual sorting* and selection of materials to ensure high quality of the recovered raw materials.
- *Assessment of physical and mechanical properties* of secondary materials to guarantee their safe and effective integration into new construction projects.

Additionally, laboratory testing was performed to assess the homogeneity and durability-related properties of recycled materials intended for base layers of road pavements.

Bibliometric analysis of modern approaches to post-conflict reconstruction highlights a growing scientific interest in construction material reuse technologies. In particular, research emphasizes the efficiency of processing demolished concrete into recycled aggregate as a key component of sustainable construction. This approach significantly lowers the costs of purchasing virgin materials while minimizing environmental impact. Analysis also confirms the economic feasibility of implementing such projects at the local level, as the use of secondary raw materials fosters job creation, reduces municipal waste disposal costs, and stimulates local markets for recycled materials. Implementing these practices within Ukraine's "green" recovery strategy is critical for balancing economic development with environmental safety.

Figure 1 illustrates the initial stage of demolition waste management – selective demolition and on-site sorting – which determines the quality of secondary materials and their suitability for reuse in road construction. The figure highlights the role of controlled dismantling as a prerequisite for ensuring technical performance and environmental benefits in post-conflict infrastructure recovery.

Figure 1. Selective demolition and sorting of construction and demolition waste

Construction and Demolition Waste (CDW) in Europe is managed through various methods, including screening to determine soil and stone content, crushing concrete and rubble to produce base materials, shredding wood and boards, and segregation to recover metals, plastics, glass, and gypsum board. Incineration, with or without energy recovery, is utilized for wood, plastics, and flammable hazardous materials, while landfilling is reserved for inert, non-hazardous, and hazardous waste, including specialized asbestos and low-level nuclear waste. These methods support EU circular economy and waste management policies by maximizing material recovery and minimizing environmental impact.

In this context, Table 1 provides a structured overview of construction and demolition waste components and their potential reuse and recycling pathways in road construction.

Table 1. CDW component recycling strategies

Waste component	Reuse / Recycling pathways
Concrete	Production of crushed stone (aggregate), road pavement, clinker
Bricks	Drainage systems, road subgrade stabilization
Ceramic tiles	Stabilization of rural and forest roads
Wood	Insulation materials, wood composites, fuel briquettes
Glass	Dry construction mixes, reflective road marking paint, remelting
Plastics	Polymer products, refuse-derived fuel (except PVC)
Bituminous materials	Reclaimed Asphalt Pavement (RAP) for road mixtures
Metals	Complete metallurgical recycling
Mixed fractions	Sorting for aggregates or raw materials for clinker production

3. Discussion and results

One of the most promising directions for sustainable post war recovery is the integration of demolition waste into road construction systems. Recycled Concrete Aggregates (RCA), Reclaimed Asphalt Pavement (RAP), crushed bricks, and mixed mineral fractions can be effectively utilized in base layers, sub-bases, embankments, and the construction of local roads (Silva et al., 2019; Tam et al., 2018). Modern research confirms that, with proper preparation, the physical and mechanical properties of secondary materials are comparable to those of natural analogues.

In order to ensure the uniformity and durability of the road surface, the authors conducted additional laboratory tests of secondary mineral materials obtained from construction waste. The studies included the determination of the particle size distribution, density, water absorption, strength, deformation modulus, as well as frost resistance and water resistance indicators. The quantitative results of these tests, presented in Table 2, indicate the uniformity of the material and its compliance with the requirements for the base and subbase layers of road structures, and also confirm the potential for ensuring long-term operational reliability of the coating.

The above indicators confirm that additional tests allowed to ensure the homogeneity of secondary materials and the predicted durability of the road surface when used in base layers (Bu et al., 2022).

The technological processing cycle typically involves mobile or stationary crushing, sorting, and fractionating of materials in close proximity to destruction zones, which significantly reduces logistical costs and greenhouse gas emissions. Additional treatment methods, such as chemical stabilization with lime or cement, carbonation curing, and bitumen regeneration, enhance the durability and load-bearing capacity of road structures (Jean et al., 2024).

