Biocides in urban environments – A growing concern?

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Our urban Environment

- **Buildings with different architecture – height, structure etc.**

www.rnz.de/nachrichten/bergstrasse_artikel,-Bergstrasse-16-Haeuser-in-Altenbacher-Neubaugebiet-geplant-_arid,229891.html

Different Materials

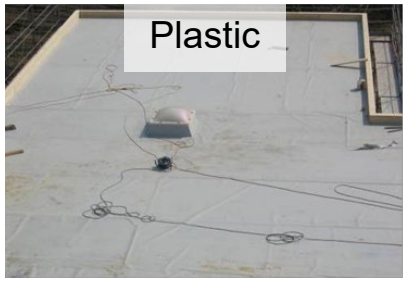
- **… bricks, bituminous, polymeric, glass, wood, metal, concrete ...**

Large Variety of Products

- **Different products – polymeric and mineral paints, uncoated and coated tiles etc.**

Construction Products

- **Additives (increasing market share)**
  - Biocides
  - Root protection agents
  - Vulcanizers
  - Phthalates
  - UV-Filter
  - Flame retardants
  - Antioxidants
  - Nano- and microplastics
- **Concern**
  - Persistent, mobile and toxic (PMT)



Additives used in Construction Products (Examples)

- **Biocides in wood preservatives (regulated by BPR)**
  - Active ingredients as IPBC, Permethrine, Tebuconazole, Propiconazole etc.
- **Additives as anti-root penetration agents (no biocides, not much regulated)**
  - Esters of Mecoprop-P (MCPP) or MCPA in bitumen sheets (used as pesticides)

1 Burkhardt, et al. (2016): Biozidprodukte – Eintrag in Gewässer. Aqua und Gas, 4: 46-54. ; 2 Gartiser et al. (2015): Reduction of environmental risks from the use of biocides. Report, UBA, Dessau-Rosslau.
3 Vermeirssen et al. (2017): Corrosion protection products as a source of bisphenol A and toxicity to the aquatic environment. Wat. Res., 123:586-593

What are Biocides?

- **Biocidal active substances or preparations (21 product types)**
  - Positive: Prevent or mitigate the effects caused by harmful organisms (bacteria, etc.)
  - Negative: They are intended to destroy or deter organisms – biological mode of action

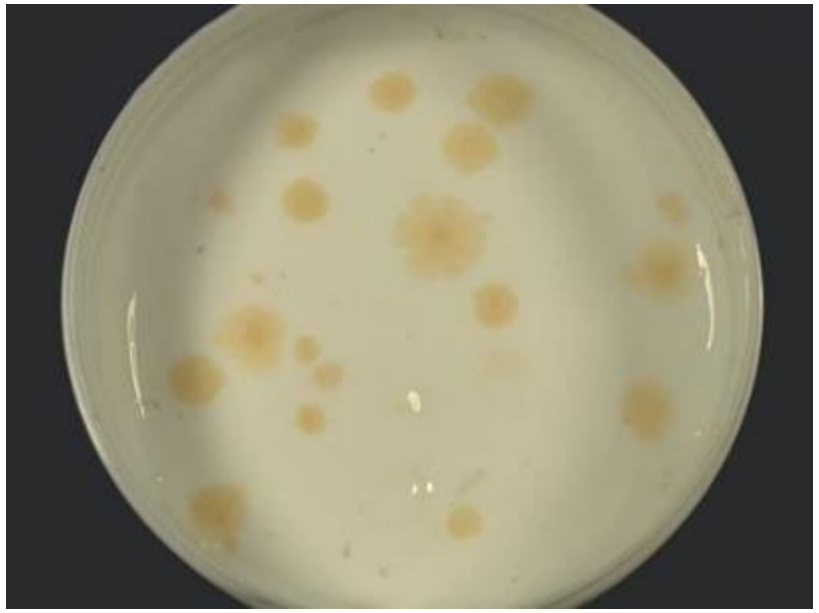

Material protection

Disinfection


Antifouling

Example of Biocides: Plasters and Paints for Façades

- **Controlling microbial growth (algae, fungi) in waterborne products**
  - In the container (in-can preservatives; PT 6) and on the façade (film preservatives; PT 7)
  - Infestation causes visual damage and leads to warranty cases and reclamations



Biocides in Façade Coatings

- **Amounts (PT 7)**
  - 2 to 4 biocides in combination - 500 to 6000 mg/m^2 per active ingredient
  - In Germany, 120 to 280 tons per year (declined by 30 % in 10 years)
- **Concern**
  - Substance with long half-life (slow degradation)

Againts Algae	Degradation
Terbutryn	slow
Diuron	slow
Isoproturon	slow

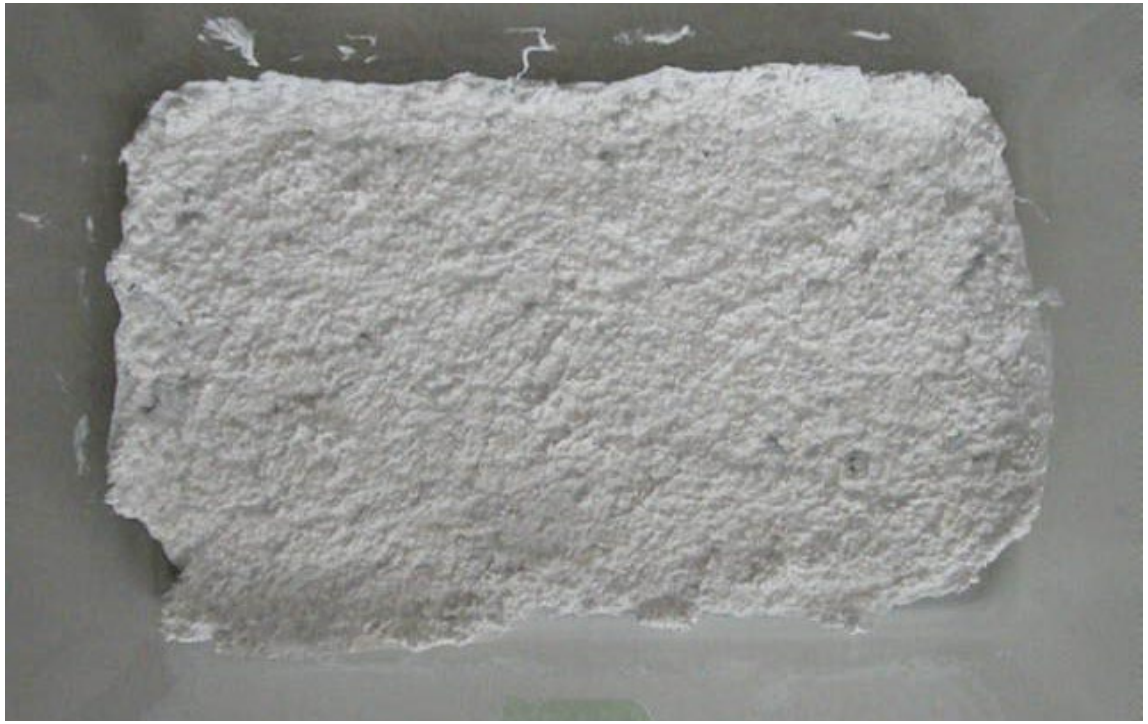
!

