Response to Referee #1's Comments on Manuscript hess-2020-91 "A new criterion for determining the representative elementary volume of translucent porous media and inner contaminant" by Ming Wu, Jianfeng Wu, Jichun Wu, and Bill X. Hu

Note that the following text in Arial Narrow font denotes Editor's and Reviewers' comments and in Times New Roman font denotes our response to the comments in the review. In our resubmission, the marked PDF file (Wu_et_al_R1_marked.pdf) has clearly indicated all changes to the original manuscript. Also, in our marked PDF file, marked in ~~a green strikethrough font~~ is the text that should be removed from the original manuscript and marked in a red font is the text that has been added to the revision. In addition, Line number(s) mentioned below is referred to as that line numbering in the marked revised manuscript.

Response to Anonymous Referee #1's Comments

Anonymous Referee #1

Received and published: 24 June 2020

This paper presents a study of determining the REV of translucent porous media and inner contaminant based on two sand-box experiments. This paper is interesting, however, some details are missing. So I suggest "Major revision".

[Response] Comments accepted. We appreciate Referee #1's conscientious and positive recommendation. We have fully addressed Referee #1's concerns in the revised manuscript.

My comments are as follows.

(1) In the abstract, the new method of determining criterion should be pointed out clearly.

[Response] Comments accepted. We have revised this sentence to point out the new criteria (Lines 15-16).

(2) Light transmission techniques are very useful in two experiments. As shown in Eqs. (1)-(5), some parameters are important, but these parameters are not introduced in the following experiments and analysis.

[Response] Comments accepted. We have added a heterogeneous case (Experiment-III) to validate the applicability of new criteria for REV estimation.

To derive two fitting constants, some procedures should be taken. For heterogeneous case (Experiment-III), six grades of commercial translucent Accusand silica sand were used to pack the sandbox. Background material was packed by the F20/30 mesh sand and F70/F100, F70/F80, F40/F60, F50/F70, F35/F50 mesh sands with low permeability were used to pack five lenses (Fig. 2c and **Table A1**).

Table A1 Properties of six kinds of translucent silica sand

Property of sands	F20/30 background	F30/40 Lens E	F50/70 Lens D	F40/50 Lens B	F70/80 Lens C	F70/100 Lens A
Median grain diameter (cm) [a]	0.072	0.036	0.026	0.034	0.022	0.016
Porosity [b]	0.331	0.304	0.249	0.277	0.221	0.201
Permeability (m^2) [a]	1.35×10^{-10}	8.85×10^{-11}	3.66×10^{-11}	6.38×10^{-11}	8.19×10^{-12}	4.69×10^{-12}
Entry pressure (kPa) [a]	0.049	0.203	1.058	0.490	2.048	3.895

[a] refer to O’Carroll et al. (2004)

[b] from experiment measurement and refer to Bradford et al. (1999)

Temporal emergent light intensity distribution before PCE injection into sandbox was collected as in Fig. 3a which every pixel is 0.482mm×0.523mm. Obviously, area of every pixel approaches zero and obey the requirement of Light transmission technique. The average emergent light intensity of lenses A, B, C, D, E and background material F20/30 mesh sand are derived from Fig. 3a and their porosity is listed in **Table A1**. The relationship between light intensity and porosity developed by Light transmission technique as Eqs. (1)-(5) is validated in **Fig. A1**. There is a fairly agreement between light intensity and porosity with R^2 value equals to 0.9818 that any significant bias doesn’t appear in the validation results (**Fig. A1**). The parameters γ and β in Eq. (5) are achieved from validation results and the porosity distribution of 2D porous media achieved by Light transmission technique is shown in **Fig. A1**. The whole mass of sand packed in the sandbox is calculated:

$$M_c = \sum_{i_2}^{m_2}\sum_{i_1}^{m_1}(1-\theta_{i_1,i_2})L_1L_2L_3\rho_s \tag{A1}$$

where M_c is the total mass of sand calculated from Light transmission technique; i_1 is the layer number of computing grid; i_2 is the row number of computing grid; m_1 is total number of layers; m_2 is the total number of rows; $\theta_{i,j}$ is the porosity of computing grid; L_1 is the length of computing grid; L_2 is the width of computing grid; L_3 is the thickness of computing grid; ρ_s is the density of sand particles. In comparison with the actual mass of sand in experiment, the relative error of 4.85% is achieved by Light transmission technique for calculation of sand mass. These results indicate a good agreement between the quantifications by Light transmission technique and experiment observations.

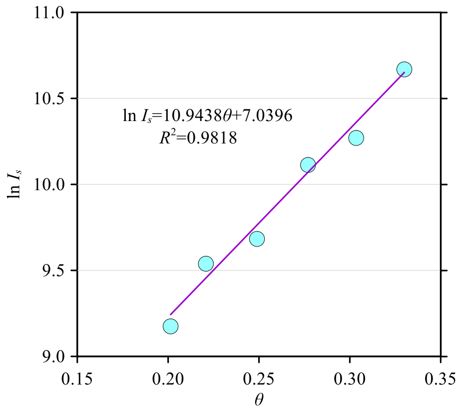

Fig. A1 The emergent light intensity versus porosity for different mesh sands used in experiment.