Table 2. Results of additional laboratory testing of recycled materials for base layers

Indicator	Unit of measurement	Obtained values	Base layer requirements*
Average grain size	mm	0–40	0–40
Bulk density	kg/m³	1850–2050	≥ 1800
Water absorption	%	4.5–6.8	≤ 8.0
Compressive strength	MPa	6.2–9.5	≥ 5.0
Deformation modulus (E_2)	MPa	180–260	≥ 150
Frost resistance	cycles	≥ 50	≥ 25
Water resistance	–	satisfactory	not lower than the regulatory

Note: * The normative values are summarized on the basis of current European and national requirements for materials of base and subbase layers of road structures.

From an environmental perspective, the reuse of demolition waste ensures a reduction in landfill volumes, conservation of natural mineral resources, and a decrease in CO_2 emissions associated with the extraction and transportation of virgin materials. According to Life Cycle Assessment (LCA) results, the implementation of secondary materials in road construction can reduce the total environmental burden by 20–50%, depending on the material type and transportation conditions (Borghi et al., 2018; Akhtar & Sarmah, 2018). A systematization of the primary technological solutions and their environmental benefits is presented in Table 3.

The general logic for the reuse of demolition waste in road construction, incorporating the environmental aspects of the life cycle, is shown in Figure 2.

Demolition waste (concrete, reclaimed asphalt pavement, bricks, ceramics, mixed mineral fractions, metals, and wood) is characterized by heterogeneous physical and mechanical properties that determine its suitability for use in road construction. Crushed concrete and RAP generally exhibit sufficient strength and bearing capacity for base and sub-base layers, although increased water absorption, bitumen aging, and material variability necessitate quality control and, in some cases, stabilization. Brick, ceramic, and mixed mineral fractions have lower mechanical performance and are primarily applicable in drainage layers, embankments, or subgrade improvement after processing. Metals are mainly reused for ancillary or reinforcement purposes, while wood is limited to temporary structures or energy recovery due to low durability. The suitability assessment is based on matching material properties with functional road layers while ensuring compliance with mechanical requirements. From a life cycle perspective, the reuse of demolition waste significantly reduces natural resource

Table 3. Technological solutions for the reuse of demolition waste in road construction and their environmental benefits (LCA approach) (author's development)

Waste type	Technological process	Application in road construction	Main environmental effect	Energy demand for processing*	Limitations / remarks
Concrete	Crushing, separation, fractionation	Base and sub-base layers, CTB	Reduction of quarrying, reduced transport emissions	5–15 MJ/t	Lower strength vs. natural aggregates, quality control required
Asphalt pavement → RAP	Crushing and screening of reclaimed asphalt	Component of new HMA (partial aggregate + binder substitution)	Reduction of virgin aggregate and bitumen demand	10–20 MJ/t	No standalone bitumen regeneration; aged binder used proportionally in HMA
Warm-Mix Asphalt (WMA)	Reduced-temperature mixing technology	Surface and base asphalt layers	Reduced fuel consumption and emissions during production	20–40% lower than HMA	Separate technology, not inherent to RAP use
Bricks and ceramics	Crushing, grading	Drainage layers, sub-base	Landfill reduction, substitution of natural materials	8–18 MJ/t	Variable properties, frost resistance issues possible
Mixed mineral fractions	Mechanical processing, stabilization	Embankments, subgrade improvement	Use of low-quality materials, reduced waste disposal	6–12 MJ/t	Limited bearing capacity, testing required
Metals	Dismantling, remelting	Reinforcement, ancillary use	Significant reduction of primary metal production	2–6 GJ/t	High capital intensity, off-site processing
Wood	Shredding, reuse or energy recovery	Temporary structures, fuel	Waste volume reduction, partial fossil fuel substitution	5–10 MJ/t	Not suitable for permanent road layers

Note: * Energy demand values are indicative ranges based on literature data and may vary depending on equipment type, processing scale, and transport distance; suitable for comparative LCA.

consumption, landfill disposal, and CO_2 emissions, supporting circular economy principles in road infrastructure development.

