ON THE INTERACTION OF WATER REPELLENT TREATMENTS OF BUILDING SURFACES WITH ORGANIC POLLUTION, MICRO ORGANISMS AND MICROBIAL COMMUNITIES

Wolfgang E. Krumbein° and Anna A. Gorbushina*°,

° Geomicrobiology, ICBM, Carl von Ossietkzy Universität Oldenburg, Postfach 2503, D-26111 Germany

* Dept. of Botany, St. Petersburg State University, St. Petersburg, Russia

ABSTRACT

Water repellents are used frequently in connection with the following problems:(1) New buildings and building surfaces are to be protected against the passage of water into the building through the protective layers (building stones, wall coverings, insulation materials); (2) old buildings, the structure of which is submitted to changes are to be protected for heat and humidity insulation; (3) culturally valuable monuments are to be protected from further physico-chemical and biological decay as well as from vandalism by e.g. graffiti. In all cases consolidants and water repellents are applied either directly during the construction or insulation processes or in order to protect existing elements of the buildings from further decay without destroying the outlook and status of the monument surface. The water repellents are usually organic silicium compounds (ethyl silicates, organosilicones, organosiloxanes, ethoxysilanes, methylalkoxysilanes, acrylsiliconic or other organosilicic components) and rarely other chemical compounds as e.g. polysaccharides which are applied using organic solvents such as xylen. They are applied with several different techniques and make open spaces of the building material as impenetrable as possible against the direct capillary flow of water but should keep it open for the transfer of water vapour. These water repellent surfaces interact with environmental factors and the microbiota, hereby often changing the aspects of the building itself. Cases of changes are increasing in number in the recent years. This is probably caused by environmental organic pollution and the treatment itself whereby the microbial biofilms always occurring in such environments are seriously modified.

1 INTRODUCTION

Any solid surface exposed to the open-air environment is submitted to (1) rapid changes in temperature and humidity (daily and in the course of the year), (2) to high levels of UV-irradiation and (3) a constant deposition or sorption of gaseous and particulate inorganic and organic compounds coming from the air. Among the particles are mineral, organic and biogenic ones, including propagules of micro-organisms which are capable of settling on the surface. The number of living germs reaching rock surfaces annually per cm^2 is higher then the numbers actually living on and in the rock in reality. But usually -in the course of time- a fragile equilibrium is established, which, however, is easily disturbed by any additional factor. In the case of inhabited building surfaces there are always additional factors as heating (keeping the surface temperature more stable and higher and favouring this way the growth of organisms) or additional sources of organic materials.

Further it is often overlooked that not only the vegetation but also building surfaces react considerably to extended periods of e.g. rainy summers and mild winters in contrast with hot summers and cold winters, a situation occurring often with climatic shifts. Thus not only the structure of the building, the general climate and atmospheric physical and chemical conditions but also gradual and episodic changes in these conditions are important for the activity and buffer capacity of the external coating of a building.

The transfer of water vapour as well as the direct influences of humidity herein are of utmost importance. Therefore water repellent treatments will interact with these processes in multiple ways which deserve to be further analysed and studied. The interaction of water repellents with surface films and the process of soiling was the subject of several communications and conferences before. Krumbein (1993b) and Sramek (1993) for example were treating the topic of water repellents in chemical and microbiological ways. One of the most important and constant causes of problems in relation to surface treatments is the question of patina formation (Krumbein 1993a; Krumbein and Warscheid, 1992, Krumbein et al. 1991; 1993). This is especially important when the patina on the building surface is developed as a dirty, grey, brownish or black coating, which makes the building unesthetical and ugly looking although damage by water and its relations to physical, chemical and biological decay mechanisms may not yet be in action (Diakumaku et al., 1995; Gorbushina et al., 1993; Krumbein et al., 1993). The question of interaction of air pollutants with building surfaces that were untreated or treated with impregnants and water repellents was discussed also by Urzì and Krumbein (1994) and Urzì et al. (1993). In this contribution we concentrate on the question of microbial interaction with the atmosphere, especially with organic pollutants and with treatments, which may interact with the water repellence of the surface layers. We are especially concerned recently with the interaction of chemotrophic micro-organisms with treated and untreated building surfaces. The chemoorganotrophic micro-organisms may have several different serious consequences for the status of the building and its water capacity.