Against Fungi	Degradation
DCOIT	rapid
OIT	rapid
Carbendazim	medium
IPBC	rapid
Zincpyrithione	rapid

Burkhardt, M. et al. (2025): Groundwater discharges of biocides from façades in urban regions. Bericht, UBA, Dessau-Roßlau.

Film Preservatives are State-of-the-Art

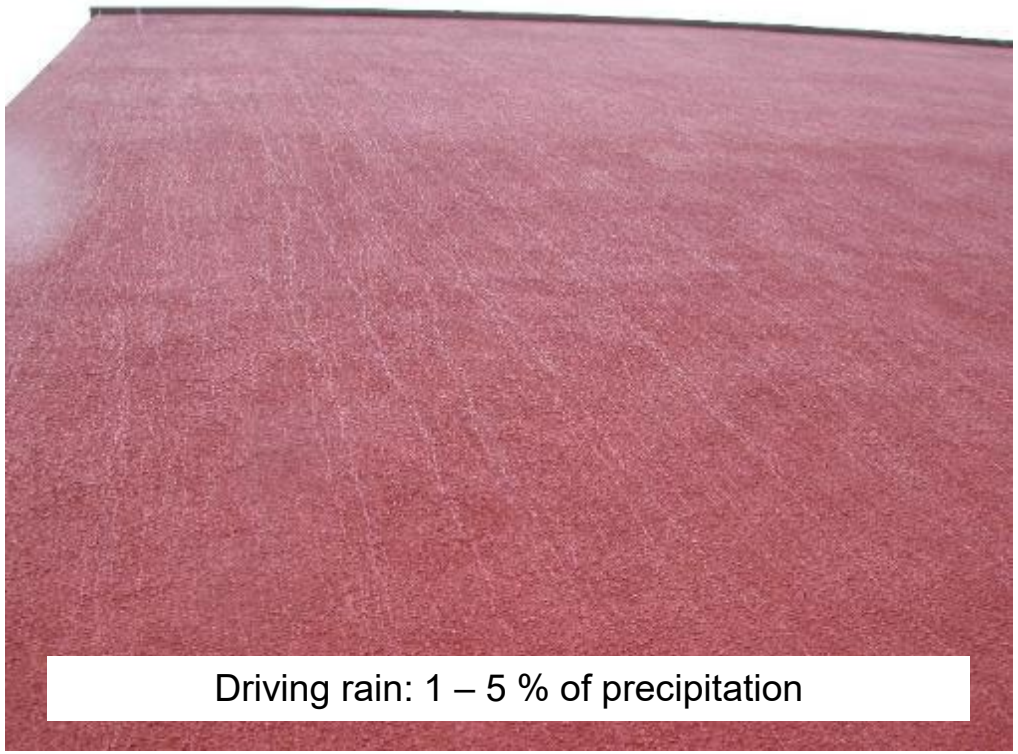
- **Polymeric coatings (organic binder; like rubber)**
  - Cheap and rapid – but with a short lifetime



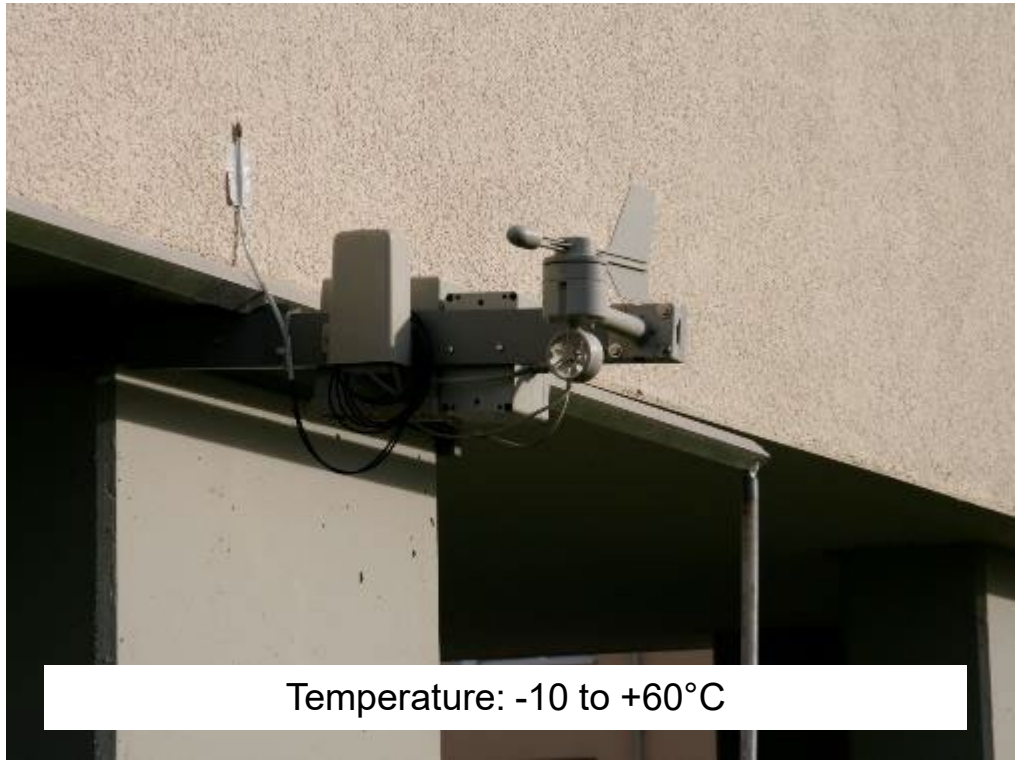
Extensive wet periods

Impact of Weather on Façades

- **Driving rain, temperature, UV radiation, and condensation**
  - Material deterioration and release of substances to the environment