The effective transformation of waste into resources requires modern technologies, including crushing concrete fragments, melting metals, shredding wood, purifying glass, and recycling plastics as additives to virgin raw materials. Special attention must be paid to the disposal of hazardous materials, particularly asbestos present in older buildings. Its decontamination should be carried out strictly within closed cycles in compliance with international environmental standards, such as ISO 14001 for environmental management, ISO 21930 for sustainability in construction, the European Union Waste Framework Directive (2008/98/EC) for proper waste classification and recovery (The European Parliament & the Council of European Union, 2008), and EU Directive 2009/148/EC for worker protection from asbestos exposure (The European Parliament & the Council of European Union, 2009). Adherence to these standards ensures safe handling of hazardous materials while minimizing risks to human health and the environment.

Establishing an efficient recycling system requires regional sorting and crushing centers, mobile units for operation in combat zones, robust transport logistics, and digital platforms for tracking and monitoring waste movement. The state must create conditions for investment through tax incentives, a transparent regulatory

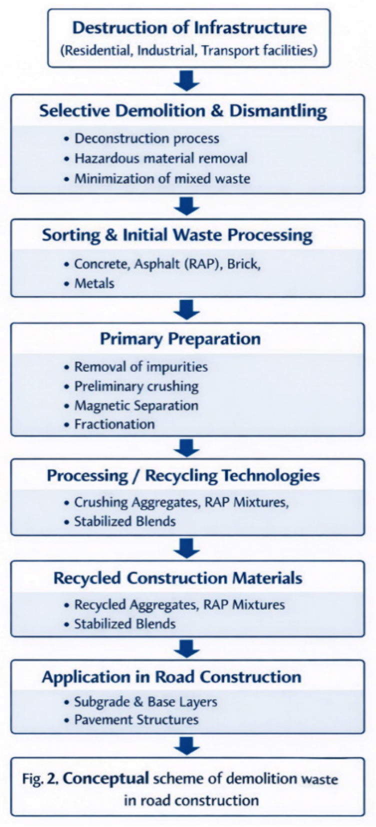

Figure 2. Conceptual scheme of demolition waste reuse in road construction

framework, and public-private partnership mechanisms.

The reuse of demolition waste in road construction is based on a complex of technological solutions covering all stages of the material life cycle. The key principle is the maximum involvement of local secondary materials while minimizing energy and logistical costs.

At the first stage, selective dismantling technologies are implemented, allowing for the separation of materials directly at the site of destruction. Unlike traditional mechanical demolition, selective dismantling ensures the preservation of the physical and mechanical properties of concrete, asphalt, and brick, which is critical for subsequent use in road construction.

Primary preparation includes:

- Removal of impurities (metal inclusions, wood, plastic);
- Preliminary crushing of large concrete elements;
- Magnetic separation of reinforcement steel;
- Fractionation of materials in accordance with road regulation requirements.

Recycled concrete is one of the most promising materials for road construction (Pitso et al., 2024). Modern crushing technologies produce recycled aggregate with controlled grain size distribution suitable for use in:

- Base and sub-base layers of the road pavement;
- Cement-Treated Base (CTB) layers;
- Stabilized material for the subgrade (embankment).

Additional technological techniques, such as carbonation curing and cement stabilization, enhance the strength, frost resistance, and water resistance of recycled materials. This allows for load-bearing capacity levels comparable to natural crushed stone. Crushed bricks and ceramic materials can be applied in drainage layers, temporary roads, and access paths, especially in rural and frontline areas. (Silva et al., 2018; Vieira et al., 2020; Liang et al., 2024).

Reclaimed Asphalt Pavement (RAP) is a key component of circular road construction (Borghi et al., 2020). When incorporated into new Hot-Mix Asphalt (HMA), the aged binder in RAP is not regenerated separately; rather, it is rejuvenated together with the old aggregates during mixing with new bituminous materials. The addition of RAP does not inherently reduce energy consumption: when RAP is added at asphalt plants using cold-feed systems, the aggregates are heated more intensely to compensate for the lower temperature of the recycled material. The proportion of RAP in new HMA can be adjusted according to the plant's capacity, particularly if a parallel drum is available. Energy savings can be achieved separately through the production of warm-mix asphalt, which is a distinct technology. Authors may specify the expected percentage of RAP in new HMA mixtures based on design requirements and material properties. In local road structures, the share of secondary asphalt can reach up to 50% without compromising performance (Elnaml et al., 2024).