2 MATERIAL AND METHODS

In the past 10 years the geomicrobiology and material ecology group of Oldenburg has analysed more than 250 buildings concerning microbial growth, its detrimental influence and its interaction with atmospheric pollutants, treatments and among them treatments which increase hydrophobicity of the building surface. We have further analysed changes in the variables of climate and air pollution as related to the status of buildings. Based on these statistical materials as well as on the presence or absence of certain types of micro-organisms on buildings we have developed a scale of damage functions which may be important in the maintenance of building surfaces. The methods used were microbial counts using selective media (Krumbein et al., 1991; Krumbein, 1966), SEM analyses of building surfaces and a variety of analytical techniques to differentiate colour changes on building surfaces (Krumbein, 1992; Gorbushina et al., 1993). Buildings which were insulated or stabilised under inclusion of water repellent treatments were especially analysed in the industrial and urban centres of Nordrhein-Westfalen, Saxonia and the Netherlands. In several cases we have directly studied the influence of water repellents such as silicic and silicone compounds, waxes and acrylic compounds (for composition see Sramek, 1993; ICCROM, 1995) in laboratory experiments described to more detail by Krumbein (1993b). From these analyses we derived the following results and considerations of the interactions between non-treated and treated building surfaces, the atmospheric environment and the microbial biofilms on building surfaces.

3 RESULTS AND DISCUSSION

The main questions in relation with water repellent treatments and impregnations as well as with insulating treatments of ancient building surfaces made of brick or other materials is concentrated on the following major factors with respect to the building itself.

(1) Is the treatment protective?
(2) Does the treatment reduce physical and chemical damage
(3) Does the treatment enhance microbial growth?
(4) Does the treatment enhance or reduce the danger of unesthetical stains on building surfaces?
(5) What are the causes of increased problems with soiling of building surfaces?

The facts derived from the analysis of more than 250 buildings can be described as follows:

(1) In recent years the occurrence of black and grey stains and dirty spots on white building surfaces was remarked increasingly and caused increased problems to constructors and restorers of building surfaces. In many cases dark stains and spotty to large-scale changes of colour of originally white or bright yellow surfaces was remarked as fast as two to three years after a new building was constructed or a new surface finish was accomplished. This was a nuisance for many constructing companies and restorers, because the damage was occurring so fast after a treatment was done.

(2) Invariably we found that darkening, grey and black unesthetical spots and other changes of the surface were caused by intensive growth of a variety pigmented fungi of Dematiaceae group (black yeast and fungi).

A detailed analysis of all cases in a statistical sense lead to the conclusion that there are three major reasons for this phenomenon, which increasingly irritates the market of constructors and restorers of building surfaces:

(1) New materials were introduced into building surface treatment, which contain increasing amounts of synthetic organic polymers instead of natural occurring minerals.

(2) Organic pollution of the atmosphere increased constantly and practically without major control in the natural environment, while other pollutants (e.g. dust particles, soot, heavy metals, asbestos, SO_2 , NO_x, and others) were gradually decreasing in the atmosphere in response to environmental laws and regulations.

