

## Supplement

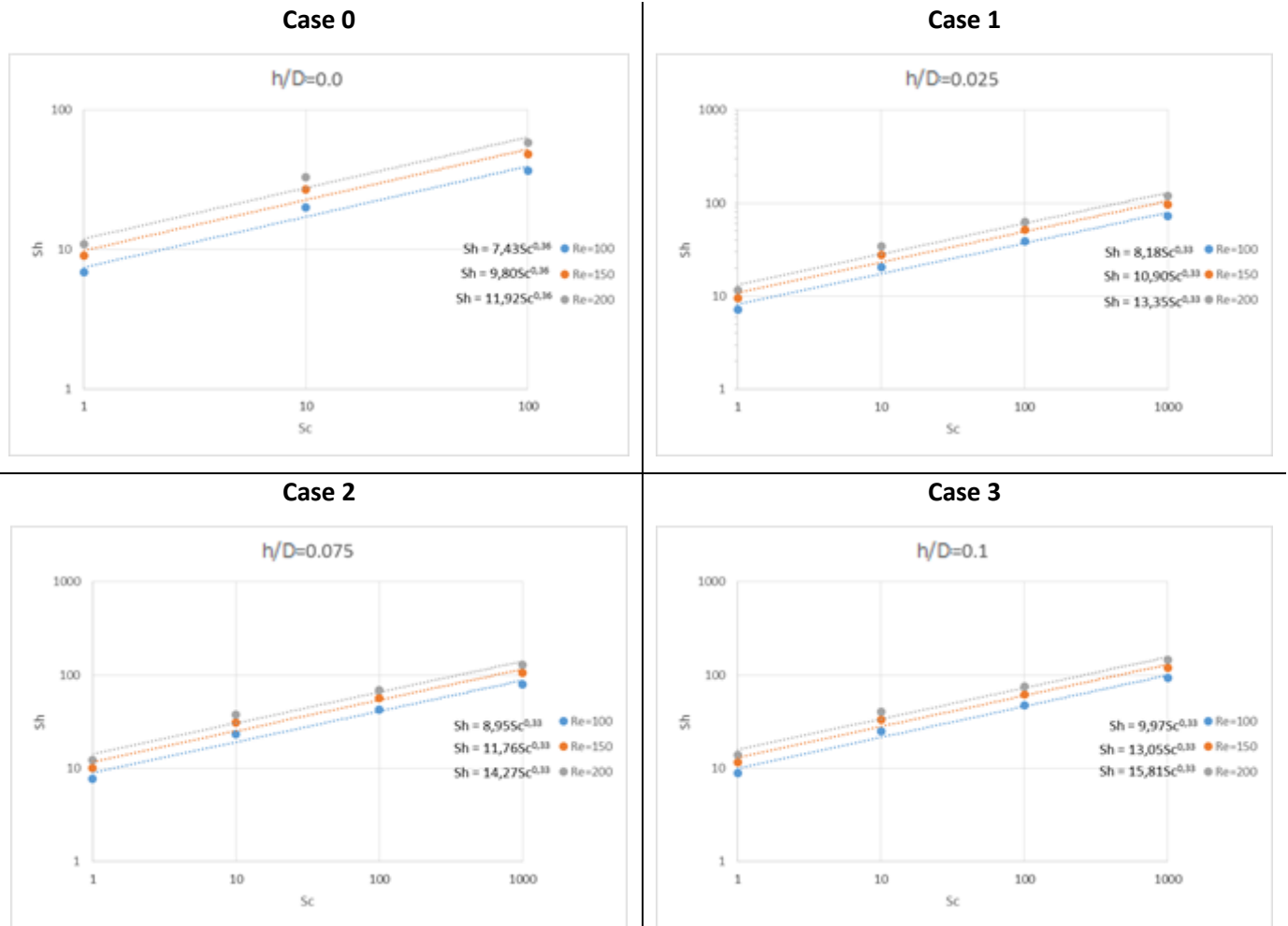
### *The effect of gap reduction on fluid dynamics and mass transfer in membrane narrow channels filled with novel spacers - A detailed computational study*