To increase the durability of road structures using demolition waste, stabilization technologies are applied:

- Lime stabilization to reduce plasticity and increase water resistance;
- Cement stabilization for forming rigid bases;
- Combined stabilization using industrial by-products (fly ash, blast-furnace slag).

Such approaches enable the use of even mixed mineral fractions that would otherwise be subject to landfilling.

According to scientific literature, the use of recycled concrete and asphalt in the base and sub-base layers – which are primarily intended to stabilize the subgrade and provide structural support – could potentially reduce CO_2 emissions, mainly by lowering the demand for virgin materials and the energy required for their production (Azam et al., 2024; Gruber & Hofko, 2023). The actual environmental benefit depends on transportation distances, processing methods, and the specific composition of the recycled materials.

The findings confirm that reusing demolition waste in road construction is not only technically feasible but also environmentally justified in post-conflict conditions. Compared to traditional reconstruction approaches, the proposed solutions allow for faster infrastructure recovery while simultaneously reducing resource consumption and greenhouse gas emissions. However, the large-scale implementation of these technologies requires further pilot projects and the adaptation of national standards.

4. Conclusions

In accordance with the objectives of this study, the following results were achieved. First, modern technological approaches to the reuse of construction and demolition waste generated as a result of military actions in Ukraine were systematically reviewed and classified, including mechanical processing, stabilization methods, and their application in different road pavement layers. Second, the environmental and economic benefits of using recycled materials in road construction were assessed from a life cycle perspective, confirming significant reductions in natural resource consumption, landfill disposal, and greenhouse gas emissions. Third, practical recommendations were developed regarding the suitability of various demolition waste fractions for base, subbase, and auxiliary road layers, taking into account their physical and mechanical properties.

Thus, the study provides a structured and scientifically sound basis for the practical implementation of demolition waste reuse technologies in the post-war reconstruction of transport infrastructure, supporting sustainable waste management and resilient recovery strategies. The results confirm that the reuse of demolition waste is a key element of the sustainable post-war recovery of Ukraine's transport infrastructure.

Additional laboratory testing demonstrated the homogeneity of recycled materials and their suitability for durable pavement base layers. The use of secondary materials reduces environmental burdens, decreases the consumption of natural resources, and lowers greenhouse gas emissions. Combined with economic benefits and accelerated recovery processes, these technologies form a cornerstone of the strategy for the sustainable post-war development of Ukraine's transport infrastructure,

The practical implementation of the proposed solutions is feasible through pilot projects on local roads, which will allow for testing structural durability and adapting national regulatory requirements.

References

Akhtar, A., & Sarmah, A. K. (2018). Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. *Journal of Cleaner Production*, *186*, 262–281. https://doi.org/10.1016/j.jclepro.2018.03.085

Arulrajah, A., Yaghoubi, M., Wong, Y. C., & Horpibulsuk, S. (2017). Recycled plastic granules and demolition wastes as construction materials: Resilient moduli and strength characteristics. *Construction and Building Materials*, *147*, 639–647. https://doi.org/10.1016/j.conbuildmat.2017.04.178

Azam, A., Gabr, A., Ezzat, H., Arab, M., Alshammari, T. O., Alotaib, E., & Zeiada, W. (2024). *Life cycle assessment and pavement performance of recycled aggregates in road construction*. *Case Studies in Construction Materials*, *20*, Article e03062. https://doi.org/10.1016/j.cscm.2024.e03062

Borghi, G., Pantini, S., & Rigamonti, L. (2018). Life cycle assessment of non-hazardous construction and demolition waste (CDW) management in Lombardy region (Italy). *Journal of Cleaner Production*, *184*, 815–825. https://doi.org/10.1016/j.jclepro.2018.02.287

Elnaml, I., Mohammad, L. N., Baumgardner, G., Cooper, S., III, & Cooper, S., Jr. (2024). *Sustainability of asphalt mixtures containing 50% RAP and recycling agents*. *Recycling*, *9*(5), Article 85. https://doi.org/10.3390/recycling9050085