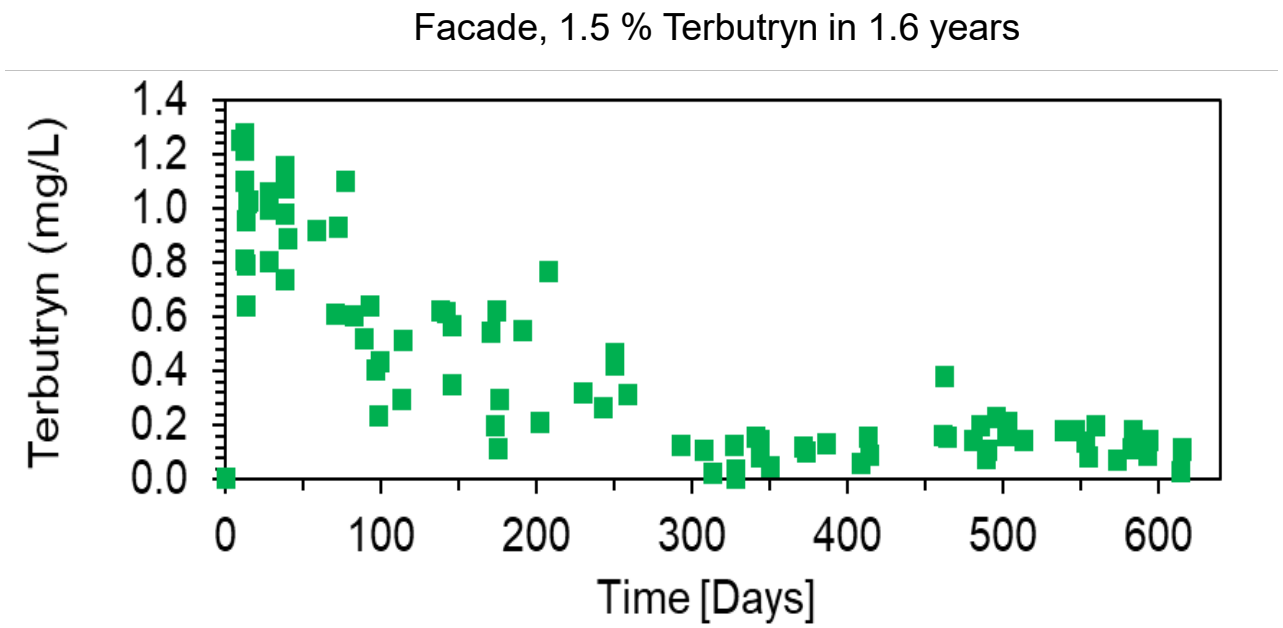
Driving rain: 1 – 5 % of precipitation



Temperature: -10 to +60°C

Leaching under natural Weather Conditions (Field)

- **Significant release to facades runoff**
  - Dilution by factor of 1’000 to 10’000 needed (including transformation products)
  - Assessment of release lacking in Environmental Product Declarations (EPD)

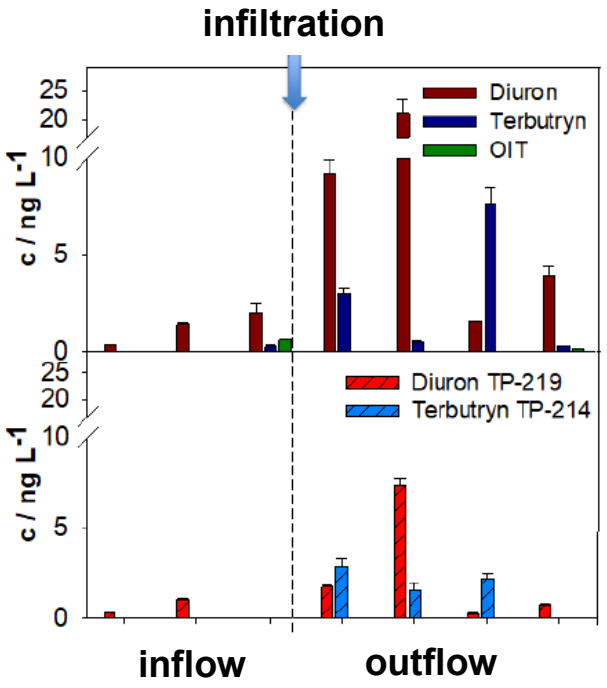


Diffuse Pathways to Aquatic Systems

- **Transport via separated sewer systems**
  - Infiltration (ponds) or direct discharge to surface waters
- **Decentralized, separated sewer systems are in favor (closing the water cycle)**

Pollution of Groundwater

- **Stormwater retention and infiltration – closing the water cycle**
  - Pollution is crucial for sponge city concepts
  - Biocides released from facades even observed in “eco” cities

