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Research Paper

Ecotoxicological impact of deactivated asbestos-cement on soil ecosystems

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ABSTRACT

The effects of thermally deactivated asbestos cement (DAC) on the soil ecosystem were evaluated using the soil model organism *Folsomia candida* (Collembola). Two materials were obtained by treating asbestos cement slates, commonly used for roofing, at 1100 °C under oxidizing conditions (Red DAC) and at 1150 °C under reducing conditions (Green DAC). Ten age-synchronized juveniles of *F. candida* were exposed to DAC powder:soil mixtures in ratios of 1:1 and 1:10 for both types. After 28 days, adults and juveniles were counted to assess treatment effects.

The results indicate distinct toxicity profiles. The Red powder did not induce adult lethality at the tested concentrations; however, a significant reduction in juvenile production was observed at the higher concentration (1:1). In contrast, the Green powder caused adult lethality at 1:1 concentration, with no juveniles produced.

Both materials contain a high percentage of silica glass (~40% by weight), a well-known insect dehydration agent and mechanical insecticide. At the highest concentration, silica glass may cause detrimental effects on juveniles, which are more sensitive to dehydration than adults. Green DAC also contains 8.5% lime (CaO), an antimicrobial and insecticidal agent that can disrupt soil pH. The combination of silica-induced dehydration and lime-mediated alkalinity may account for the lethal effects of Green DAC on *F. candida* adults. These findings reinforce the need for proper DAC recycling. While asbestos deactivation effectively eliminates its hazard in the built environment, improper disposal or soil contamination may pose ecological risks. Recycling DAC into stable matrices, such as ceramics or mortar, minimizes environmental contamination while promoting circular economy.

1. Introduction

Asbestos is a fibrous material that has been used in a variety of applications because of its physical strength, thermal and acoustic insulation properties, chemical and fire resistance, etc. It has been used in about 3000–5000 different applications (Frank and Van Zandwijk, 2024), but those volumetrically more important are related to the construction industry, as roofing tiles (Eternit®), vinyl-asbestos floors, thermal and acoustic insulating panels, chimneys, water tanks and pipelines.

Once established that the inhalation of asbestos fibres causes serious pulmonary diseases, starting from the 1980s asbestos has been banned in most world countries, but after about one century of global asbestos production and usage, there are enormous amounts of asbestos containing materials (ACM) hidden inside buildings and water pipes all over the world. Moreover, several countries continue to mine asbestos, such as Russia, the largest asbestos producer in the world, mining some 700,000 metric tons each year, followed by Kazakhstan (230,000 mt/y), China (120,000 mt/y) and Brasil (110,000 mt/y). Major users are China and India, together using about one-half of all asbestos used in the world. Worldwide an estimation of 125 million workers continues to be exposed to asbestos almost every day. Annual asbestos deaths worldwide are estimated to be 250,000 (Frank and Van Zandwijk, 2024).

The current strategies for asbestos remediation, namely confinement (i.e., creating a physical barrier that separates the ACM from the environment), insulation (treatment with resins that holds asbestos fibres within the ACM) and landfilling (the most used, while producing toxic and harmful waste), do not eliminated the health risk and throw away a potential secondary raw material.

Smarter solutions for asbestos remediation have been recommended by the European Community with the resolution 2012/2065(INI) on “Asbestos related occupational health threats and prospects for abolishing all existing asbestos” dated 14/3/2013. Basically, it encourages energy sustainable methods of asbestos detoxification followed by reutilization of the treated material as secondary raw material in a perspective of circular economy. Since then, several processes have been investigated and, in some cases, patented, founded either on physical (mechanical and thermal) or chemical or biological methods or a combination of a couple of them (for a review see Spasiano and Pirozzi, 2017; Paolini et al., 2019). Regarding biological methods, although asbestos is highly resistant to degradation, recent studies suggest that bioremediation, i.e. the use of microorganisms to remove heavy metals

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or other toxic compounds by converting them into less harmful forms (Turan, 2024a and references therein), might contribute to its weathering by extracting key elements such as iron and magnesium from asbestos fibres, thereby reducing their toxicity (Spasiano and Pirozzi, 2017). Moreover, physical and biochemical interactions between rhizosphere fungi and asbestos fibres could offer promising perspectives for asbestos bioremediation (Farhad et al., 2024; Ilyas et al., 2024). However, bioremediation strategies are slow processes highly influenced by environmental conditions. About the other available methods, thermal processes remain the most effective, despite the high energy requirements, and chemical methods have to deal with the high cost of reagents employed and the disposal of the large amount of highly acidic fluids produced (Spasiano and Pirozzi, 2017; Paolini et al., 2019).