Ghisellini, P., Cialani, C., & Ulgiati, S. (2019). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Gruber, M. R., & Hofko, B. (2023). *Life cycle assessment of greenhouse gas emissions from recycled asphalt pavement production*. *Sustainability*, *15*(5), Article 4629. https://doi.org/10.3390/su15054629

Ferriz-Papi, J. A., Lee, A., & Alhawamdeh, M. (2024). Examining the challenges for circular economy implementation in construction and demolition waste management. *Buildings*, *14*(5), Article 1237. https://doi.org/10.3390/buildings14051237

Kyiv School of Economics. (2024). *$155 billion – the total amount of damages caused to Ukraine's infrastructure due to the war, as of January 2024*. KSE Institute. https://kse.ua/about-the-school/news/155-billion-the-total-amount-of-damages-caused-to-ukraine-s-infrastructure-due-to-the-war-as-of-january-2024/

Liang, C., Wang, S., Cai, Z., Yin, Y., Gao, Y., Guo, M.-Z., Wang, X., & Ma, Z. (2024). Effects of CO_2 curing methods on frost resistance and mechanical properties of recycled aggregate concrete. *Case Studies in Construction Materials*, *20*, Article e02973. https://doi.org/10.1016/j.cscm.2024.e02973

Jean, B., Liu, H., Zhu, X., Wang, X., Yan, X., Ma, T. (2024). Enhancing the mechanical and durability properties of fully recycled aggregate concrete using carbonated recycled fine aggregates. *Materials*, *17*(8), Article 1715. https://doi.org/10.3390/ma17081715

Bu, C., Liu, L., Lu, X., Zhu, D., Sun, Y., Yu, L., OuYang, Y., Cao, X., & Wei, Q. (2022). The durability of recycled fine aggregate concrete: A review. *Materials*, *15*(3), Article 1110. https://doi.org/10.3390/ma15031110

Pitso, R. I., Mostafa, M. M. H., & Elsaigh, W. A. (2024). Incorporation of recycled concrete aggregates as road pavement material in South Africa. *International Journal of Pavement Research and Technology*, *19*, 199–207. https://doi.org/10.1007/s42947-024-00453-9

Silva, R. V., de Brito, J., & Dhir, R. K. (2019). Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production. *Construction and Building Materials*, *218*, 128–139.

Silva, R. V., de Brito, J., & Dhir, R. K. (2018). Fresh-state performance of recycled aggregate concrete: A review. *Construction and Building Materials*, *178*, 19–31. https://doi.org/10.1016/j.conbuildmat.2018.05.149

Tam, V. W. Y., Soomro, M., & Evangelista, A. C. J. (2018). A review of recycled aggregate in concrete applications (2000–2017). *Construction and Building Materials*, *172*, 272–292. https://doi.org/10.1016/j.conbuildmat.2018.03.240

Vieira, C. S., Pereira, P. M., Lopes, M. L., & Correia, A. G. (2020). Recycled construction and demolition wastes as filling material for road embankments and pavement layers. *Journal of Cleaner Production*, *253*, Article 119978.

World Bank. (2023). *Ukraine rapid damage and needs assessment: February 2022 – February 2023*. World Bank Group. https://documents1.worldbank.org/curated/en/099184503212328877/pdf/P1801740d1177f03c0ab180057556615497.pdf

The European Parliament & the Council of the European Union. (2008). *Directive 2008/98/EC on waste and repealing certain Directives (Waste Framework Directive)* (2008, November 19, No. 32008L0098). Official Journal of the European Union, L312/3. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

The European Parliament & the Council of the European Union. (2009). *Directive 2009/148/EC on the protection of workers from the risks related to exposure to asbestos at work* (2009, November 30, No. 32009L0148). Official Journal of the European Union, L330/28. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0148

United Nations Environment Programme. (2023). *UNEP in 2022 (Annual Report)*. https://wedocs.unep.org/rest/api/core/bitstreams/be60ffea-34e9-45e0-91ab-b86d47d90bea/content