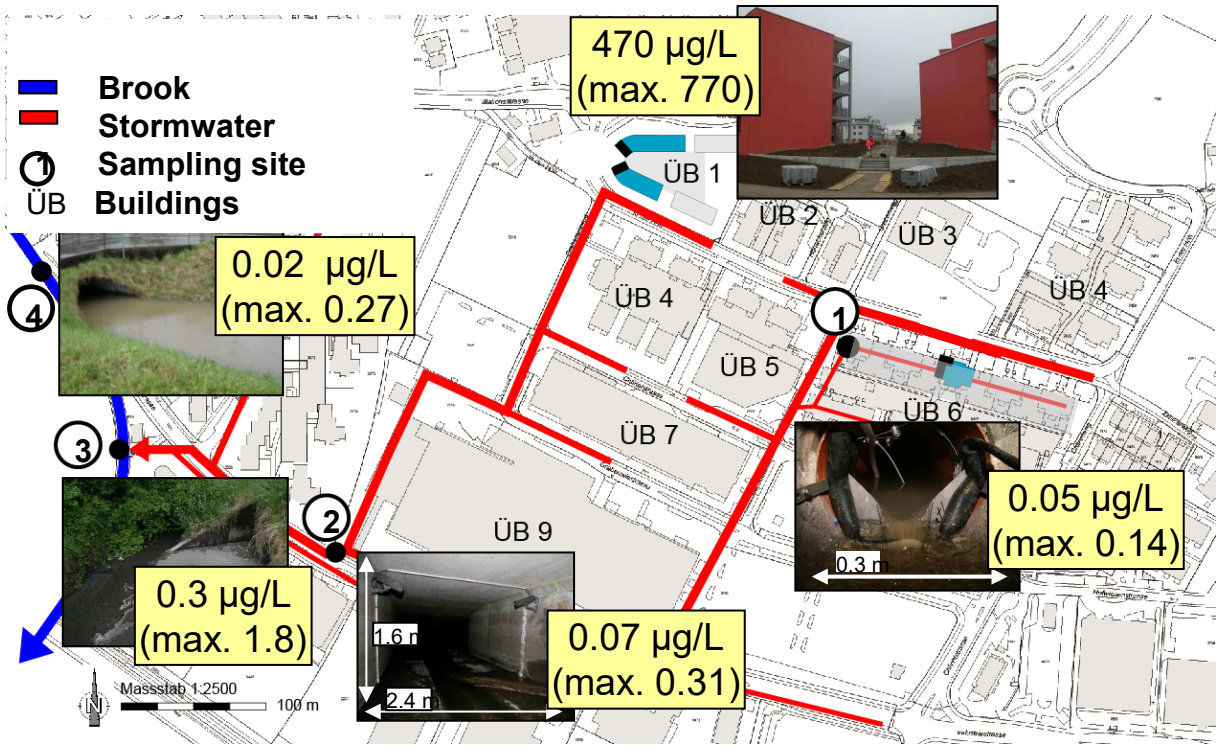


1 Lange, J., et al. (2017): Urbane Regenwasserversickerung als Eintragspfad für biozide Wirkstoffe in das Grundwasser? KA, 10:198-202.

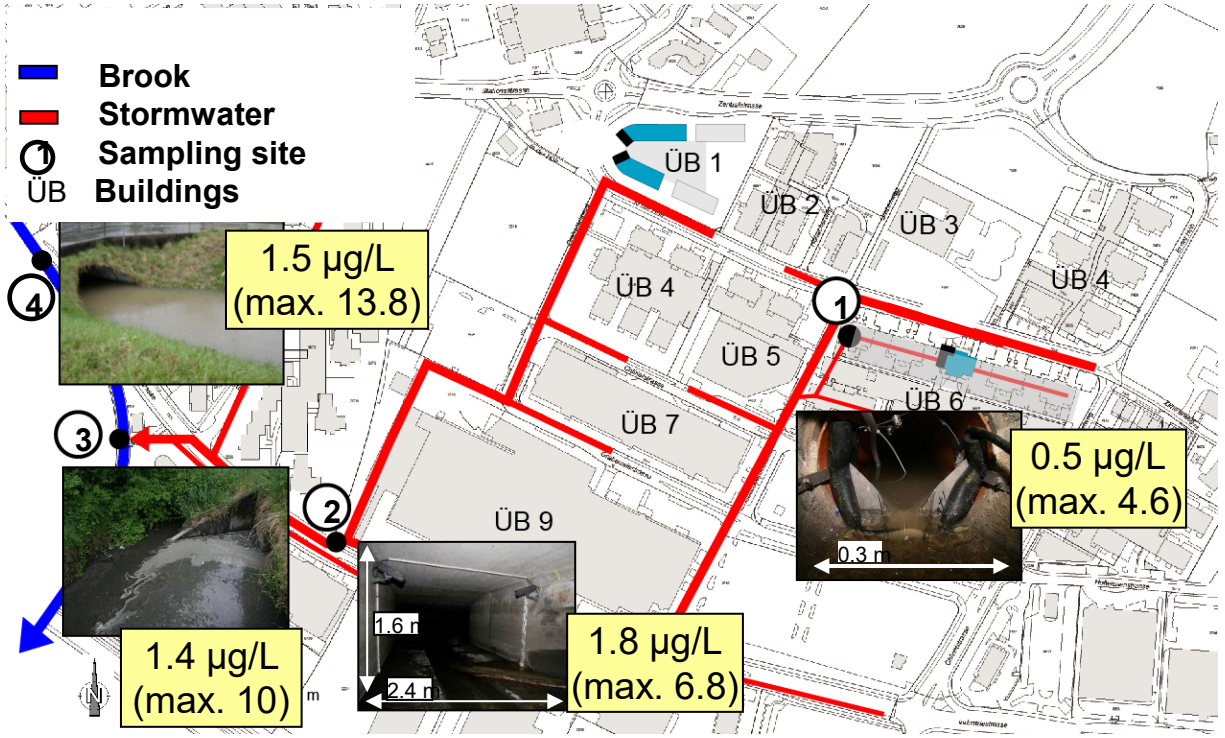
Pollution of Stormwater Runoff and Surface Water

- **Stormwater runoff in an urban catchment (Switzerland) with diffuse discharge**

Terbutryn (Facades)



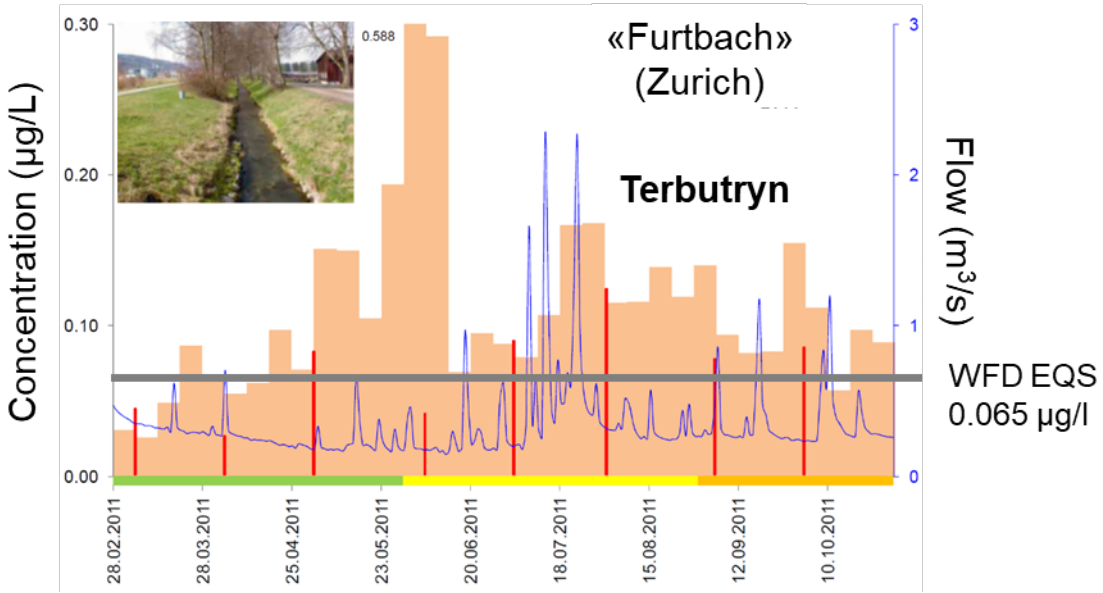
Mecoprop (green roofs)

