

Soil sealing in German cities Forty years investigation

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Abstract: Soil sealing is the process of removal of the vegetation covering of soils by more or less impermeable materials (bitumen, concrete, stone pavements etc.) and their result the sealed soil. The phenomenon is always progressing with the spatial urban growth but underestimated by urban planning and decision making. There are tremendous influences of urban soil sealing on natural processes relevant for ecosystem services, on water regime, climate, vegetation, and fauna. First investigations on urban soil sealing and the by this phenomenon caused processes had been investigated in Germany in the beginning on the 1970th. The reasons were the development of ecological research in cities and the political reaction by legal acts as nature protection laws and biotope mapping. With this many German cities started already in the 1980 with exact mapping of its sealed soils. This qualitative survey has to be added by urgently needed quantitative surveys of the different forms of soil sealing and its process related influences. A new and necessary ecological planning of cities has to include ecosystem services which are degraded by urban soil sealing and to calculate this degradation separate by services and its real quantity and location.

Key words: soil sealing, removal of vegetation, spatial urban growth, German cities

Introduction

The soil sealing in urban agglomerations is particularly a phenomenon progressing always further with the spatial urban growth. Soil sealing is the process of removal of the vegetation covering of soils by more or less impermeable materials (bitumen, concrete, stone pavements etc.) and their result the sealed soil. The purpose of soil sealing is to use these areas as building grounds or as sidewalks, places, streets and roads (Breuste et al. 1996).

Soil sealing is usually used as general indicator of anthropogenic denaturation. In addition, partially it is tried to also connect the term with clearly understandable ecologically relevant function. Some authors understand by soil sealing the covering of surfaces by only "impermeable substances" the stops all exchange processes between soil and near-surface air layer (Boecker 1985, p. 58). On the other hand it is partly in such a way defined that only such soil surfaces are included, the certain values of the run-off and the evapotranspiration rates exceed (Pietsch, Kamith 1991, p. 119). Both definitions try only a already in ecology, planning and politics firmly embodied term to describe and scientifically support.

Influence of soil sealing on natural processes, relevant for ecosystem services

Further Investigations of different sciences showed that with these surfaces, dependent on their material, different and substantial influences on the urban ecological system are connected. These are in the meantime



Fig. 1 Soil sealing of a public open space in Leipzig, Germany

generally well-known, but must be clearly further differentiated. This means that the term “soil sealing” is still broad and includes much ecological different subjects. This applies likewise to the biology, which only rear use the term “vegetation cover”.

Thus soil sealing is both as general indicator for denaturalization in cities (vegetation, soil), and for anthropogenic changes of natural processes (climate, water regime, species diversity etc.). This can be showed as follows:

Soil and water regime (by “loss” of the vegetation cover and physical change of the soil surface and the upper soil layer)

- partial or complete removal of the upper soil layer,
- decreased infiltration of precipitation water into the soil and thus reduced ground-water renewal,
- increased evaporation,
- more increased and accelerated storm water run-off,
- more frequent high tides in drains and waters streams with heavy rain and thaw.

Urban climate (by “loss” of the vegetation cover and thermal and energetic effects of the new technical surfaces)

- increased thermal capacity and thermal conductivity of the sealing materials,
- increased air temperatures,
- increased precipitation,
- lower and time reduced snow covers,
- reduced humidity.

Vegetation and fauna (by destruction of the vegetation cover and change of the local ecological conditions, intensive use by trampling and driving on)

- reduced, usually minimal development possibilities for plants,
- lacking oxygen and water supply for soil fauna and decreased exchange of matter and gasses in the soil and between soil and near-surface air layer,
- depletion of the native flora,
- loss of levels of the food pyramid, and
- by cutting of habitats increasing isolation of populations (Breuste et al. 1996, Breuste 2009).

Soil sealing in the German urban and nature conservation concepts

Investigations on soil sealing outside technical and engineering sciences started in the 1970s in Western Germany (FRG) together with the rising attention to environmental problems including in cities (e.g. Kaule 1975, Sukopp, Kunick, Schneider 1979, Auhagen Sukopp Müller, Waldert 1981, 1983). Because of political reasons in East Germany (GDR) it didn't become the same practical importance than in Western Germany at the same time but was included into theoretical and scientific concepts (e.g. Richter, Kugler 1972, Richter, H. 1984, 1989, Schmidt 1985, Schrader 1985, Schönfelder 1988, Breuste 1985, 1986, 1989). These research aspects were also adopted in Austria (e.g. Schacht 1981) and other countries, mostly in Europe.