In this context, we thermally treated asbestos cement slates commonly used in the past for roofing, following two different thermal processes (see ahead). Both processes revealed effective in transforming the original asbestos and associated minerals of the original slates in non-toxic minerals and glass. However, since the ultimate goal of the deactivation process is the reutilization of the treated material in several applications, as in ceramics, cement, polymers, etc. (e.g. Bernasconi et al., 2022; Campanale et al., 2023; Capitani et al., 2024a, 2024b), at least two aspects arise as contingent: (i) the sustainability of the entire process, including not only its environmental impact but also its economic feasibility through the valorization of hazardous byproducts, as demonstrated in other contexts such as arsenic remediation (Koley, 2023) or end-of-life tyres (Gigli et al., 2019); (ii) the safety of the material obtained from the thermal inertization (deactivation). As regard the former, the subject has been tackled by a recent paper by Ferrini et al. (2024) by means of life cycle assessment and cost–benefit analysis, finding that inertization technologies and recycling can provide a sustainable alternative to deep landfill burial. The latter is explored in this study, where we aim to evaluate the potential ecotoxicological risks of thermally deactivated asbestos cement (DAC) when introduced into soil ecosystems. Specifically, we assess the survival and reproductive responses of the soil model organism *Folsomia candida* upon exposure to different DAC formulations, simulating potential environmental contamination scenarios. By identifying toxicity differences between DAC variants and linking them to the mineralogical composition, our findings provide essential insights into the safe recycling and sustainable management of DAC.

Collembola are among the most abundant soil-dwelling organisms, playing a critical role in terrestrial ecosystems by facilitating organic matter decomposition, driving nutrient cycling, supporting energy flow in above- and below-ground food webs, regulating microbial community dynamics, and serving as an important prey base for soil predators (Potapov et al., 2023; Negri, 2004; Fountain and Hopkin, 2005). Their close interaction with the soil environment and direct exposure to potential contaminants make these insects valuable bioindicators for assessing soil pollution. Among collembola species, *F. candida* is the most widely used model organism (Popescu et al., 2024) and is recognized as a standard test species for ecotoxicological studies by both the International Organization for Standardization (ISO) and the Organization for Economic Cooperation and Development (OECD) (International Organization for Standardization (ISO), 2011; Organization for Economic Cooperation and Development OECD, 2016, International Organization for Standardization (ISO), 2014). In the present study, the potential sub-lethal effects, such as changes in reproduction, behaviour, or survival of *F. candida* exposed to soil contaminated by different DAC powders are assessed. Our results will help safeguarding soil ecosystems and supporting the sustainable reuse of DAC.

2. Experimental

2.1. Deactivated cement-asbestos

Asbestos cement slates were thermally treated according to two different thermal processes, one operating at 1100 °C under oxidising conditions in a static furnace, and another operating at 1150 °C under reducing conditions in a continuous kiln (details in Vergani et al., 2022; Marian et al., 2021, respectively). Since after the treatment under oxidising conditions the asbestos cement slates assumed a reddish colour, for brevity, the sample obtained with this process has been named "Red". Analogously, those treated under reducing conditions assumed a greenish-grey colour and the related product has been named, for brevity, "Green" (Fig. 1).