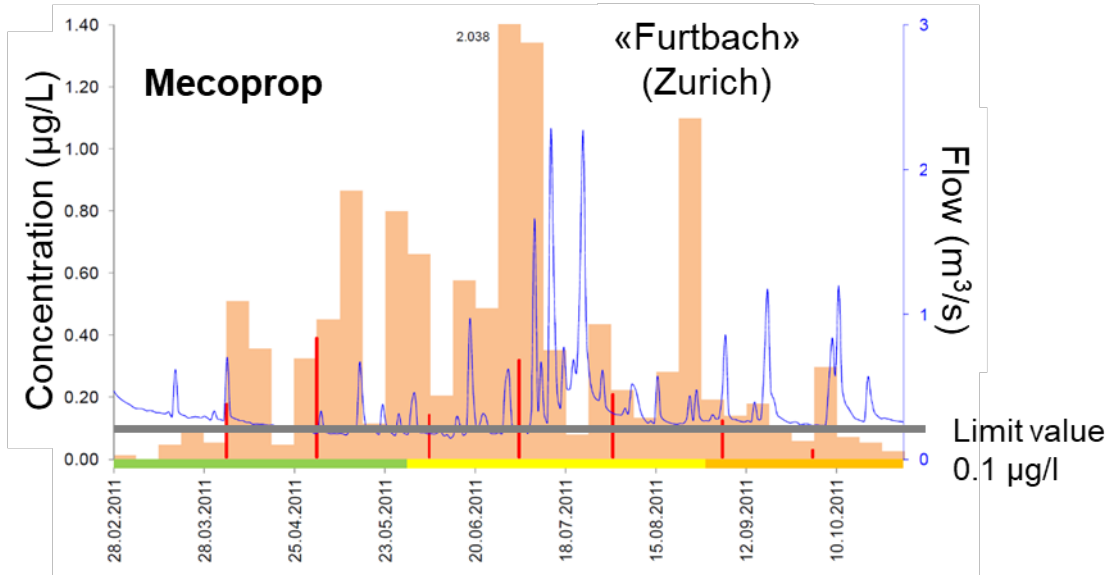


Burkhardt, M. et al. (2011): Leaching of additives from construction materials to urban storm water runoff. Water Science & Technology, 63(9), 1974-1982.

Occurrence in Surface Water

- **Terbutryn released by facades (and painters)**
  - At dry and wet weather flow
- **Mecoprop released by bitumen sheets on green roofs**
  - During wet weather flow

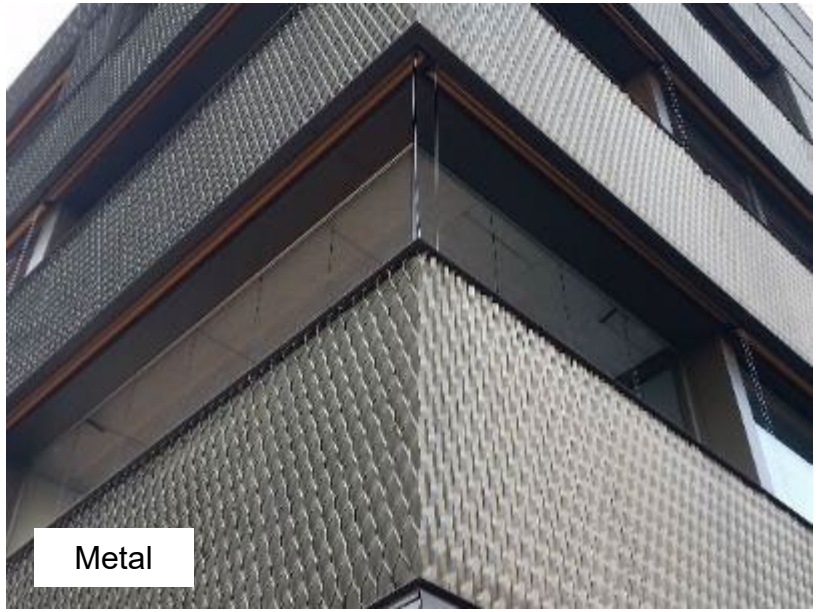




Sinniger et al. (2012): Pestiziduntersuchung, AWEL, Zürich.

Solutions for Source Control – Risk Mitigtion by Materials and Products

- **Products without biocides - ecologically sustainable**
  - Smooth or finely textured material surfaces such as glass and metal
  - Mineral materials such as clinker and silicate coatings (e.g. labels like Blue Angel)


Metal


Bricks

Eco-Label for Construction Products

Solutions for Source Control – Rethink Building Standards (Architecture)

- **Protect buildings from weathering and ageing**
  - Keeping the facades dry is the key to preventing infestations
  - Standards often addressing design and not sustainability (design matters!)