It was very fast brought in by empirical landscape-ecological mapping (e.g. habitat mapping) and understood first only as during the survey of the vegetation structures "remaining" surfaces without vegetation cover (Sukopp, Kunick, Schneider 1979, 1980, Billwitz, Breuste 1980). These predominantly "vegetation-hostile" surfaces were named by the summarizing category "Versiegelung" (soil sealing). The term was developed in Germany and adopted in many other countries by translation (soil sealing) or different terms (impervious surfaces, pavements etc.).

In the 1970's, there was rising social awareness of the value of nature in the city and the realization that already extensive losses had taken place. Spatial planning in Germany came under the pressure of public and politics and was required to achieve clear improvements in the environmental management of cities and to act as a moderator in the reconciliation of the interest groups. Politics and its executive, planning, were requested



Fig. 2 Soil sealing degree mapping (Halle/Saale, Germany, Billwitz, Breuste 1980)

to react. This required the creation of a methodological framework for the protection of nature in the cities, and an adapted form of the "Kartierung schutzwürdiger Biotope in Bayern" (mapping of habitats necessary to protect in Bavaria; Kaule 1975) was used. Planning departments began to conduct comprehensive surveys of the urban landscape and surrounding countryside (e.g. Wittig, Schreiber 1983, Sukopp, Weiler 1986). These surveys involve broad-scale spatial analyses of landscape components, particularly by remote sensing and GIS, in conjunction with detailed investigations of the condition and interrelationships of the individual elements of the urban ecosystem (e.g. plant societies, climate conditions, soils etc.). Similar frameworks were also implemented in nearly all other federal countries of the Federal Republic of Germany in the following 10 years (1975 - 1985) and habitat mapping became the most important means for fulfilling the requirements outlined by the new federal nature protection law in Germany (1977) (Sukopp, Kunick, Schneider 1980). The central goals of the law were protection of species, scenic (landscape) values as well as landscape functions. This reduced the protection often on very special elements of the urban landscapes as wetlands, food plain forests etc. Floristic and vegetation science based surveys of the urban landscape began, with the initial goal of using easily recognized homogeneous areas as the basic landscape components for investigation (Sukopp, Kunick, Schneider 1979, 1980, Kunick 1978, Hülbusch 1982). In 1986, land-use-referred habitat mapping became the standardized method for mapping the habitat of urban landscapes (Arbeitsgruppe 1986). This program was revised in 1993 (Arbeitsgruppe Methodik der Biotopkartierung im besiedelten Bereich 1993). Between 1978 and 1986 urban habitat mapping using land-use as the basic component had become the most widely accepted approach underpinning urban nature conservation. It included already soil sealing as special category, often represented by types of soil sealing (Sukopp, Weiler 1986, Wickop 1997, Stadt Berlin 1996, Breuste 2001). With the increase of urban ecological research, information was emerging on the ecological conditions within the urban ecosystem. Much of the early research was based on the premise that utilization is the most important and fundamental process influencing plants, animals and their communities. "Within the settled areas there are primarily the utilization forms, which are dominating the pattern and distribution of organisms. Basis of the nature protection work in the city is therefore to analyze the most important types of land-use systematically and to describe species content and ecological characteristics. In the final result becomes clear, which land-use forms are extraordinarily poor of species and demand management for re-implementation of nature" (Sukopp, Kunick, Schneider 1980, p. 565). This stimulated the very exact and large scale mapping of soil sealing in different variants and degrees as relevant factor for plant distribution. Land-use became the key tool for undertaking applied urban ecological research and urban nature conservation. An entire field of pure and applied research was developed, urban habitat mapping, and the research relied heavily on land-use, in terms of "land-use types" or "urban structural types", as a foundation. This has enabled the use of structural units in urban landscapes as reference content in the urban ecology in and the 70's and 80's. Mapping legends were developed and recommended for a broad, comparative application in the urban and non-urban nature protection (Arbeitsgruppe 1986, 1993). The implementation of land-use types as ecological units started without detailed investigations into the associated function and processes which were influenced by the anthropogenic inputs of these land-uses and without the inclusion of available scientific information from landscape research. The results of anthropogenic change were taken as indicators: soil sealing types and vegetation types (Blum 1991, Duhme, Pauleit 1992a,b, 1994, Duhme, Lecke 1986, Leykauf et al. 1989).