The products of the thermal inertization were characterized with several instrumental analyses, including scanning (SEM) and transmission electron microscopy (TEM) and X-ray powder diffraction (XRPD), aiming at certifying the disappearance of the dangerous asbestos fibres and fibrils (thin fibre fragments). All converged in assessing the complete transformation of asbestos and associated minerals occurring in the original cement asbestos slates into non-toxic minerals and glass (Marian et al., 2021; Vergani et al., 2022). The chemical composition and the mineralogical association of the Red and Green samples used in the experiments were obtained by energy dispersive X-ray fluorescence (EDXRF; PANanalytical Epsilon 3X) and by XRPD (PANalytical X'Pert-Pro PW3060), respectively. The volatile content was determined by loss on ignition (LOI) at 960 °C.

As it can be realized from Fig. 1, after the thermal treatment the DAC slates – although deeply transformed inside – preserve their external shape. Therefore, before the reuse as secondary raw material, they must be fragmented and powdered. In the present case we used a centrifugal ball mill (Retsch S100) for ten minutes to get the desired powder. Because the grain size distribution may be a critical parameter in some applications, the Red and Green DAC powders were also characterized by dynamic laser scattering (DLS; Malvern Mastersize APA 2000).

2.2. Ecotoxicological tests

The ecotoxicological tests were conducted in accordance with the OECD Guideline 232 (2016) for Collembola reproduction tests in soil, with minor modifications. In brief, 9–12 day-old juveniles of *Folsomia candida*, cultured under controlled conditions (20 ± 1 °C, 80 % relative humidity, RH) in the Entomology Laboratory at Università Cattolica del Sacro Cuore, were utilized for the experiments. Tested ratios were 1:1 and 1:10 DAC powder:soil (Lufa 2.2, Speyer, Germany). LUFA 2.2 standard soil is a sandy loam with 1.84 % ± 0.48 organic carbon, 0.21 % ± 0.05 nitrogen, pH of 5.66 ± 0.23, cation exchange capacity of 9.46 ± 1.33 meq/100 g, and maximum water holding capacity of 46.6 % ± 3.5 (g/100 g). The experiments were performed in triplicate for each ratio, using both Red and Green DAC powders (hereafter just "Red" and "Green", respectively), along with three control replicates containing only standard soil. The 1:1 mix consisted of 9 g of Red or Green mixed with 9 g of control soil, while the 1:10 mix consisted of 0.9 g of Red or Green and 8.1 g of soil. The soil and DAC powder were mixed thoroughly in a glass beaker using a metal spatula. The pH of the different mixtures, measured using the 1:5 soil–water suspension method, was as follows: 7.4 for both the 1:10 Red and Green mixtures; 10.1 and 11.9 for the 1:1 Red and Green mixtures, respectively; and 6.3 for the control soil (International Organization for Standardization (ISO), 2005).

For the ecotoxicological tests, Petri dishes were prepared with a base layer of gypsum and graphite and filled with either 6 g of the 1:1 mixture or 3 g of the 1:10 mixture. After 24 h, ten synchronized juveniles of *F. candida* were added to each dish, along with approximately 2.5 mg of baker's yeast as food (Fig. 2). The Petri dishes were placed in a climate chamber at a temperature of 21 ± 1 °C and 80 % RH and incubated for 28 days. Water and yeast were added periodically as needed. On day 28, individuals from each dish were retrieved by flotation. Adults and juveniles were counted to assess treatment effects.

To compare the survival of *F. candida* adults exposed to Red samples, the non-parametric Kruskal-Wallis test was applied, as the Shapiro-Wilk test for normality indicated that not all mixture groups (0, 1:10, and 1:1

Fig. 1. Top: “Red” DAC; bottom: “Green” DAC; left: asbestos cements slates after thermal deactivation; right: powdered DAC.

Red:soil ratios) followed a normal distribution. For all other analyses, i.e. the number of developed juveniles in the Red test (0, 1:10, and 1:1 mixtures) and the survival of adults and the number of developed juveniles in the Green tests (0, 1:10, and 1:1 mixtures), a one-way Analysis of Variance (ANOVA) was performed. This was followed by Tukey’s Honestly Significant Difference (HSD) post-hoc test at a significance level of $\alpha = 0.05$.