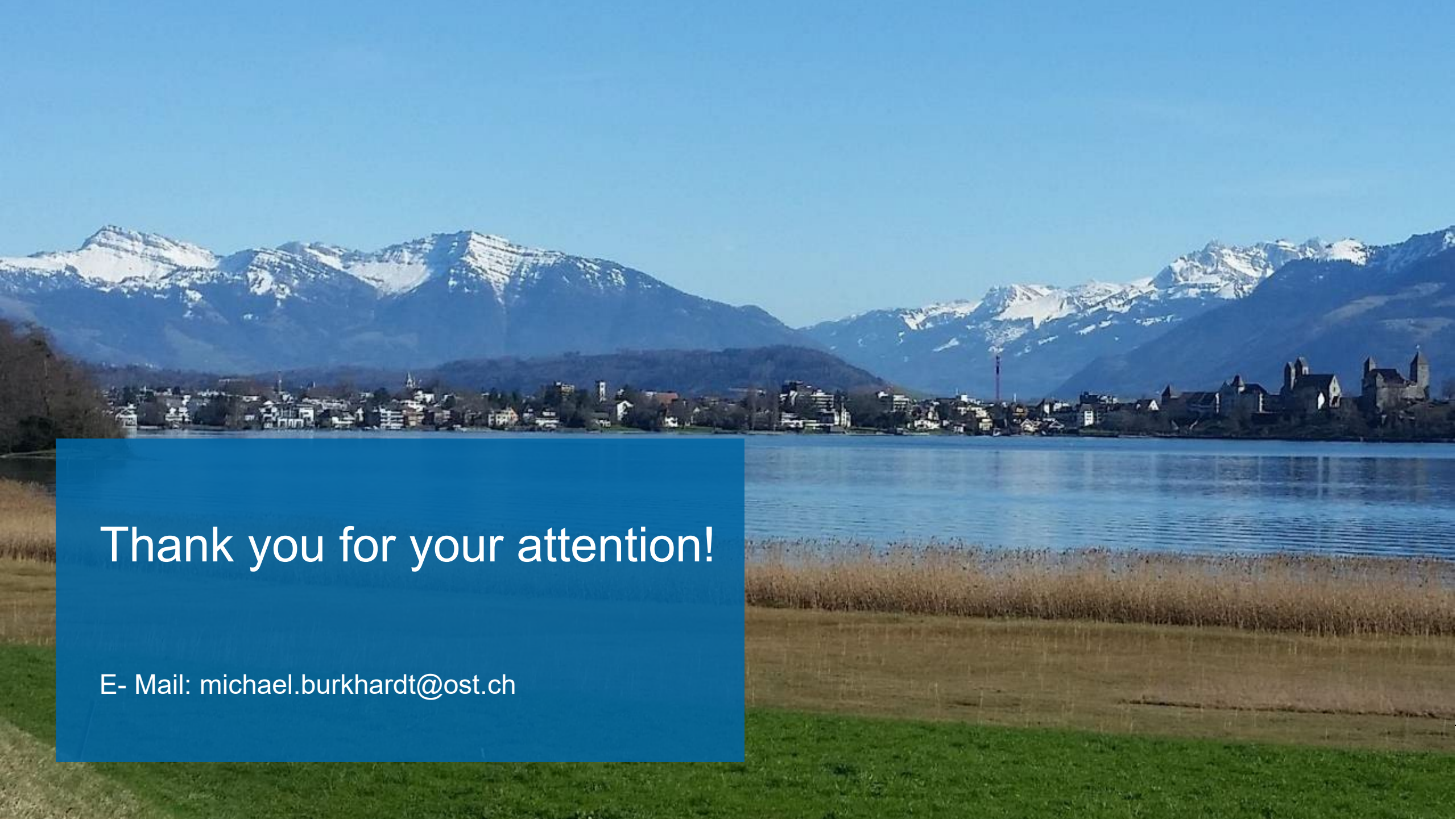
Roof overhang 30 cm

Window reveal and splash water protection

Conclusions and Need for Action

- **Risk assessment and EPDs**
  - Preferred assessment for long-lasting substances with direct emissions to the environment
  - Lack of information in EPDs – improving declaration practice in EPDs (leaching tests)
- **Blue-Green building practice**
  - Creating incentives for the development and use of environmentally sustainable products
  - Awareness rising and promoting sustainable building practice – Public contractors as leaders

source



Thank you for your attention!

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Literature

Environmental Science & Technology

Article

pubs.acs.org/est

Leaching of Biocides from Façades under Natural Weather Conditions

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Supporting Information

ABSTRACT: Biocides are included in organic building façade coati
protection against biological attack by algae and fungi but have the poter
enter the environment via leaching into runoff from wind driven rai
following field study correlates wind driven rain to runoff and measur
release of several commonly used organic biocides (terbutryn, Irgarol
diuron, isoproturon, OIT, DCOIT) in organic façade coatings from four
systems. During one year of exposure of a west oriented model house fa
the Zürich, Switzerland area, an average of 62.7 L/m², or 6.3% of
precipitation came off the four façade panels installed as runoff. Th
method for calculating wind driven rain loads is adapted to predict run
can be used in the calculation of emissions in the field. Biocide concent
tend to be higher in the early lifetime of the coatings and then reach
consistent levels later, generally ranging on the order of mg/L or hundr
μg/L. On the basis of the amount remaining in the film after exposur
calculated amounts in the leachate, degradation plays a significant role

INTRODUCTION

At real buildings, façade coatings become moist due to wind
driven rain and dew depending on characteristics of the site
(latitude, altitude), architecture (height of façade, roof
overhang, position on the façade), exposure (orientation),
and weather conditions (wind speed, wind direction,
precipitation, temperature). External thermal insulation com-
posite systems (ETICS) are a mature building cladding
technology that promote high energy savings but typically are
offered with coatings containing biocides. ETICS are layered
systems typically consisting of an insulation panel, upon which
a ca. 5 mm mineral render, or mortar, is laid with an embedded
fiberglass mesh for mechanical support. Upon this a finishing
layer of a hydrophobic textured render with a polymeric
binding phase (e.g., 2 mm thickness due to 2 mm grain size of
certain fillers) is placed, and sometimes two paint layers of a
few hundred micrometers are added. Organic biocides are an
integral part of the organic renders and paints of ETICS by
providing protection from growth of algae and fungi. They are
typically added to the renders and paints in the wet state and
are meant to slowly migrate to the surface of the dry coating