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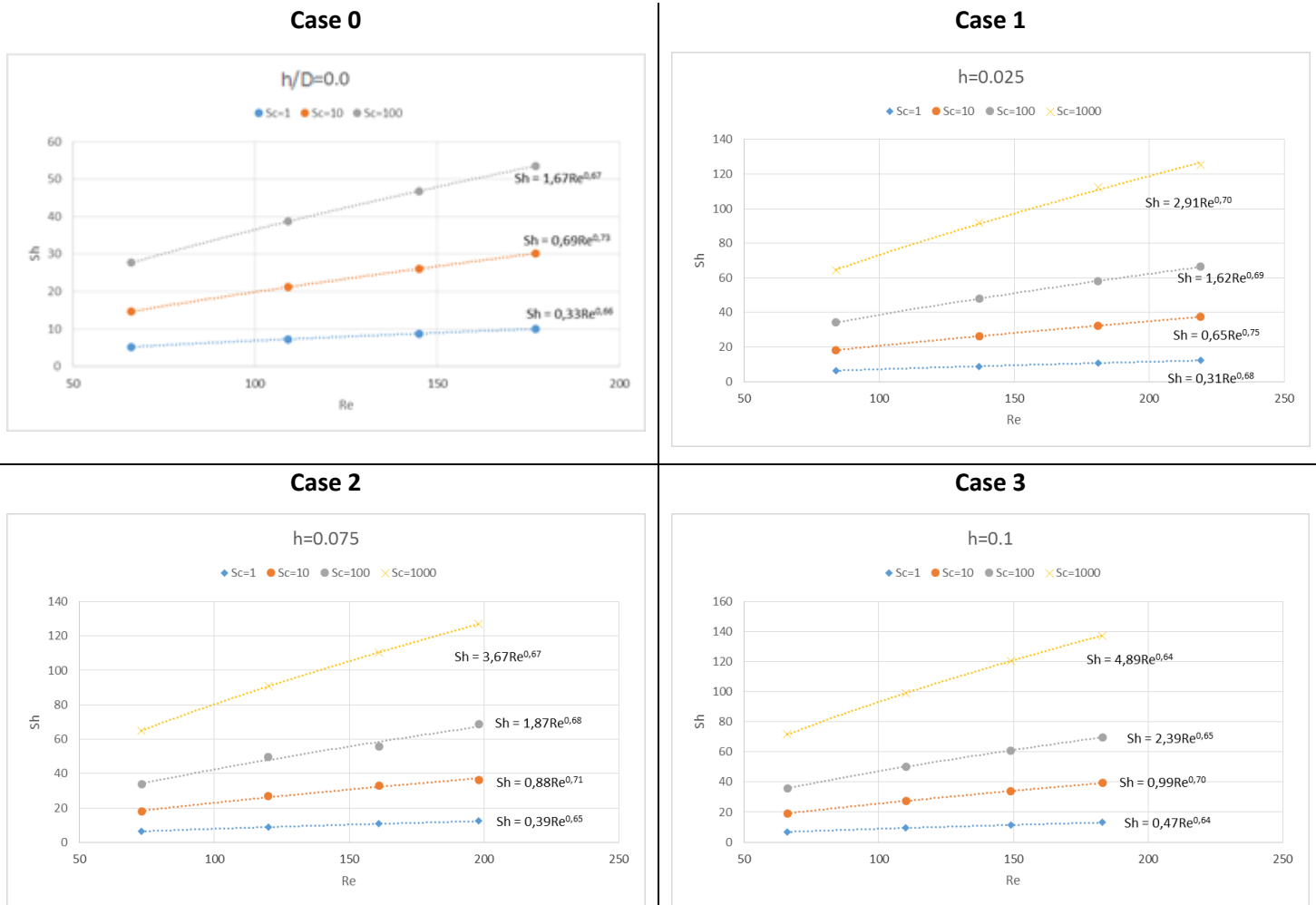
#### **A. Development of mass transfer correlations**

Supplementary information is provided herein regarding the development of generalized mass transfer correlations based on the data obtained from the numerical simulations. The satisfactory correlation with  $\sim 0.33$  exponent is evident in the diagrams of **Figure S1**, where the  $Sh$  number is plotted as a function of  $Sc$  number for the range of channel gap numbers studied.