3. Results

3.1. *Deactivated asbestos cement*

The chemical and mineralogical compositions of the Red and Green samples used in the experiments are reported in Table 1 and Table 2, respectively. Major chemical differences are in the CaO/SiO_2 ratio and total iron, both inherited from the original asbestos cement slates (hereafter ACS), since only volatile components (H_2O, CO_2) are supposed to evolve during the thermal treatment. The higher water content of the Green sample may be due to water resorbed during storage.

Major differences also exist in the recrystallized phases, which reflect the original CaO/SiO_2 ratio of the ACS: mostly Ca-Mg-silicates in the Red sample (åkermanite, bredigite, merwinite); mostly Ca-silicates (jasmundite, larnite) and CaO (lime) in the Green sample. Apparently, the MgO component is taken up by periclase and minor monticellite in the Green sample. The glass content is high, the most abundant phase in both DAC samples ($\sim$40 % by weight).

The results of DLS experiments are summarized in the grain size distributions curves reported in Fig. 3. Both samples show a trimodal distribution, although more pronounced in the Red sample than in the Green one, which spans from $\sim$400 nm to $\sim$100 μm for the Red and form $\sim$500 nm to 200 μm for the Green. Most probably the shown lower limit represents either the sensibility limit of the instrumentation or the fact that small particles may aggregate, more than the actual material grain size, because, as observed by TEM, actual nanoparticles, e.g. particles smaller than 100 nm, are present in both materials (Marian et al., 2021; Vergani et al., 2022).

3.2. *Ecotoxicological impact on Folsomia candida*

The Kruskal-Wallis test carried out to compare the survival of adults exposed to Red samples revealed no statistically significant differences ($p = 0.777$; Fig. 4). The statistical analysis on the number of juveniles showed a significant difference between the groups (ANOVA, $F = 8.77$, $p = 0.017$), with post-hoc Tukey’s HSD test indicating a significant reduction in juvenile development in the 1:1 Red:soil mixture compared to the control ($p = 0.0136$; Fig. 4). However, no significant differences were observed between the control and 1:10 concentration or between the 1:10 and 1:1 concentration.

To compare the effects of the different concentrations of Green (0, 1:10, and 1:1) on adult survival a one-way ANOVA was carried out. The