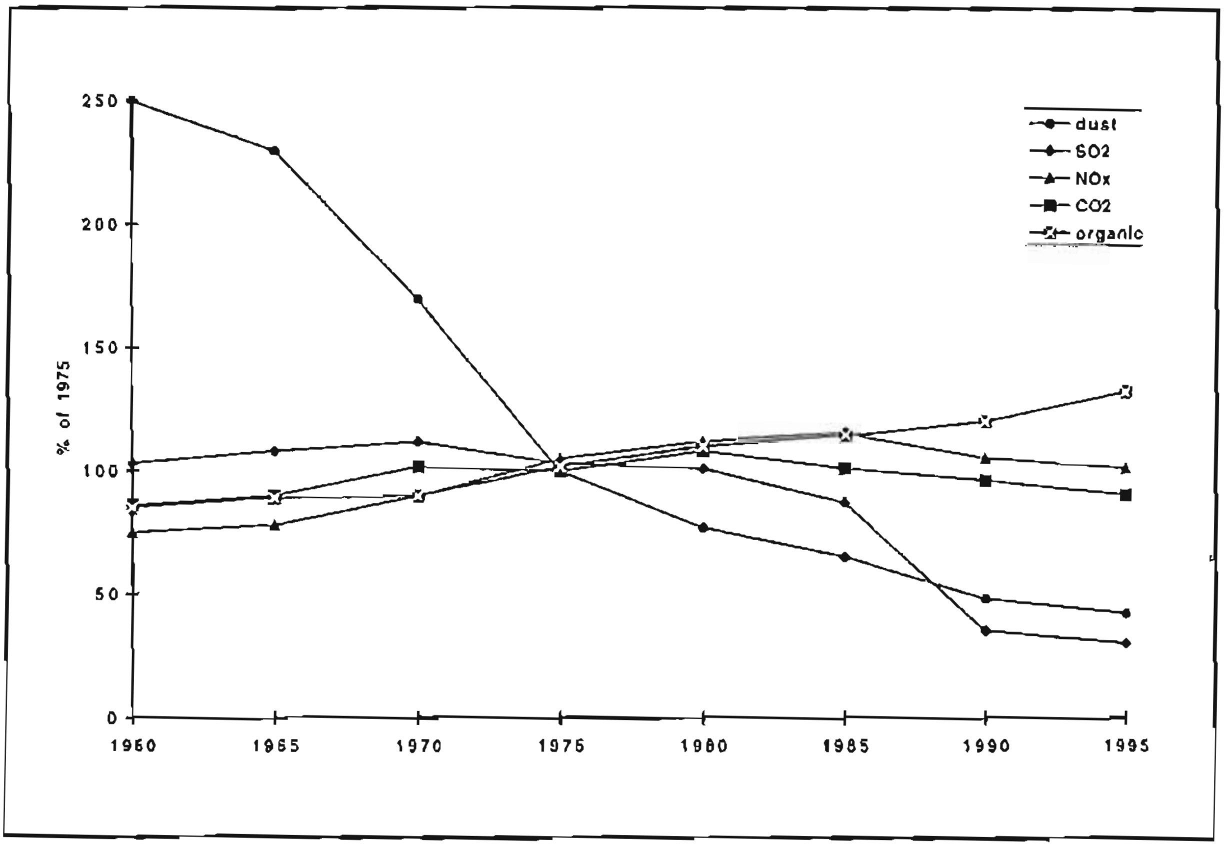
(3) chemoorganotrophic micro-organisms and especially fungi turned more and more resistant against biocides and biocidal treatments with the increase of the use of these techniques in the production and application of building materials in general and water repellents in special. Many companies have started to use biocides in connection with their materials and treatment techniques as e.g. some companies advertise that their consolidants, water repellent substances, anti-graffiti treatments and also their insulation covers and systems are biocidally equipped.

These factors largely influence the present outlook and status of the biological growth on building surfaces. Recently a drastic increase in numbers and variety of black melanin-containing (UV-protected and resistant) fungal species was observed. We have also observed for example that in urban areas the heavy metal resistance of micro-organisms isolated from monument surfaces can cope with the level of (often plasmid mediated) heavy metal resistance from metal processing plants and photochemical plants.

The increase of these organisms which causes great changes in aesthetic, physical and chemical qualities of building surfaces is according to our analyses related in part to the increased use of organic protectants such as water repellents, anti-graffiti and organic-rich consolidants. To a greater extent, however, the increase of damage and complaints about colour changes is caused by an increase in organic pollution of the atmosphere. Fig. 1 gives an overview of the relative concentration changes of individual pollutants in the urban atmosphere in the past 35 years.