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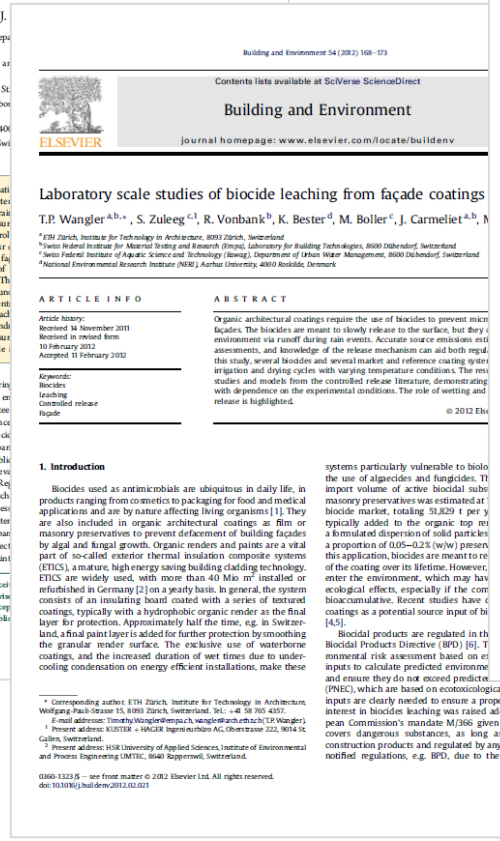

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Laboratory scale studies of biocide leaching from façade coatings

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Leaching
Controlled release
Façade

ABSTRACT

Organic architectural coatings require the use of biocides to prevent micr
façades. The biocides are meant to slowly release to the surface, but they
environment via runoff during rain events. Accurate source emissions esti
assessments, and knowledge of the release mechanism can aid both regul
this study, several biocides and several market and reference coating syste
irrigation and drying cycles with varying temperature conditions. The res
studies and models from the controlled release literature, demonstrating
with dependence on the experimental conditions. The role of wetting and
release is highlighted.

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1. Introduction

Biocides used as antimicrobials are ubiquitous in daily life, in
products ranging from cosmetics to packaging for food and medical
applications and are by nature affecting living organisms [1]. They
are also included in organic architectural coatings as film or
masonry preservatives to prevent defacement of building façades
by algal and fungal growth. Organic renders and paints are a vital
part of so-called exterior thermal insulation composite systems
(ETICS), a mature, high energy saving building cladding technology.
ETICS are widely used, with more than 40 Mio m² installed or
refurbished in Germany [2] on a yearly basis. In general, the system
consists of an insulating board coated with a series of textured
coatings, typically with a hydrophobic organic render as the final
layer for protection. Approximately half the time, e.g. in Switzer-
land, a final paint layer is added for further protection by smoothing
the granular render surface. The exclusive use of waterborne
coatings, and the increased duration of wet times due to under-
cooling condensation on energy efficient installations, make these
systems particularly vulnerable to biolo
the use of algaecides and fungicides. Th
import volume of active biocidal subs
masonry preservatives was estimated at
biocide market, totaling 51,829 t per y
typically added to the organic top re
a formulated dispersion of solid particles
a proportion of 0.05–0.2% (w/w) presen
this application, biocides are meant to re
of the coating over its lifetime. However,
enter the environment, which may hav
ecological effects, especially if the com
bioaccumulative. Recent studies have
coatings as a potential source input of bi
[4,5].

Biocidal products are regulated in th
Biocidal Products Directive (BPD) [6]. T
ronmental risk assessment based on e
inputs to calculate predicted environme
and ensure they do not exceed predicte
(PNEC), which are based on ecotoxicological data. Accurate source
inputs are clearly needed to ensure a proper risk assessment. The
interest in biocides leaching was raised additionally by the Euro-
pean Commission's mandate M/366 given to CEN TC 351 which
covers dangerous substances, as long as they are related to
construction products and regulated by any EU or Member States'
notified regulations, e.g. BPD, due to the risk of their harmful

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Hazard/Risk Assessment

Ecotoxicological Assessment of Immersion Samples from Facade Render Containing Free or Encapsulated Biocides

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Abstract: To protect house facades from fouling by microorganisms, biocid
applied. During driving rain events, these biocides gradually leach out ar
ecosystems. We studied the leaching behavior of biocides and toxicity
encapsulated biocides. Both render types contained equal amounts of ter
4,5-dichloro-2-n-octyl-4-isothiazolino-3-one (DCOIT). Nine leachate samp
according to a European standard, and biocides were quantified. The first
bioassays with algae, bacteria, and water fleas, the first sample was
Encapsulation reduced leaching of terbutryn, OIT, and DCOIT by 4-, 17-, an
water from render containing encapsulated biocides was always lower than
toxicity decreased by 4- to 5-fold over the 9 immersion cycles. Inhibition of
followed by algal growth rate, bacterial bioluminescence, and water fle
terbutryn and toxicity to bacteria was due to OIT. None of the samples aff
combining standardized leaching tests with standardized bioassays is a pro
biocides that leach from facade renders. Environ Toxicol Chem 2018;37:2

Keywords: Construction materials; Film preservatives; Leaching; Toxic effe

INTRODUCTION

Buildings and constructions that are exposed to environmen-
tal conditions are often protected against degradation by
coatings like paints or renders. Fouling and microbial deteriora-
tion of such exterior coating products can be controlled by
antimicrobial active substances (Paulus 2004; Sauer 2017). These
biocides, also known as film preservatives, are added to water-
based renders and paints that are sold for ready-to-use
application. Although hundreds of end products are offered
on the market, the number of biocides for film preservation is
rather limited. Typically, as dry-film preservation agents, exterior
paints and renders may contain mere algaecides (e.g., terbutryn,
diuron) as well as active ingredients with a primary fungicidal
function (e.g., 2-octyl-3[2H]-isothiazolinone [OIT]; zinc pyri-
thione). Other biocides that are frequently used in products

This article includes online-only Supplemental Data.
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water

Article

Emissions from Building Materials—A Threat to Environment?

