

## Non-Metal Roofs as a Source of Stormwater Pollution

### Les toitures non métalliques en tant que source de pollution des ruissellement urbains

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#### RÉSUMÉ

Les ruissellements urbains contiennent des polluants qui détériorent la qualité des eaux de surface et souterraines si elles sont rejetées sans traitement. Afin d'éviter la pollution et de développer des installations de traitement, il est essentiel de comprendre les sources des substances dangereuses. Si le comportement de lixiviation des toitures métalliques a été largement étudié, celui des toitures non métalliques est encore mal enquêté, en particulier quant aux toitures inclinées. Des tests de lixiviation en laboratoire ont été réalisés sur 15 matériaux de toiture: tuiles en terre cuite, tuiles en béton, bardeaux de bois, panneaux en fibrociment, bardeaux bitumés et tuiles en plastique. L'éluat a été analysé afin de déterminer différents paramètres organiques et inorganiques typiquement présents dans les ruissellements urbains. Ensuite, des essais de terrain ont été réalisés : Pendant un an, des toitures à l'échelle pilote ( $n = 3$ ) ont été exposées aux intempéries, et les ruissellements de tous les événements pluvieux ont été collectés et analysés pour les paramètres trouvés dans les tests en laboratoire. Les résultats ont montré que plusieurs matériaux libèrent des concentrations de substances dangereuses significatives en laboratoire et en essai de terrain : les bardeaux de bois traités sont une source importante de B, Cu et  $\text{NH}_4^+$ . Les tuiles en béton libèrent le biocide terbutryne et les produits de transformation associés et les tuiles en argile lessivent du V. Ces résultats soulignent le rôle des toitures non métalliques en tant que source de pollution des ruissellement urbains.

#### ABSTRACT

Urban stormwater runoff contains pollutants that deteriorate the quality of surface and groundwater when discharged untreated. To prevent pollution and to develop treatment facilities, understanding the sources of hazardous substances is essential. While the leaching behavior of metal roofs is well investigated, the contribution of non-metal roofing materials, especially for inclined roofs, to stormwater contamination is still poorly investigated. Based on a market and literature study to determine the most used non-metal roofing materials in Germany, laboratory leaching tests were conducted in the first step with 15 selected roofing materials: clay tiles, concrete tiles, wood shingles, fiber cement panels, bitumen shingles, and plastic tiles. The eluate of the lab test has been analyzed for different organic and inorganic parameters that occur in urban stormwater. The laboratory test results provided the basis for the subsequent field test. For a period of one year, pilot-scale roofs (triplicates) were exposed to weathering, and runoff from all rain events were collected and analyzed for the parameters found in the lab test. Results showed that several materials release environmentally relevant concentrations of hazardous substances in the lab and field: treated wood shingles are a strong source of B, Cu, and  $\text{NH}_4^+$ . Concrete tiles release the biocide terbutryn and associated transformation products, and clay tiles leach V. These findings highlight the role of non-metal roofing materials as pollutant sources in urban runoff.

#### KEYWORDS

diffuse pollution, heavy metals, roofing materials, stormwater quality, terbutryn

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## 1 BACKGROUND

The contact of rainwater with sealed surfaces in urban areas has an impact on its quality (Charters et al., 2021; Müller et al., 2023). Studies analyzing urban runoff in separate sewer systems have measured various pollutants, e.g., heavy metals, biocides, and other organic substances such as bisphenol A (Wicke et al., 2021; Zhang et al., 2024). To avoid or reduce stormwater pollution, it is essential to know the origin of the pollutants. Regarding potential contamination from roofing materials, metal roofs and their release of heavy metals have been thoroughly investigated (Galster & Helmreich, 2022). Additionally, bitumen membranes on green roofs that use Mecoprop or Mecoprop-releasing chemicals as root protection agents (Burkhardt et al., 2011). Roofing membranes typically used on flat roofs have been analyzed in detail by De Buyck et al. (2021a). However, few research was conducted regarding the role of common non-metal materials used on inclined roofs.

Two review articles have already shown that stormwater runoff from various non-metal roofs is a diffuse source of pollutants (De Buyck et al., 2021b; Degenhart & Helmreich, 2022). However, the available data often lack sufficient information on atmospheric deposition, the materials used for gutters, or other external factors that influence roof runoff. Additionally, only selected materials and parameters have been analyzed. Therefore, no clear, statistically relevant statements can be made about pollutant emissions for most non-metallic roofing materials. The release of substances from building products without external influences can be determined by laboratory leaching tests. For building products, the dynamic surface leaching test (DSLTL) described in DIN EN 16637-2 should be used. Laboratory leaching tests help identify which substances can leach from the examined materials (De Buyck et al., 2021b; Müller et al., 2021). However, field studies are required to assess and quantify the concentrations of these substances under real rainwater matrix and climatic conditions (Müller et al., 2021). All in all, there is a lack of studies containing systematically determined data for non-metal roofing materials in standardized laboratory leaching and field tests.

This gap was closed by conducting comprehensive laboratory tests on 15 non-metal roofing materials for commonly used inclined roofs. Based on the laboratory test results, runoff from six selected roofing materials was sampled in a 12-month field test under real weather conditions. The tests provide information about leachable pollutants, their concentrations, and thus enable risk assessment and the development of measures to minimize harmful environmental impacts.