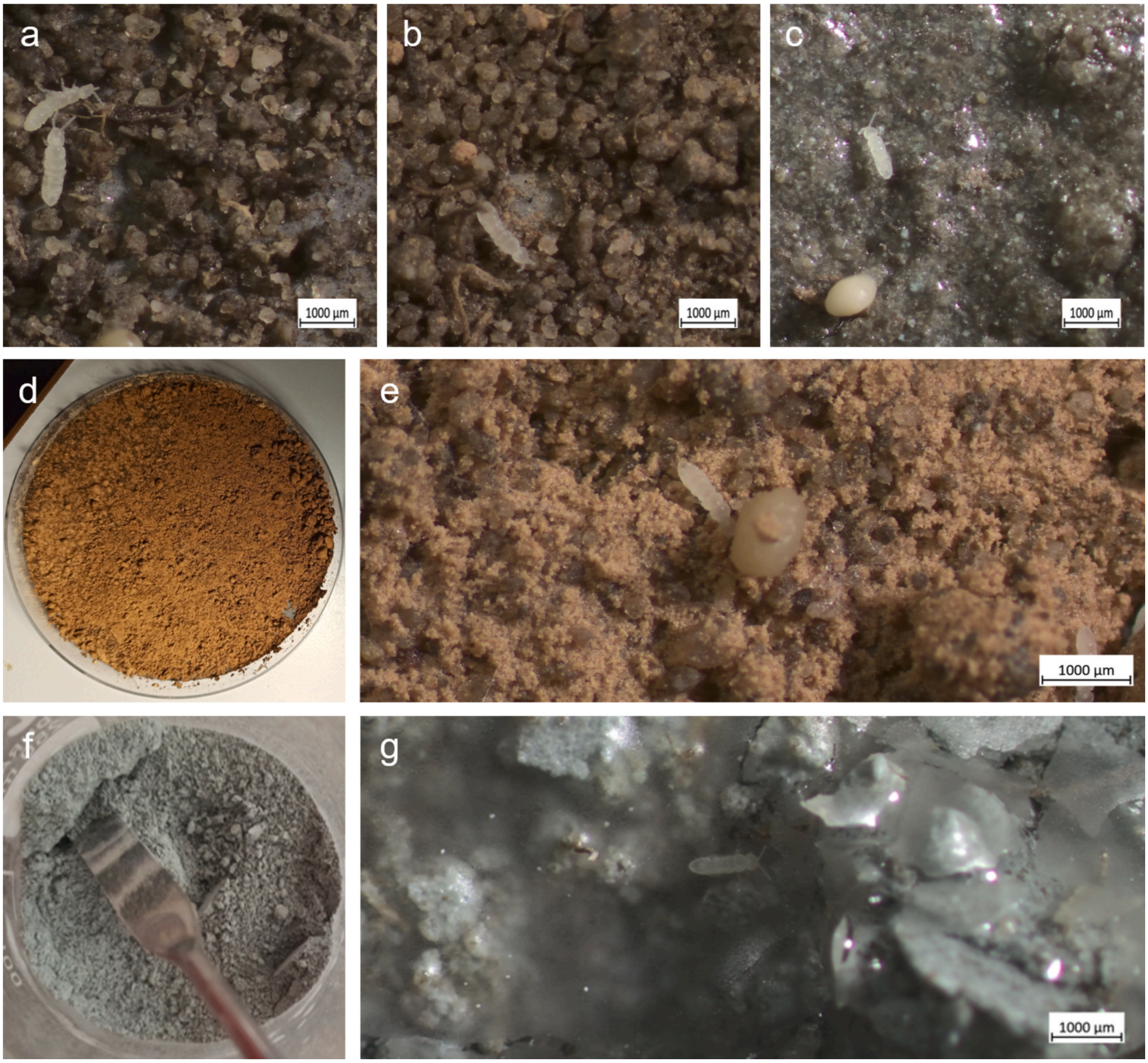

Fig. 2. *F. candida* ecotoxicological tests: (a) control test with LUFA soil; (b, c) exposure tests with Red:soil and Green:soil mixtures at a 1:10 ratio; (d) preparation of Red:soil mixture at a 1:1 ratio; (e) exposure tests with Red:soil mixture at a 1:1 ratio; (f) preparation of Green:soil mixture at a 1:1 ratio; (g) exposure tests with Green: soil mixture at a 1:1 ratio.

Table 1
Chemical compositions (wt%) of Red and Green samples used in the experiments.

	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	Cl	K_2O	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3	NiO	SrO	ZrO_2	SnO_2	H_2O	Total
Red	0.17	7.68	3.90	30.41	3.11	–	0.42	47.38	0.23	–	0.43	5.94	–	–	–	–	0.32	99.99
Green	–	7.43	3.09	20.01	3.78	0.06	0.22	59.72	0.23	0.04	0.39	2.61	0.03	0.13	0.01	0.02	2.25	100.02

Table 2
Mineralogical compositions of Red and Green samples used in the experiments.

Phase	Ideal chemical formula	Red	Green
Åkermanite	$Ca_2Mg(Si_2O_7)$	19.33	–
Bredigite	$Ca_{13.5}Ba_{0.3}Mg_{1.8}Mn_{0.4}Si_9O_{32}$	19.25	–
Jasmundite	$Ca_{11}(SiO_4)_4O_2S$	–	17.49
Larnite	Ca_2SiO_4	3.67	19.08
Lime	CaO	–	8.51
Mayenite	$Ca_{12}Al_{14}O_{32}Cl_2$	–	3.73
Merwinite	$Ca_3Mg(SiO_4)_2$	17.84	–
Monticellite	$CaMgSiO_4$	–	1.51
Periclase	MgO	–	5.58
Glass	–	39.9	44.1

analysis revealed a statistically significant difference between the groups (p = 0.00024), with post-hoc Tukey's HSD test showing that the survival rate in the control group (mean = 7.0) was significantly higher than the 1:1 concentration group (mean = 0.33, p = 0.00056; Fig. 4c), but not significantly different from the 1:10 concentration group (mean = 5.0, p = 0.07048; Fig. 4c). Additionally, the 1:10 concentration group had a significantly higher survival rate than the 1:1 concentration group (p = 0.00219; Fig. 4c). These results suggest that higher concentrations of Green negatively impact adult survival, with the 1:1 concentration showing the most pronounced effect. The statistical analysis revealed significant differences in the number of juveniles across the tested concentrations (Fig. 4d). While no progeny has been produced in the 1:1 Green:soil ratio, juveniles were present in the 1:10 concentration. A one-