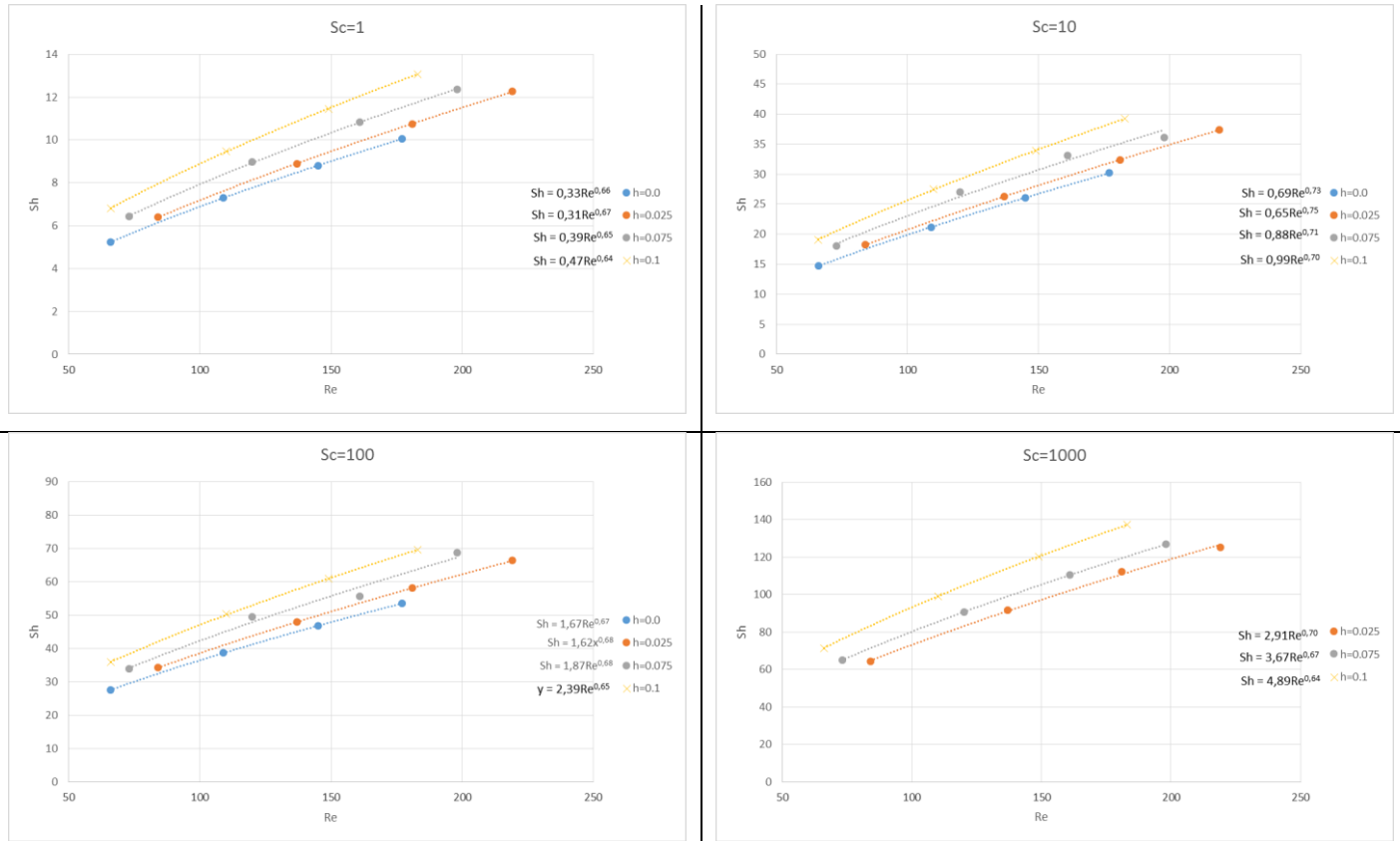


**Figure S1:** Time and space-average  $Sh$  number on the membrane surface as a function of  $Sc$  number for various gap reduction parameter ( $h/D$ ) values.

