

## ***Interactive comment on “On the measurement of solute concentrations in 2-D flow tank experiments” by M. Konz et al.***

### **Anonymous Referee #1**

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#### General comments

This paper discusses and compares two different methods to quantify solute concentration in a salt water upconing flow experiment in a quasi two-dimensional porous medium on a meter length scale. Salt water is dyed with a red tracer, so that the tracer concentration relates to the salt concentration. The first method is a light-on technique, where the green-value of a digital picture is related to solute concentration. The second method is electrical resistivity measurement. The focus of the paper is on the measurement techniques and on their sources of error. Optical methods are often used to determine solute concentration or phase saturations in laboratory experiments. The paper is a an interesting contribution to this field and offers new insights in

terms of the discussion of the errors. The most interesting conclusion is to my point of view the source of error due to the lens flare effects. One of the advantages of optical methods is that they allow for a concentration measurement over the whole medium at one time. The errors discussed here show the limitations of this capability. The paper fits into the scope of the journal. However, as both methods discussed here are not new, the paper would profit if the findings would be discussed more in the context of existing work. As an example, the methods could be compared to other methods (in particular to light transmission method or the use of fiber-optic probes in combination with fluorescent tracers) and the results could be compared to results of papers, where the same method was used (for example the paper of Rahman et al., 2005, which the authors mention, but they do not compare the different approaches of the image analysis). I would comment publication of the paper after some revisions.

#### Specific comments

During reading the paper it did not become clear to me why in this study a light-on instead of a light transmission method was used. Only at the end, in the Conclusions, it is mentioned that the light transmission method would be promising and that it was not chosen here as the construction of the chamber did not allow for it. I would expect that the light-through method would lead to more reliable results. The problem of 3D effects (which is not mentioned here, was it tested?) would be less severe, a uniform illumination could be achieved more easily, the flare effects would be less severe. Also, very good literature is available about light-through measurements to determine fluid contents (for example by the group of R. Glass and R. Detwiler, J. Selker and coworkers, among others). The image analysis discussed in these papers could be extended to analyze solute concentration in one phase. There probably exist already studies about this. I guess the light-on method has also advantages, for example, it could be used for non-transparent filling material. A comparison of the methods and a discussion of the advantages of the method used here would be helpful as a motivation for the use of the light-on method.

The correction of fluctuations in brightness (Section 3.2) is not so convincing. It is demonstrated here only for the color cards (Figure 3), which are placed close to the reference card. It would be interesting to see a demonstration of the applicability of the correction for the concentration measurement at an observation point, which is not placed in the center and where the illumination difference to the reference card is high. As written above, Rahman et al., 2005, use a similar optical method to determine the solute concentration in a lab experiment. They use a more complex procedure to compensate for the fluctuations of the light source than described here in Section 3.2. The method used here would correspond to their equation (13) with  $\gamma = 1$  and  $\alpha = 0$ . It would be useful to have a comment on that.

The applicability of the fluctuations of the brightness (Section 3.2) would also be more convincing if a mass balance for a test experiment would be shown. The input and output of concentration are known, therefore the total mass of salt water in the flume is known. It would be interesting to see if this mass is recovered with the optical method used here and if possible mass errors are in the range of the error due to the lens flare effect.

I am not very convinced of one of the major findings in the paper that the resolution of the observation point is crucial for the precision of the intensity measurement (Abstract, Conclusions and Section 3.3). The resolution areas analyzed here correspond roughly to one grain size up to an area of  $10 \times 10$  grain sizes, which is roughly an REV of the porosity. The fluctuations of the intensities become insignificant only after averaging over the REV, which is probably not so surprising and could be transferred to other experimental setups or fillings.

The mentioning of the different experiments (E1 to E4) in Section 2 without further explanation is confusing. The same is true for Section 3.4. It would be helpful if it would be explained in Section 2 what experiments were carried out.

In Rahman et al., 2005, the images had to be corrected for rotation or translation

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movement. Was this not necessary in these experiments?

I do not agree with the conclusion that both optical and electrical resistivity methods yield the same concentrations. Unfortunately in Figure 15 only the upper and lower limit of the optical curve is given. But if I understand the error estimation correctly, the measurement curve would be closer to the lower bound. So there is quite a difference between the concentration measured with electrical resistivity and the optical method in P2. Also in P3 the mass is different. It could be argued that the electrical resistivity curve is broader due to the larger sampling volume. However, if this was the only effect, the mass underneath the curves should be the same. This seems not to be the case. Which method is more reliable? Could the difference be due to the flare effect although the mask was applied?

Why is the median chosen to average the intensities in Section 3.3 and Figure 4? The change of the averaged value in Figure 4B is confusing. If the mean was used instead of the median, one would expect in Figure 4B to find always the same mean with decreasing error bars.

It would be useful to have the calibration and standard deviations in Figure 5 also for the other measurement points in order to have an impression how big the variability is. This could even be included in one figure.

Technical comments

The language seems sometimes a bit odd, in particular in the Introduction. But as I am not a native speaker I would leave comments on the language to others.

Page 4181, line 12: What are the numbers in the brackets? I guess shutter speed, f-number and ISO speed? What was the white balance mode?

Page 4185, lines 10-15: What was the concentration in this experiment?

Page 4186-4187, lines 25-6: Which are the observation points? P1, P2 and P3 or all squares visible in Figure 1?

Page 4187, lines 13-20: Why is the error of intensity equal to the error of concentration? I would expect the relation of intensity and concentration to be nonlinear, so that the error would need to be propagated.

Section 4: One sentence about the setup at the beginning would be helpful for the understanding.

Page 4188, line3: I don't understand the phrase "for measurements outside the porous media flow tank";. Why would one want to measure outside of the flow tank?

Section 4.1: For what stands RMC?

Which is the time range for the measurements in Figure 3?

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