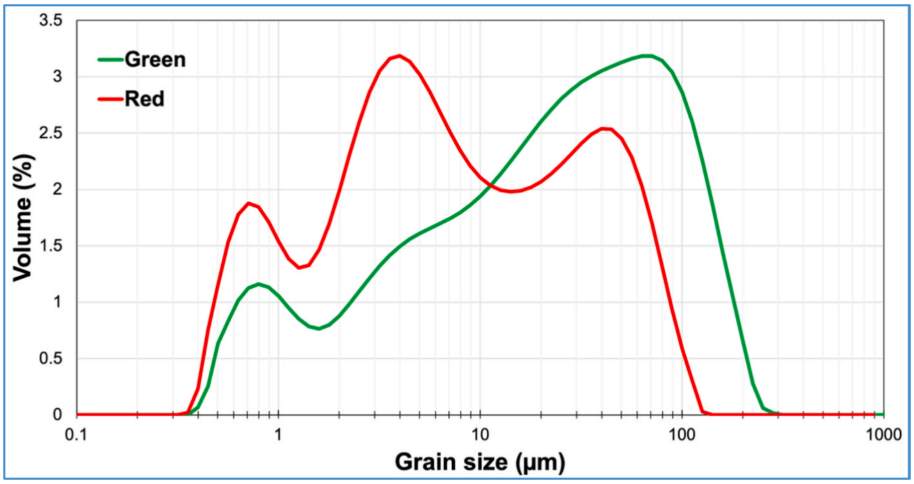

Fig. 3. Grain size distribution of the Red and Green samples employed in the experiments.

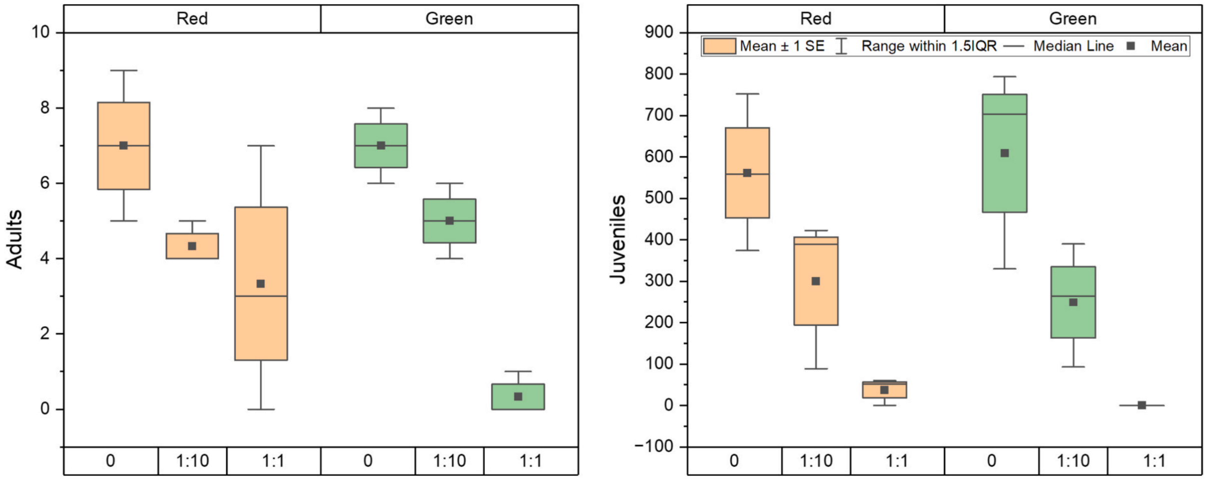

Fig. 4. Survival and reproduction of *F. candida* exposed to different concentrations of Red and Green powders. The y-axis represents the number of survived adults (left) and developed juveniles (right) at the end of the exposure tests; the x-axis represents the different concentrations of the tested materials mixed with soil (0, 1:10, 1:1, respectively).

