Characteristics of Water Repellency - Seasonal Preferential Flow Occurrence

K. Täumer, H. Stoffregen, G. Wessolek

Technical University of Berlin, Dep. of Soil Protection, Salzufer 11-12, 10587 Berlin, Germany, phone:+49 30 31421722, email:karsten.taeumer@tu-berlin.de

Aim and Introduction:

One focus of the research group Interurban is the water and solute transport in urban soils . Our measurement site is a former sewage farm (Berlin Buch). Waste water infiltration was stopped in 1985. The main problem on that site is a leaching of heavy metals and organic pollutants which were accumulated in the topsoil during 100 years of waste water application. Water repellency plays an important role on that site as it amplifies the fingering phenomenon in the sandy soil. The dry soil between the flow fingers always shows extreme water repellency. These dry profile ranges are excluded from transport processes. That reduces the effective cross section for water transport. The flow velocity in the flow fingers is increased. To calculate the water transport through the soil we looked for the effective cross section and its change over the year. This change was observed at many different sampling campaigns as well as with water content measurements (TDR) in a high spatial and temporal resolution.

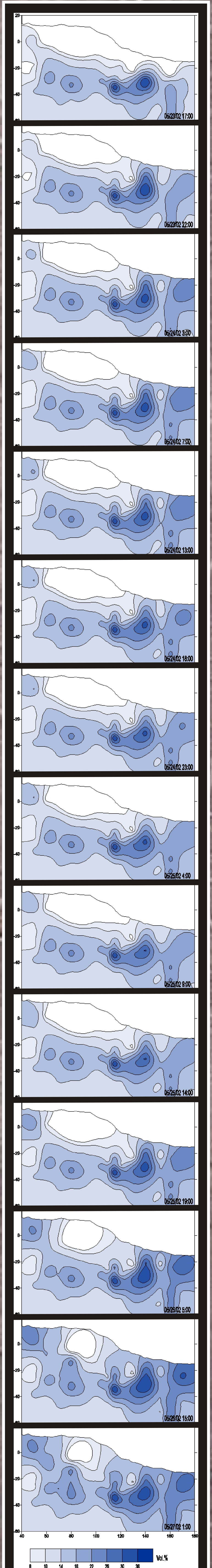

Fig.5:rainfall event May 2002, preferential flow is less Pronounced

The sampling approach:

The soil sampling was conducted from April 2001 to October 2003. 30 trenches were sampled at different dates and different locations on our investigation site after rainfall events.

Water content was measured gravimetrically and by TDR on site. The actual water repellency was tested at field moist samples using the WDPT test:
Water **D**rop **P**enetration **T**ime: three drops of water are placed on a sample, the time to absorb the drops is measured (Dekker and Ritsema 1994). Analyses were completed by texture, bulk density, organic matter content and by chemical properties like pH, and heavy metal availability to get information about the stability of the flow pattern.

Fig.1:horizontal sampling in a 10x10 cm grid, visible soil moisture pattern, Oct 2001, Berlin Buch

Fig.2: WDPT test on a water repellent soil sample

Light and dark profile ranges are related to the soil moisture and to the wettability of soil. This enables an easier calculation of the effective cross section by determining the area share of the dry profile ranges.
light colour=dry soil=water repellent
dark colour=moist soil= wettable

repellency mapping:
sampling horizontally in a grid of (10x10 or 5x5cm), calculation of the effective cross section out of WDPT data

area estimation:
representative samples were taken out of wet/dry profile ranges, appraisal of the effective cross section directly at the trench or out of pictures

The TDR approach:

A TDR transect is installed into a representative profile. 63 TDR probes are installed in a grid with 10 cm spacing from 10 to 50 cm depth. A logger stores the TDR readings every hour.
To analyse the degree of heterogeneity the transect was split in 13 equidistant (10 cm) vertical sections(fig.3). The change in water content was analysed from the beginning of a rainfall event to the time with maximum change. Figure 6 was constructed by calculating the fraction of the total amount of water content change recorded by each TDR probe (in 20 and 30 cm depth), ranking these values in descending order and plotting them with the cumulative cross-sectional area of the profile. If water percolates uniform into the profile, there would be no spatial variation and each profile section would contribute an equal amount to the total. The result is a 1 to 1 line (see fig.4). Departures from the 1 to 1 line indicate preferential flow or heterogeneity.