The  $Sh$  number results are also plotted as a function of  $Re$  number, as shown in **Figure S2**, for each  $h/D$  case studied, in the range of  $Sc$  numbers 1 to 1000. The case of nominal gap is presented for comparison, but for  $Sc$  number values only up to 100, as described in previous work [33]. While a general trend is followed in these correlations, the results for  $Sc=1000$  exhibit a somewhat steeper slope, especially with increasing  $Re$  number. Alternatively, **Figure S3** shows data plotted for the  $Sh$  number as a function of  $Re$  number, for each  $Sc$  number studied, and the three  $h/D$  cases

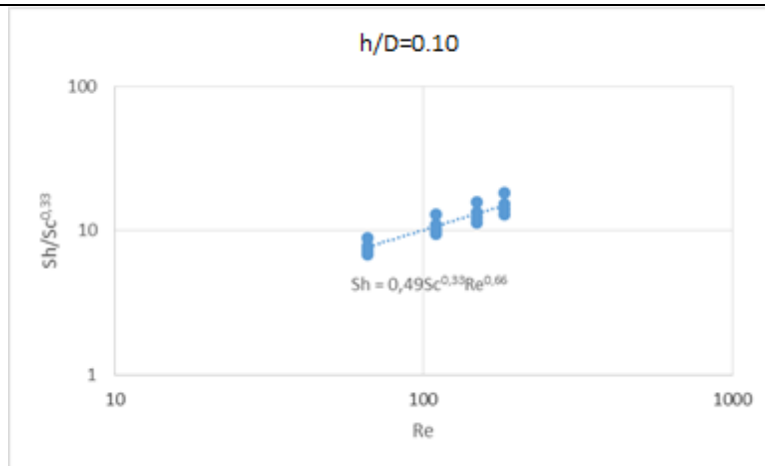
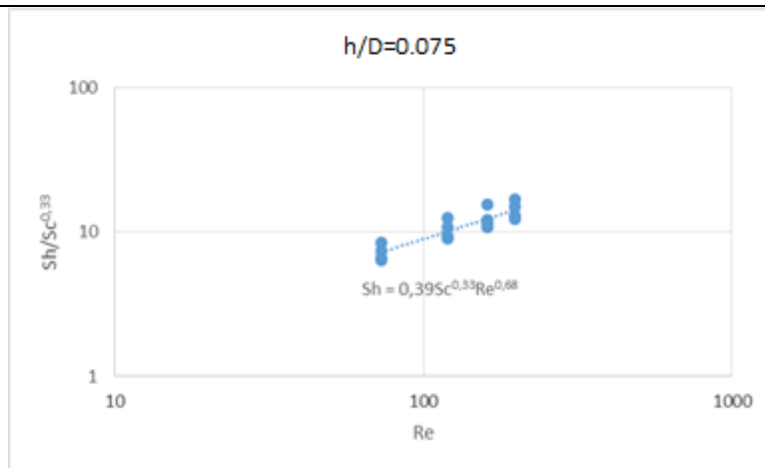
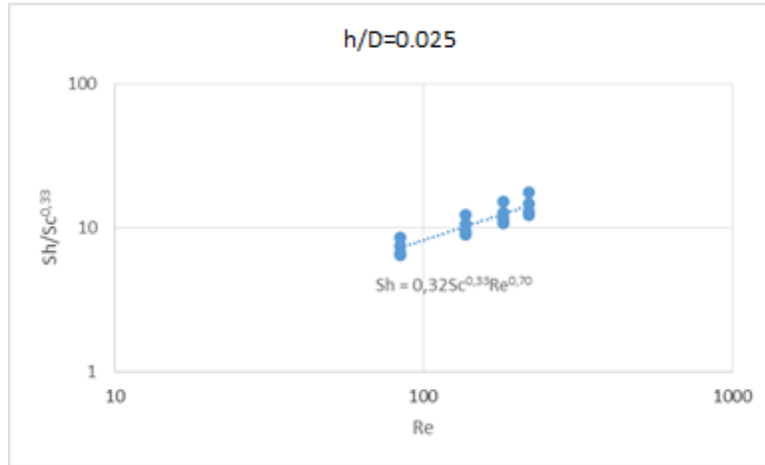