way ANOVA indicated a statistically significant effect of the concentration on juvenile counts ($p = 0.012$), with post-hoc Tukey's HSD test showing that the control group had significantly higher juvenile counts compared to the 1:1 Green:soil mixture ($p < 0.01$), while the difference between the control and the 1:10 concentration was not statistically significant. Additionally, no significant difference was observed between the 1:1 and 1:10 concentrations. These results suggest a concentration-dependent reduction in juvenile counts, with the 1:1 concentration having the most pronounced effect.

4. Discussion and conclusions

The results of our study indicate differing toxicity profiles for the two tested substances. Red DAC did not induce adult lethality at the tested concentrations. However, a significant reduction in juvenile production was observed at the higher concentration (1:1), highlighting reproduction as a more sensitive endpoint than adult survival. In contrast, Green DAC caused adult lethality at 1:1, with no juveniles produced at this concentration. These data suggest that while Red DAC primarily exerts sub-lethal effects on reproduction, Green DAC displays both acute and chronic toxicity at higher concentrations. The absence of juvenile production for the Green DAC 1:1 treatment may result from direct embryotoxicity or the inability of adults to reproduce (but also to survive) under these conditions. A possible explanation for the differing toxicity between the Red and Green samples may be related to their different mineralogical compositions. Both materials contain a high percentage of silica-based glass powder, which is the most abundant phase (Table 2). Silica-based powders, such as diatomaceous earth and silica nanoparticles, are well-known "mechanical" insecticides that promote insect dehydration. Indeed, fine particles of silica glass can adhere to the insect's exoskeleton, absorbing lipids from the epicuticle and causing the insect to lose moisture, leading to dehydration and death (Cáceres et al., 2019; Zeni et al., 2021; Saw et al., 2023). Collembola, including *F. candida*, have a highly permeable cuticle that makes them particularly sensitive to desiccation, with juvenile forms and eggs being the most vulnerable (Fountain and Hopkin, 2005; Holmstrup, 2019).The Red and Green samples used in our study contain approximately 40 % and 44 % silica, respectively. This means that the final silica concentration in the 1:10 soil mixtures is up to 4 %, which is unlikely to harm *F. candida*. Additionally, the insecticidal effectiveness of silica-based powders may be influenced by the soil humidity during the exposure tests as previous studies indicate that the higher the humidity levels, the lower the desiccation-driven toxicity (Cook and Armitage, 2000).

In 1:1 mixtures, the silica concentration increases to 20 % and 22 % for the Red and Green DAC, respectively, potentially causing detrimental effects on juvenile forms that are more sensitive to dehydration than adults. However, a reproductive effect of silica glass, specifically targeting adults, cannot be ruled out. Indeed, previous studies have demonstrated that silica-based powders, such as diatomaceous earth, can impair reproduction in certain insect species by reducing egg-laying rates and affecting egg hatchability (Krzyżowski et al., 2019).

The alkaline pH of Red DAC 1:1 mixtures may also play a role in their sublethal toxicity. Indeed, previous studies indicated that both acidic (<5) and alkaline (>8) conditions negatively affect egg production and juvenile development (Crouau and Cazes, 2003). Further studies are needed to clarify the precise mechanisms underlying the sublethal toxicity of Red DAC, particularly whether its effects are primarily directed at reproduction (adults) or development (eggs/juveniles).