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check for updates

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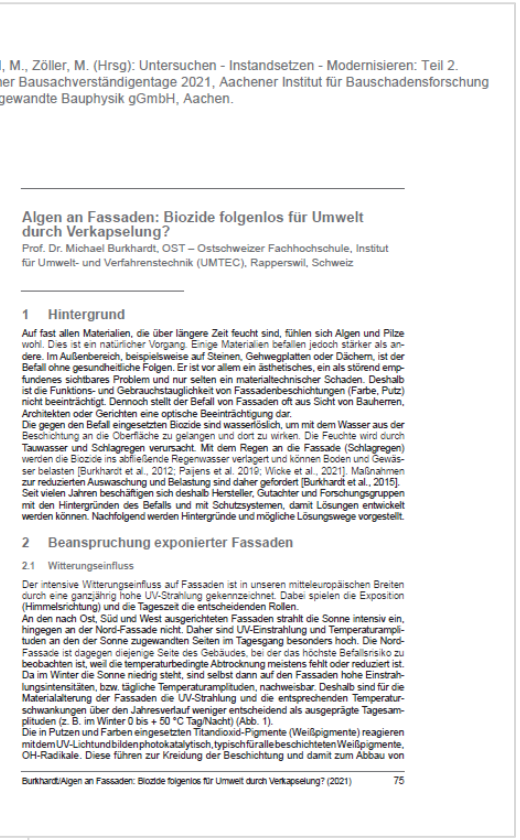
Abstract: A large variety of substances are used in building material
recent years, attention to organic additives used, for example, in rend
sheets has increased as these compounds have been detected in urba
waters. In this paper, we show the extent of emissions induced by
Berlin. For this purpose, stormwater runoff from roofs, façades, an
and analysed over a period of 1.5 years in two residential catchments
the biocides diuron and terbutryn from façades, the root protection
bituminous sheeting, and zinc from roofs and façades reach concent
that exceed limit values for surface waters. Additionally, transfor
were also detected. However, many other analysed substances were
inconspicuous in their concentration levels. The emissions, modelle
demonstrate that in urban areas the limit values in smaller surface
weather. Furthermore, the orientation of the buildings to wind-drive
load from façades. The calculated mass balances of both catchmen
all substances remains on-site and infiltrates diffusely or in swales,
discharged to stormwater sewers. For example, in one of the two stu
are discharged to surface waters. Infiltration, in particular, is therefo
for soil and groundwater. Measures for source control are propo
environmentally relevant substances from construction materials.

Keywords: stormwater runoff; micropollutants; diffuse pollution; e

1. Introduction

The quality of stormwater runoff in urban areas is influe
such as the built environment, operational conditions, and
source of pollution is traffic, which is responsible for the emis
tics (e.g., tire and brake abrasion), heavy metals (e.g., copper, z
trace substances (e.g., PAH) [1]. In addition, buildings with large surface areas in contact
with precipitation may release substances to the environment by surface runoff [2,3]. For
example, in Berlin, 38% of the total impervious surface area connected to the drainage
system is roofs. During rain events, environmentally relevant substances can be leached, de-
pending on the substance properties and material composition. Substances controlling root
penetration, such as mecoprop and the heavy metal copper from metal sheets, have been
detected in stormwater runoff for a long period [4,5]. Façades are affected by wind-driven
rain that results in façade runoff [6]. Various substances can leach out of façade materials,

Water 2022, 14, 303. https://doi.org/10.3390/w14030303 https://www.mdpi.com/journal/water



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Algen an Fassaden: Biozide folgenlos für Umwelt durch Verkapselung?

Prof. Dr. Michael Burkhardt, OST – Ostschweizer Fachhochschule, Institut für Umwelt- und Verfahrenstechnik (UMTEC), Rapperswil, Schweiz

1 Hintergrund

Auf fast allen Materialien, die über längere Zeit feucht sind, fühlen sich Algen und Pilze wohl. Dies ist ein natürlicher Vorgang. Einige Materialien befallen jedoch stärker als andere. Im Außenbereich, beispielsweise auf Steinen, Gehwegplatten oder Dächern, ist der Befall ohne gesundheitliche Folgen. Er ist vor allem ein ästhetisches, ein als störend empfundenes sichtbares Problem und nur selten ein materialtechnischer Schaden. Deshalb ist die Funktions- und Gebrauchstauglichkeit von Fassadenbeschichtungen (Farbe, Putz) nicht beeinträchtigt. Dennoch stellt der Befall von Fassaden oft aus Sicht von Bauherren, Architekten oder Gerichten eine optische Beeinträchtigung dar.
Die gegen den Befall eingesetzten Biozide sind wasserlöslich, um mit dem Wasser aus der Beschichtung an die Oberfläche zu gelangen und dort zu wirken. Die Feuchte wird durch Tauwasser und Schlagregen verursacht. Mit dem Regen an die Fassade (Schlagregen) werden die Biozide ins abfließende Regenwasser verlagert und können Boden und Gewässer belasten [Burkhardt et al., 2012; Paijens et al. 2019; Wicke et al., 2021]. Maßnahmen zur reduzierten Auswaschung und Belastung sind daher gefordert [Burkhardt et al., 2015]. Seit vielen Jahren beschäftigen sich deshalb Hersteller, Gutachter und Forschungsgruppen mit den Hintergründen des Befalls und mit Schutzsystemen, damit Lösungen entwickelt werden können. Nachfolgend werden Hintergründe und mögliche Lösungswege vorgestellt.

2 Beanspruchung exponierter Fassaden

2.1 Witterungseinfluss

Der intensive Witterungseinfluss auf Fassaden ist in unseren mitteleuropäischen Breiten durch eine ganzjährig hohe UV-Strahlung gekennzeichnet. Dabei spielen die Exposition (Himmelsrichtung) und die Tageszeit die entscheidenden Rollen.
An den nach Ost, Süd und West ausgerichteten Fassaden strahlt die Sonne intensiv ein, hingegen an der Nord-Fassade nicht. Daher sind UV-Einstrahlung und Temperaturamplituden an den der Sonne zugewandten Seiten im Tagesgang besonders hoch. Die Nord-Fassade ist dagegen diejenige Seite des Gebäudes, bei der das höchste Befallsrisiko zu beobachten ist, weil die temperaturbedingte Abtrocknung meistens fehlt oder reduziert ist. Da im Winter die Sonne niedrig steht, sind selbst dann auf den Fassaden hohe Einstrahlungsintensitäten, bzw. tägliche Temperaturamplituden, nachweisbar. Deshalb sind für die Materialalterung der Fassaden die UV-Strahlung und die entsprechenden Temperaturschwankungen über den Jahresverlauf weniger entscheidend als ausgeprägte Tagesamplituden (z. B. im Winter 0 bis + 50 °C Tag/Nacht) (Abb. 1).
Die in Putzen und Farben eingesetzten Titandioxid-Pigmente (Weißpigmente) reagieren mit dem UV-Lichtund bilden photokatalytisch, typisch für alle beschichteten Weißpigmente, OH-Radikale. Diese führen zur Kreidung der Beschichtung und damit zum Abbau von

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