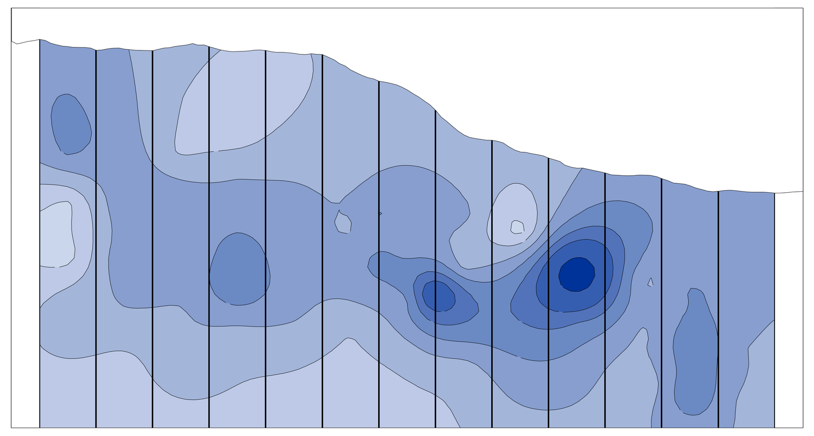

Fig.3:fragmentation of the TDR transect into 13 sections

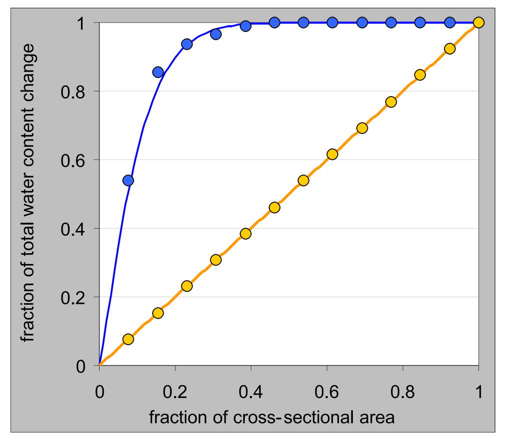

Fig.4:fractions of water content change plotted with the fraction of the cross sectional area
orange = piston flow
dark blue = preferential flow

A beta function as defined by Bronstein and Semendyayev (1979) was fitted to the measured data where is the gamma function and and are free parameters.

$$p(x;\ ;\ )\quad \frac{(\qquad)}{(\ )\ (\ )}\,x^{\ \ 1}(1\quad x)^{\ \ 1}$$

$$for\qquad 0,\qquad 0,\ 0\quad x\quad 1$$

The fitted function was then used to calculate the effective cross section which carries 90% of water content change in 20 - 30 cm depth.

Meteorological Data:
The basic data like temperature, humidity and rainfall were measured on site. A logger stores the readings every 5 minutes.

Results:

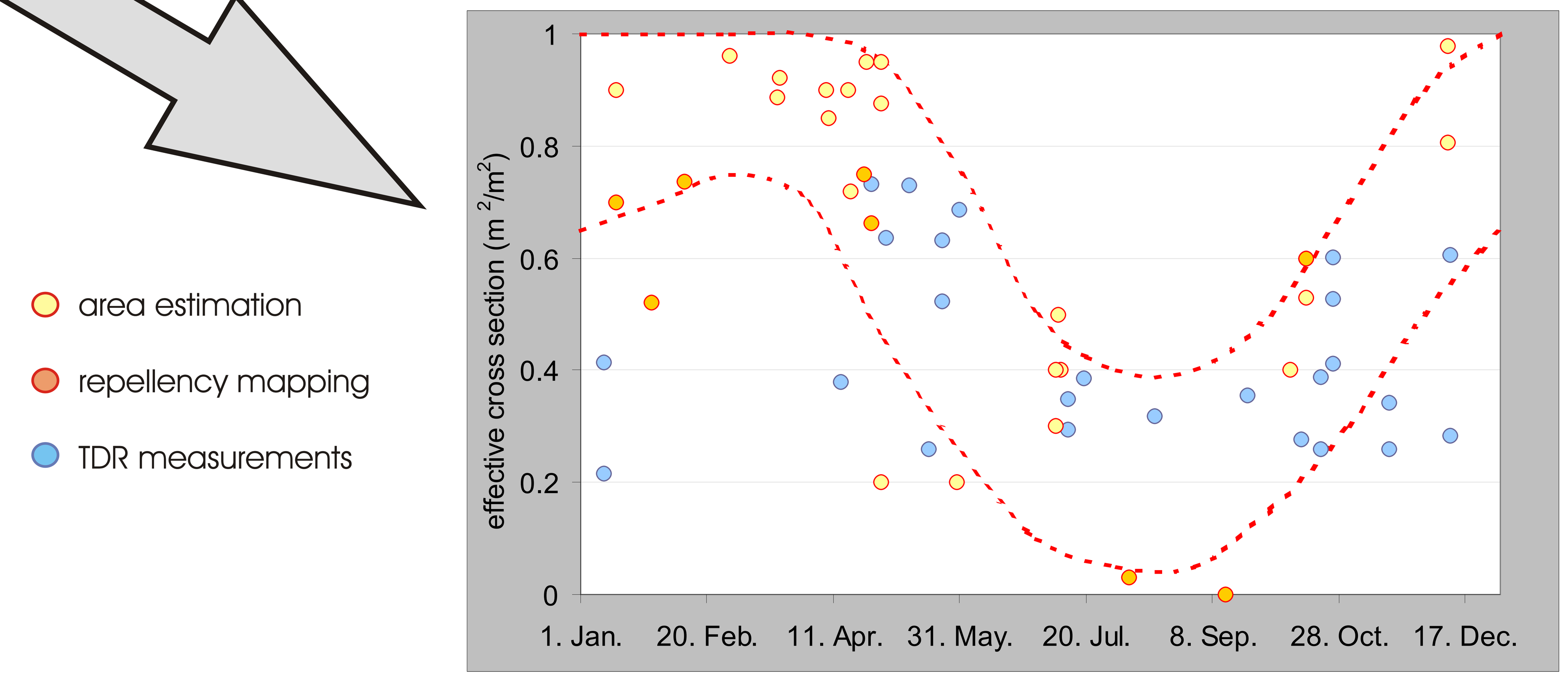

Fig.7: seasonal change of the effective cross section, measurements were carried out from April 2002 to January 2004

Both approaches indicate a seasonal change in water flow heterogeneity with a high degree of preferential flow in summer and autumn on that site (compare fig. 5 and 6). This change is mainly caused by the climatic conditions, as the climatic water balance becomes negative from April to September. The amount and the duration of rainfall events also influence the seepage pattern. A mismatch is visible between sampling and TDR data in December and January. The TDR data indicate a much higher degree of preferential flow than the observed soil moisture pattern. This heterogeneity not caused by water repellency but by frost. Within one season the flow fingers occur at the same position. But the TDR data also show a change in the flow finger location from one season to another, the flow pattern is not stable for a long time.

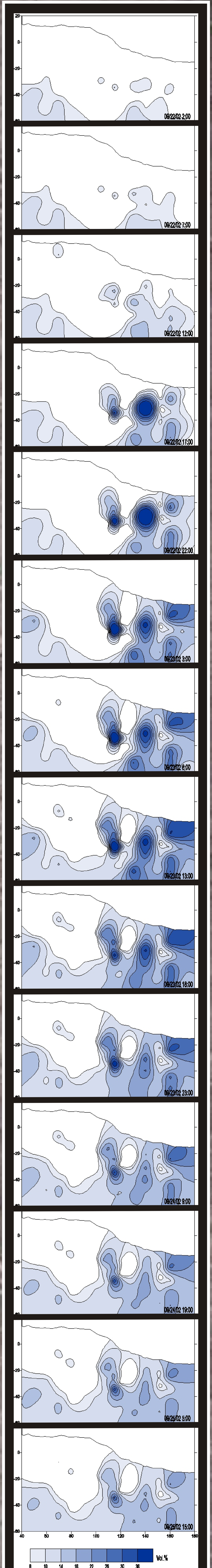

Fig.6: rainfall event Sep.2002 clearly visible preferential flow paths, profile ranges remain dry

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Conclusions and Outlook:

-water repellency was found all over the year with a maximum in summer and fall
-more than 60% of the soil volume do not take part on transport processes in summer and autumn, flow velocity is highly increased, the plant available water is more limited,

Outlook: calculation of the effective cross section using climatic parameters only

References:

Bronstein, I.N., Semendyayev, K.A.,1979:Handbook of mathematics. Frankfurt/Main,Van Nostrand Reinhold, pp 973.
Dekker, L.W.,Ritsema, C.J.,1994: How water moves in a water repellent sandy soil. 1. Potential and actual water repellency. Water Resour. Res. 30, 2507-2517