The lethal toxicity of the 1:1 Green DAC:soil mixture on *F. candida* adults may be attributed to the additional presence of calcium oxide (CaO), which constitutes 8.5 % of the material. Calcium oxide is a highly reactive substance that reacts with water forming calcium hydroxide ($Ca(OH)_2$), resulting in a strong pH-disrupting effect which contributes to its well-documented antimicrobial and insecticidal activity (European Food Safety Authority (EFSA), 2020; Ayoub et al., 2022; Inbaraj et al., 2023; Yu et al. 2023). Studies indicate that *F. candida* is relatively insensitive to soil pH, with a slight preference for pH 5.6, and can survive across a relatively wide pH range (Luo et al. 2022). However, exposure to highly alkaline conditions as those present in Green DAC 1:1 is likely lethal due to severe physiological stress (Hutson, 1978). Furthermore, Green DAC shares chemical and mineralogical similarities with clinker, a material known for its potentially harmful effects on soil biota (for a review see Iqbal et al., 2024).

Finally, as regard the possible role of the different grain size distribution in the toxicity of Red and Green DAC, it is worth noting that both samples have a trimodal grain size distribution, although more pronounced in the Red than in the Green, and similar grain size ranges (~400 nm–100 μm and ~500 nm–200 μm, respectively, Fig. 3). Therefore, it is unlikely that these small differences could have determined the different toxicity recorded for the Red and Green DAC powders, influencing, for instance, their bioavailability and direct interaction with *F. candida*.

Beyond the harmful effects on *F. candida*, the presence of DAC in soil may have broader ecological implications for soil health and nutrient cycling. Collembola play a critical role in organic matter decomposition, facilitating nutrient cycling by fragmenting detritus, enhancing microbial activity, and contributing to soil structure (Potapov et al., 2023; Papa et al., 2023). Any decline in collembolan populations due to DAC exposure could therefore disrupt these processes, potentially slowing organic matter turnover, affecting plant nutrient availability, and altering microbial community composition. Further studies involving other key soil organisms, including for example protists, earthworms, and soil microbial community compositions (Turan, 2024b; Calisi et al., 2025; Vaccari et al., 2022), are needed to assess the broader ecological consequences of DAC contamination and its potential long-term effects on soil biodiversity, nutrient cycling, and ecosystem resilience.

This study also highlights the importance of assessing multiple ecotoxicological endpoints, as observed in previous research on *F. candida* toxicity to chemical mixtures (Amorim et al., 2012). The differentiation between reproductive and survival effects observed in Red and Green DAC further supports the need for comprehensive risk assessment frameworks that consider both lethal and sub-lethal endpoints in evaluating the environmental impact of industrial by-products. However, for a more comprehensive ecological risk assessment, multiple groups of organisms should be included and any possible synergistic effects arising from the presence of additional chemical stressors should be evaluated.

In conclusion, the accidental contamination of soil by DAC powder or the direct disposal in landfills may be harmful for the soil ecosystem, and should be avoided. While the hazard represented by the toxic asbestos fibres can be effectively removed by thermal inertization (Gualtieri and Zanatto, 2009; Marian et al., 2021; Vergani et al., 2022), the potential ecological risks associated with silica glass and lime content must also be considered. This observation further reinforces the common perception that the right route to solve the asbestos problem still present in the built environment is through deactivation and recycling. Indeed, as demonstrated by numerous studies, DAC can be successfully recycled as secondary raw material in mortar (Gualtieri and Boccaletti, 2011; Viani and Gualtieri, 2013; Capitani et al., 2024a), ceramics (Gualtieri and Tartaglia, 2000; Ligabue et al., 2020; Bernasconi et al., 2023), polymers (Campanale et al., 2023), stone wool (Capitani et al., 2024b), and some other applications (Gualtieri et al., 2011). Once within these matrices, the DAC powder is either well confined or transformed and, in all cases, diluted, therefore reducing the possibility of accidental contamination of the environment at significant level. As further encouragement towards this circular economy route, in a recent paper Ferrini et al. (2024) present a life cycle assessment with an extended cost–benefit analysis about the thermal inertization of asbestos cement, providing insights into the financial, economic, and environmental dimensions of asbestos-containing waste and concluding that inertization technologies can provide a sustainable alternative to deep landfill burial.

CRediT authorship contribution statement

Ilaria Negri: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Data curation, Conceptualization. **Erica Saldi:** Writing – review & editing, Visualization, Investigation, Formal analysis, Data curation. **Giancarlo Capitani:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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