## 2 METHODS

### 2.1 Laboratory Tests

After conducting literature and market research, the following most used materials (in Germany) were selected for the laboratory leaching test: four clay tiles, two concrete roofing tiles, fiber cement panels and shingles, untreated and treated wood shingles, two bitumen shingles, artificial slate panels, and two plastic roofing tiles. The DSLTL (double determination) comprises eight leaching cycles over a total period of 64 days. Next to standard sum parameters like pH-values, electrical conductivities, and DOC, the eluate concentrations and the (cumulative) area-related emissions for inorganic parameters and biocides were determined. Phthalates, polychlorinated biphenyls, PFAS, PAHs, nonylphenol, and bisphenol A were examined in a mixed sample of each eluate. A detailed description was published in (Udvary et al., 2025).

### 2.2 Pilot Scale Field Tests

Six of the 15 roofing materials were selected and built as triplicates with an area of approximately 1 m<sup>2</sup> in the field: engobed clay tiles, black concrete roofing tiles, fiber cement panels, plastic roofing tiles, treated wood and bitumen shingles. Additionally, three stainless steel roofs were installed as blank values. Over a period of 12 months, the runoff from the individual test roofs will be analyzed after each rainfall event according to the parameters found in the laboratory test.

### 3 RESULTS

#### 3.1 Laboratory Test Results

The results of laboratory tests show that non-metallic roofing materials can be a source of several pollutants in urban runoff. Treated wood shingles release high concentrations of copper, boron, and ammonium. The different clay roofing tiles are a source of arsenic, manganese, and/or vanadium. Concrete roofing tiles and fiber cement materials release relevant amounts of various biocides, such as OIT, BIT, IPBC, and terbutryn. An analysis of further organic substances in a mixed sample of the eluates showed that bitumen shingles can be a source of bisphenol A. The laboratory tests also indicate the release mechanism: here, in most cases, the substances are released by diffusion. (Udvary et al., 2025)

#### 3.2 Field Test Results

Sampling of runoff from the pilot-scale roofs started at the beginning of 2025. Analysis of 6 months sampling corresponding to 29 runoff samples shows, among others, the following mean concentrations: treated wood shingles released 7.73 mg/L  $\text{NH}_4^+$ , 0.79 mg/L B, and 5.82 mg/L Cu, clay tiles released 4.94  $\mu\text{g/L}$  V, concrete roofing tiles released 9.06  $\mu\text{g/L}$  terbutryn, and between 16.7 - 21.3  $\mu\text{g/L}$  of three terbutryn transformation products, bitumen shingles released 29.1  $\mu\text{g/L}$  Cu and some bisphenol A in the first rain events. The same observations can be made for OIT from concrete tiles, pointing out that OIT was only used as a can-preservative, which explains the fast leaching, while terbutryn is used as a film-preservative and released continuously over time. Overall, the field results indicate that non-metal roofing materials, particularly treated wood shingles and concrete roofing tiles, release environmentally relevant substances. The sampling will be continued for at least 6 more months to gain insights into annual mean concentrations and runoff rates.

#### 3.3 Lab vs. Field

To compare the laboratory and field experiments, sample concentrations were transformed into cumulative area-specific releases ( $\text{mg/m}^2$ ) and visualized as a function of cumulative contact water volume ( $\text{L/m}^2$ ). Selected results for one treated wood shingle roof are displayed in Figure 1.

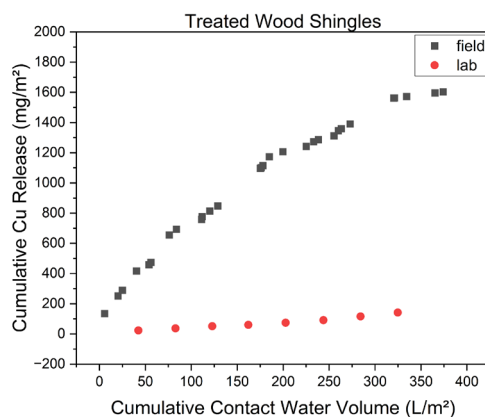


Figure 1: Cumulative release of pollutants from a treated wood shingle roof (triplicate) in  $\text{mg/m}^2$  per cumulative contact water volume in  $\text{L/m}^2$

Overall, laboratory tests have provided a good qualitative indication of the possible released pollutants. However, field tests are necessary for a quantitative assessment of the distinct pollutant releases. Concentrations in the lab sometimes overestimate and sometimes underestimate the concentrations in the field.

#### 3.4 Outlook

Field sampling will be completed at the beginning of 2026. Based on the full year of data, the leaching behavior and mechanisms of the substances will be evaluated using the laboratory results. Furthermore, annual mean concentrations and annual runoff rates per  $\text{m}^2$  will be calculated. Additionally, the influence of factors such as temperature, rain intensity, and antecedent dry days will be assessed.

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The data obtained from laboratory and field tests on material emissions will finally be used to derive recommendations for regulations on the handling of contaminated roof runoff. The findings can also serve as a basis for the development of rainwater treatment plants. The aim is to enable the sustainable use of stormwater from urban areas and to prevent pollution of our water bodies.

**Funded** by the Federal Institute for Research on Building, Urban Affairs, and Spatial Development on behalf of the Federal Ministry of Housing, Urban Development, and Construction from funds provided by Zukunft Bau Research Funding (10.08.18.7-23.15.2).

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