FIGURE 1

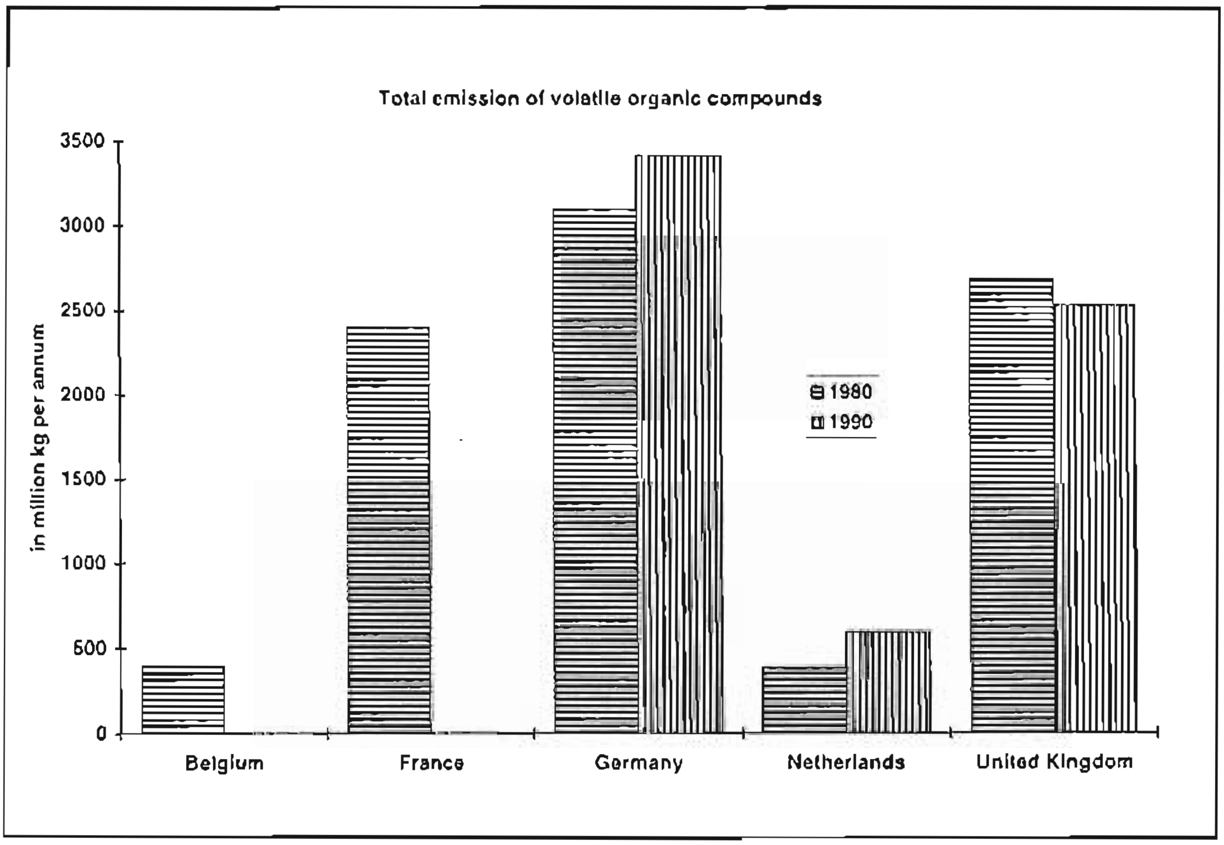
Graphic representation of the decrease of classical pollutants in comparison to the constant increase of organic pollutants in the atmosphere over the past 30 years in Germany



without doubt classical pollutants such as soot and dust as well as sulphur and nitrogen oxides have a decreasing tendency, while organic pollution is constantly increasing in many countries. It is astonishing to see (Fig.2) that the absolute concentration of organic pollutants is as high or sometimes even higher as the concentration of the sum of SO_2 and NO_x. Laws and regulations for organic pollutants do exist. In many cases, however, they relate to insecticides, cancerogens and other highly dangerous substances. The content of e.g. kerosene, methane, fatty acids, aromatics and aliphatics, however, is measured only in few cases and is not submitted to severe regulations. As a matter of fact the absolute amounts of organic compounds emitted in Germany (former Democratic Republic and Federal Republic summarised) were in 1986 7000 kt/a and in the Netherlands 475 kt/a. The data for SO_2 and NO_X together in comparison were for Germany at 4600 kt/a and for the Netherlands 830 kt/a. There is no doubt that particulate dust (ash, soot and other compounds that could produce dirty surfaces) have a drastically decreasing tendency over the past 30 years, while sulphur and nitrogen emissions are moderately decreasing and organic emissions rather increasing in tendency.

FIGURE 2

The amounts of sulphur dioxide, nitrous oxides and organic compounds in the atmosphere of several European countries. Data from 1993 environmental report of the Netherlands.