**Figure S2:** Theoretical predictions of  $Sh$  number dependence on  $Re$  number for the novel spacer, for various gap reduction  $h/D$  values.

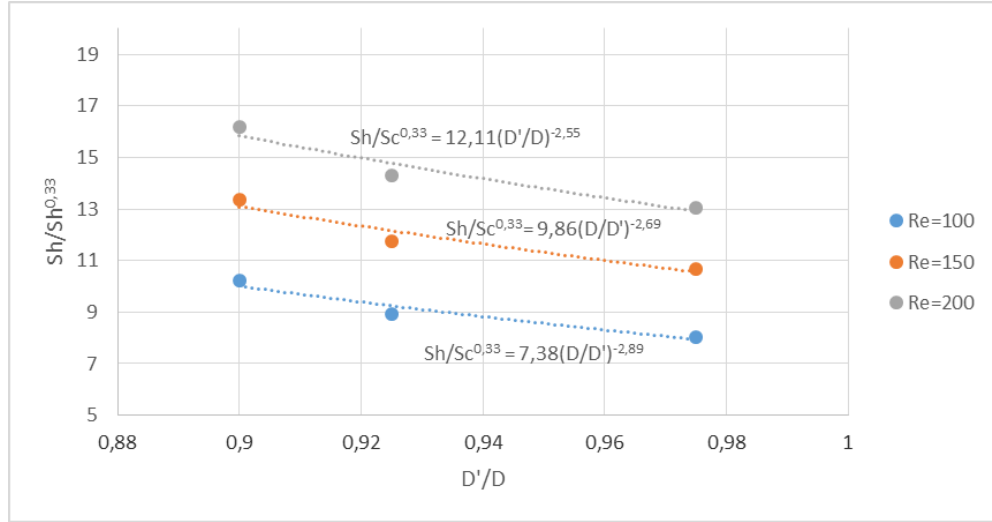


**Figure S3:** Theoretical predictions of  $Sh$  number dependence on  $Re$  number for various layer thicknesses of the novel spacer, for the same  $Sc$  number.

In order to develop a generalized correlation, the data of **Figure S1** are replotted in **Figure S4**, in the form of  $Sh/Sc^{0.33}$  as a function of  $Re$ , for each  $h/D$  value studied. Next, the  $D'/D$  dependence needs to be determined; thus,  $Sh/Sc^{0.33}$  versus the ratio  $D'/D$  is plotted in **Figure S5**, showing a dependence approximated with an exponent  $-2.71$ .



**Figure S4:** Correlation of dimensionless  $Sh$  number parameter as a function of  $Re$  number, for gap reduction parameters  $h/D$ .



**Figure S5:** Time and space-average  $Sh$  number, on the membrane surface, as a function of ratio  $D/D'$ .

### **B. Implementation of numerical computations**

- The simulations were executed in a computer with technical specifications: Intel® Core™ i7 CPU @ 3.07GHz and 12GB memory capacity.
- Computation time varied depending on input data (pressure drop and  $Sc$  number). Typical computation time was 2 days to reach/ensure a steady state (statistically), thus leading to time series with no or constant fluctuation.
- The computational mesh consisted of approximately  $3 \times 10^5$  elements (i.e. 61636 nodes with 328820 elements).