For other experiments, the emergent light intensity is corrected using the method expressed by Bob et al. (2008). All images collected were automatically corrected for the dark signal (baseline) associated with the CCD detector by subtracting an image taken at the same exposure time with the camera shutter closed. To correct for the inevitable temporal variation in light intensity, a small region, referred to as a "correction box", in one of the collected images (referred to as the reference image) was identified. The reference image was chosen to be the image collected when the model was fully saturated with water and was packed by background material (F20/30 mesh sand) for Experiment-III. In choosing the correction box, it was very important to make sure that, for all other images of Experiments-I and II, this region always remained under the same conditions of full water saturation and same mesh sand. Thus, any change in light intensity within the correction box was due to changes in source light intensity. The average light intensity of this correction box was calculated for all images including the reference image. To correct a particular image of other experiments, light intensities from image were simply multiplied by the ratio of the average light intensity of the correction box for the reference image and the average light intensity of the correction box for the image to be corrected.

Afterward, porosity is quantified by Eq. (5). Then density and tortuosity can be achieved using Eqs. (6) and (7).

(3) In Lines 141-142, an assumption that the particles and pores are with lamellar structure is made. Further explanation and justification should be made for the reasonability of the assumption.

[Response] Comments accepted. To quantify the porosity of translucent silica sand by light transmission method, we suppose 2D translucent silica sand is consist of various infinitesimal elements whose area approaches zero. An infinitesimal element is selected from 2D translucent silica sand which area approaches zero (Fig. 1d). The size of cross-sectional area of infinitesimal element is less than the particle size of silica sand. Therefore, the infinitesimal element can be treated as lamellar structure shown in Fig. 1d. Obviously, area of every pixel approaches zero and obey the requirement of Light transmission technique. In comparison with the actual mass of sand in experiment, the relative error of 4.85% is achieved by Light transmission technique for calculation of sand mass.

(4) From Figure 7, the pattern of minimum REV sizes of porosity, sand density and torturosity is quite different. Further explanation should be given based the new criterion.

[Response] Comments accepted. The materials packed in two sandboxes are different. F40/50 and F20/30 mesh translucent silica sands are used for Experiments-I and II. So the minimum REV sizes of two experiments are different. What's more, the REV sizes of different parameters have different patterns. The REVs of porosity, moisture saturation (S_W) and interfacial area (A_I) also obtained different values according to Costanza-Robinson et al. (2011). The relationship observed for S_W-REV and S_W are different from the relationship between A_I-REV and S_W. Therefore, the REV of different parameter is possible to be different.

(5) The innovative point of this paper lies in the proposed criterion of determining REV. Two experiments have been carried out to validate the accuracy and reasonability of the criteria. However, the applicability of this method still requires to be further validated and clarified, because two cases are not enough and scale effects exists.

[Response] Comments accepted. We have added a heterogeneous case (Experiment-III) into the revised manuscript.

(6) The mean size of REV is made based on its relations with porosity, density and tortuosity. Other variables, such as pressure or saturation, can be served as an additional indicator?

[Response] Comments accepted. The REV of porous media is made based on its relations with porosity, density and tortuosity. However, PCE saturation is an indicator for PCE plume in porous media, the REV of PCE saturation can be used to obtain the REV of PCE plume.

Minor comments:

(1) In Line 14, what are "previous REV estimation"?

[Response] Comments accepted. We have corrected "previous REV estimation criteria" to "existing REV estimation criteria" (Lines 14-15).

(2) In Line 15, a new criterion should be clarified.

[Response] Comments accepted. We have made correction to clarify the new criterion (Lines 14-17).

(3) In Line 23, cannot ?

[Response] Comments accepted. We have replaced 'can not' with 'are not effective' (Line 25).

(4) In Line 51-52, Fig.1c is cited before Fig.1a and 1b.

[Response] Comments accepted. We have modified the numbers of figures in Fig. 1 (Lines 653-659, 683-685).

(5) In Line 119, Table1 should be “Table 1”.

[Response] Comments accepted. We have corrected “Table1” to “Table 1” (Line 128).

(6) In Lines 217-218, the sub and sup i should be consistent.

[Response] Comments accepted. We have corrected the sub and sup i (Line 256).

(7) In Line 552, volume?

[Response] Comments accepted and correction made accordingly (Line 618).

(8) In Table 1, how do you know permeability of the sand?

[Response] Comments accepted. The average permeability of silica sand is obtained by experiment and research references. Moreover, accurate permeability of 2D translucent silica sand can be calculated by the help of light transmission technique and fractal method. Afterward, average permeability of silica sand also can be obtained.

(9) In Line 623, the subtitle of Fig.5a can be confusing, and it is suggested to replace porosity, density and tortuosity with other words.

[Response] Comments accepted. We have made correction according to suggestion (Lines 693-695).