In Fig. 3-4 we give some examples of the heavy development of biofilms of black yeast-like and filamentous fungi on building surfaces, which were treated also with water repellents of different composition, productions and companies. These examples stem from buildings in the Rhine-Ruhr area and from the urban centres of Amsterdam and Haarlem.

FIGURE 3

Heavy biofilm of melanin producing fungi on a freshly insulated building in Amsterdam. The building was equipped with biocidal protective and water repellent coating two years prior to sampling of blackened surface.

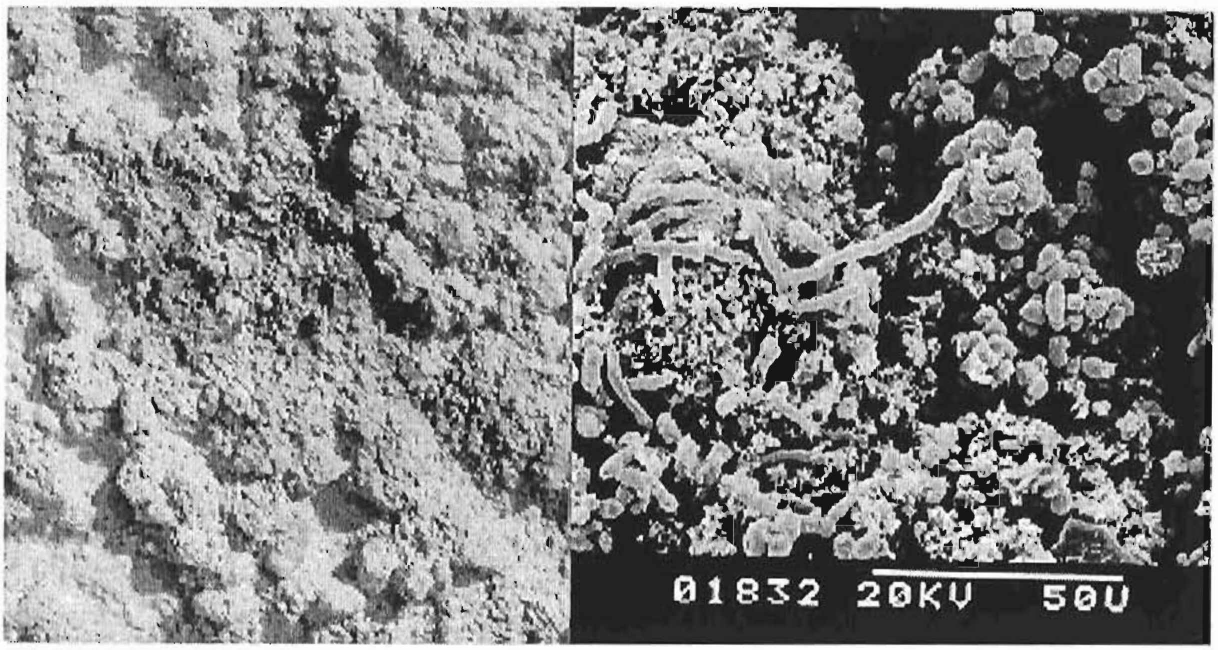
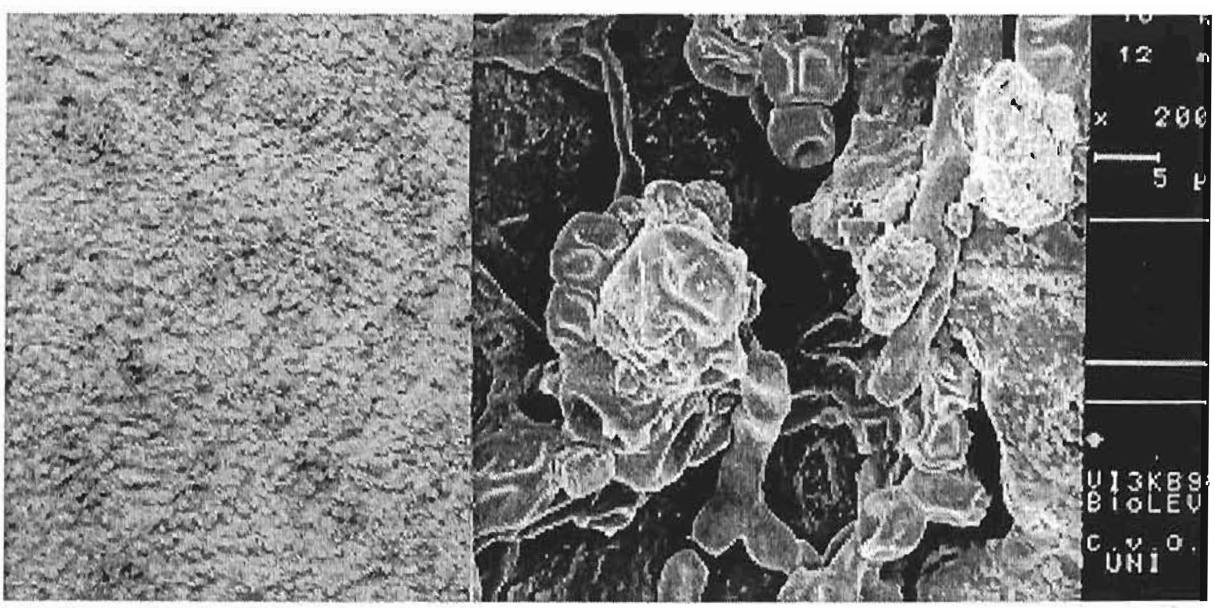