New functional approaches

It is clearly visible that additional characteristics of sealed soils are in demand depending of the target of the investigation. A strongly infiltration-promoting surface (pavement of smaller stones) must be not also an equally strongly temperature-increasing surface. Therefore sealing should be differentiated depending upon question and generally be gone off from the "comprehensive term" sealing degree as complex indicator. For these question oriented problems of soil sealing still neither a sufficient methodical equipment, nor reliable data, still experiences with a meaningful and balanced handling for planning are appropriate (Pietsch, Kamith 1991, p. 119). A substantial research deficit was stated and must be further stated.

The most strongly noticed risks of soil sealing are apart from the even stronger general loss of vegetation in

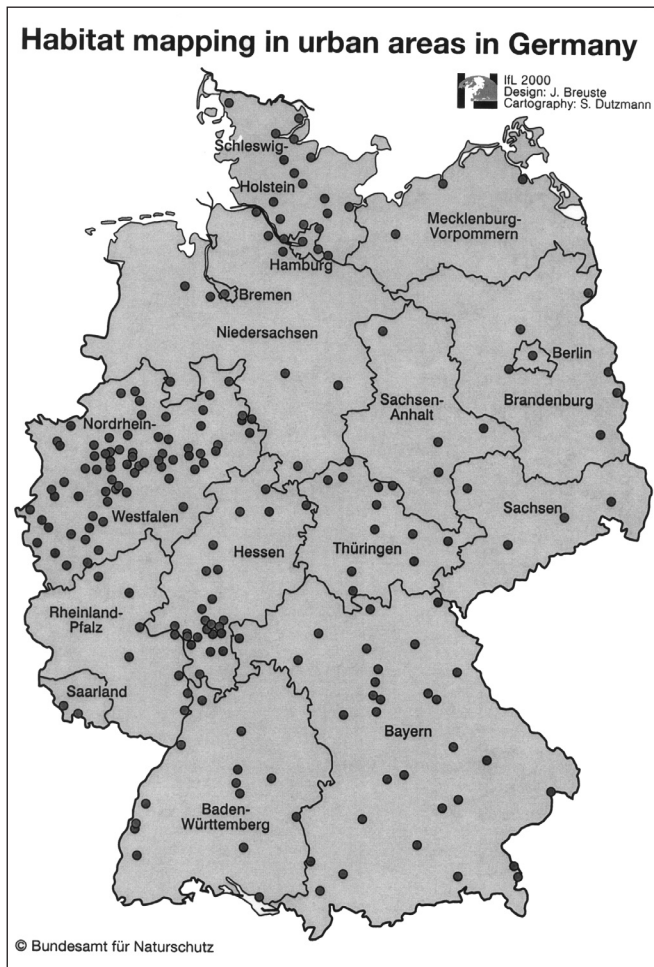


Fig. 3. Habitat mapping in Germany until 2000 (Breuste 2001)

cities are the effects on the urban water regime. High storm water run-off on the one hand and low ground water table in cities on the other hand are increasingly steered by soil sealing. This justifies extensive efforts for the analysis of the expansion and characteristics of the soil sealing (e.g. by aerial photographs and satellite images), measurements of influencing factors and urban programs to reduce soil sealing (e.g. by application of adjusting and economic instruments). A general goal of the ecological urban development must be to infiltrate a substantially larger part of the precipitation in cities than so far and by this to reduce the storm water run-off. This should reflect that the different kinds of soil sealing (pavement types) have a different infiltration capacity.

Investigations for the infiltration behavior of differently sealed soils (sealing types) show that usual classifications of the types of soil sealing using physiognomic characteristics as “gaps” between the pavement elements (stones etc.) (physiognomic type of texture) is not sufficient to reflect the hydrological functions. Vegetation density of the “gaps”, collected fine material enrichment (indicator “aging”), intensity, duration and frequency of the precipitation events are among other things of high relevance. For different soil sealing types descriptions and typical characteristics can be summarized in “soils sealing catalogues”. These contain statements about infiltration capacity and run-off and evaporation under different conditions of precipitation events and include the ability to assess soil sealing to improve urban environmental management (Breuste et al. 1996, 2002. Múchow, Schramm 1997).

Reduction of the sealed surfaces, improvement of their water permeability and additional decentralized infiltration belong to the necessary measure of a complex management. A necessity of this task is apart from the improvement of the monitoring methodology (remote sensing, geographical information systems) also in

the technical process analysis and its spatial evaluation (experimental research and determination of sealing characteristics for different functions) (Brunner et al. 1979, Landesanstalt 1989, Bönsel, Wagner, Malten 2007, Breuste, Niemelä, Snep 2008, Breuste 2009, 2010a, b, Pauleit, Breuste 2011).

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