FIGURE 4

Melanin forming fungal biofilm from a building in Leverkusen. Both buildings (Amsterdam, Figure 3) and the building from which the sample of Figure 4 was taken are exposed to heavy organic pollution favouring the growth of fungal bifilms.



As documented by investigations of a large number of normal houses, public buildings and monuments, the surfaces are exhibiting heavy biofilms with very little if any inclusions of soot and ash material. It seems legitimate to correlate the blackening by micro-organisms depending on organic energy sources with the increased atmospheric pollution by organic compounds, while at the same time noxious emissions, which could help to reduce microbial growth on outdoor surfaces were rather decreasing. Thus several effects would be overlapping in the feature and trend of pigmented microbial biofilms on building surfaces:

(1) Increased use of compounds in the production and consolidation of building surfaces;
(2) increased organic emissions and thus nutrient supply from the atmosphere;
(3) decreased toxicity of the atmosphere by decreased sulphur and nitrogen gas emissions as well as dust deposition and finally
(4) increase in UV-B-irradiation caused by changes in global climate and the ozone shield which in turn would favour the development of black pigments in fungal biofilms.

Also the environment of building surfaces in urban centres may be compared to the indoor environment of a normal house. Depending on the degree of organic pollution and water activity (humidity) multiple microbial effects may interfere with chemical factors which lead to the feature that e.g. a kitchen is endangered of colour change and unesthetical growth of fungi by the larger input of organic compounds with cooking steams. Further bath-rooms wherever they are not exhibiting water repellent and inert tiles will have fungal growth especially in the joints of tiles, when the cement contains organic materials, or when soap and other organic compounds are not carefully washed. Evidently, wall-papers serving as an excellent food source for fungi will show unesthetical blackening by fungi, when they are constantly or periodically humid. If we transfer these well known facts to outdoor building surfaces we should not be astonished to observe the same effects:

In places, where either by the constructing material itself or by organic pollution of the atmosphere, supply of nutrients is guaranteed, a detrimental often black stained fungal microflora will develop. This development is further enhanced and accelerated by the fact, that many species of black yeast and fungi detected on and isolated from building surfaces are increasingly insensitive to biocides, which in turn cannot be used in concentrations high enough to really kill the organisms because environmental regulations do not allow really antifungal concentrations of the biocides in question. This is simply the same mechanism, which makes the cure of fungal infections of the skin so difficult today. On the other hand the reduction of water uptake and adsorption by really efficient water repellent systems may counteract these influences. It is, however, difficult to find an equilibrium between hydrophobicity of the surface cover and the necessity to guarantee water vapour transmittance. Also it is necessary to create relatively smooth surfaces, because the degree of roughness or relief on a building surface will create better physical conditions for the establishment of microbial biofilms. The higher the roughness or surface fractal coefficient the higher the probability of settlement of biofilms in niches, which also may physically collect water despite efficient water repellent treatments were incorporated or applied.

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