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Editorial

Editorial for Mass Transfer in Multiphase Reactors

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1. Introduction

Gas–liquid reactors (especially bubble columns (BCs)) are the most widely used in both the chemical and biochemical industries [1]. Numerous industrial processes (methanation and Fischer–Tropsch synthesis, oxidations, chlorinations, etc.) are performed in BC reactors. These important gas–liquid contactors are characterized by excellent degrees of mixing, mass transfer (MT) and heat transfer coefficients [2]. The key parameters are the gas holdup, bubble rise velocity, gas–liquid interfacial area and volumetric liquid-phase MT coefficient k_La [1]. Most of the articles are focused on the investigation of these parameters. The k_La coefficient determines the MT time [1] and takes part in several important dimensionless MT numbers (such as the Sherwood number, Stanton number, etc.). These dimensionless numbers play a key role in the development of every scale-up methodology [2]. Other important topics in the gas–liquid reactors are the effect of eddy turbulence on the MT, the identification of the transition from bubble-induced turbulence to eddy-induced turbulence, the investigation of the effect of vortices on the MT, the development of empirical correlations for prediction of gas holdup, both small and large bubble diameters, k_La coefficient and interfacial area, the determination of the onset of foaming, etc. The most notable revisions of these engineering problems in gas–liquid contactors have been published by [1,3,4].

2. Review of Contribution to the Special Issue

In this Special Issue (https://www.mdpi.com/journal/fluids/special_issues/TX0RK3PZW2, accessed on 31 May 2025) of the journal *Fluids*, eight articles have been published. Authors from the following five countries have contributed: Poland (two articles), Germany (two articles), Austria (two articles), France (one article) and China (one article). Each published article has been reviewed by at least two experts from different countries.

The first review article (Contribution 1) from Poland summarizes the available measurement techniques for the determination of the MT coefficients in various BCs. In addition, the major semi-empirical correlations (with their applicability ranges) for prediction of the MT coefficients have been summarized. Some MT correlations have been based on the corrected penetration theory. The primary reason for the correction has been well explained. The different definitions of the gas–liquid contact time, including the one based on the local isotropic turbulence theory, have also been presented. It has been clearly underlined that in tall bubble columns the mixing in both phases should be taken into account when the MT coefficients are being estimated. A system of two differential equations (involving gas and liquid dispersion coefficients) should be solved in order to obtain the accurate MT coefficients. In the second part of the article, the various chemical methods for determination of the gas–liquid interfacial area have been presented. Additionally, the main correlations for prediction of the gas–liquid interfacial area have been reported. Finally, the effects of pressure, temperature and viscosity on the interfacial area and the MT

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coefficient are discussed. This article has been viewed 5254 times and five citations have been found in the literature.

In the second article (Contribution 2) from Poland, the author has investigated the dependence of the MT ratio (MT coefficient-to-gas holdup) on the superficial gas velocity U_G in a BC operated with seven organic liquids and four mixtures under ambient conditions. The volumetric liquid-phase MT coefficients have been recorded by means of a polarographic oxygen electrode in a BC (0.095 m) equipped with a single tube (orifice diameter = 3 mm) as a gas sparger. It has been found that the MT ratio decreases monotonically through all main flow regimes. Both the constant and the exponent of the empirical correlation between the MT ratio and U_G have been analyzed and it has been found that they depend in a complicated fashion on the Schmidt number Sc. In three different regions of the Sc number, potential new correlations have been discussed. The main conclusion from this work is that the MT ratio is not constant in the heterogeneous regime, as reported by other researchers. In the case of four binary mixtures between benzene and cyclohexane, it has also been found that the MT ratio decreases monotonically as a function of U_G. The effects of both liquid viscosity and surface tension on the MT ratio have also been investigated. This article has been viewed 540 times so far.

In the first article (Contribution 3) from Germany, important characterization data for the establishment of scale-up and process transfer strategies between stainless steel and single-use bioreactors have been reported. A scale-up study for three single-use bioreactors (200, 2000 and 15,000 L) has been presented. Both the scale-up and process transfer strategies have been based on the comparison of the mixing times and the modeling of the volumetric MT coefficients k_La in an aqueous PBS/Kolliphor solution. The k_La coefficients have been predicted very well by the famous van't Riet correlation (at constant stirrer-tip speeds). This article has been viewed 6522 times and seven citations have been found in the literature. The second article (Contribution 4) from Germany has been focused on the statistical analysis of bubble parameters from a model BC with and without counter-current flow. Numerous experiments using shadow imaging and particle image velocimetry (PIV) techniques in a lab-scale bubble column (with and without counter-current flow) have been performed. 108 different operating conditions have been investigated. In addition to the liquid flow fields recorded by PIV, shadow imaging data (bubble diameter, velocity, aspect ratio, bubble motion direction and inclination) have also been statistically evaluated. The authors have found that the counter-current liquid flow has a substantial influence on both bubble velocity and motion direction. In the case of carbon dioxide usage as a gas phase, a remarkable bubble shrinkage has been observed for counter-current liquid flow due to the enhanced MT. The authors plan to use further the obtained bubble data for the development of correlation and validation of numerical simulations. This article has been viewed 2360 times so far.

The first article (Contribution 5) from Austria has been focused on the impact of the solid particle concentration and liquid circulation on gas holdup in counter-current slurry bubble columns with a rectangular cross-section. Air, water and glass beads have been used as the three phases. The obtained results have demonstrated that the increase in the solid content from 0% to 6% can decrease gas holdup by 50% (due to the increased slurry phase viscosity and enhanced bubble coalescence). As the liquid circulation rate has been increased, a weak effect on the gas holdup has been observed. Additionally, a slight incremental effect has been noticed due to the promotion of bubble breakup and the extension of the bubble residence time. A novel correlation for the prediction of the gas holdup has been developed. It has been based on the solid concentration and liquid circulation rate. This article has been viewed 2231 times and once has been cited. In the second article (Contribution 6) from Austria, a comparative analysis of various

disperser designs and process optimization in BCs used for efficient bio-methanation has been performed. Various disperser designs have been examined in a 0.14 m BC. Their performance has been compared in terms of both bubble diameter distribution and gas holdup. The authors have found that an optimized disperser design featuring a porous structure outperformed other designs by maintaining high gas retention without significant coalescence. The commercially available porous pin dispersers have produced smaller bubbles compared to the other designs, yielding high gas holdups at lower gas velocities. Correlations between disperser type and column design parameters have been established. The authors argue that their models can be used for the development of digital twin models. This article has been viewed 2378 times so far.

In the article (Contribution 7) from France, the authors have used the elastic catalytic-foam bed reactor (EcFR) technology to enhance a model catalytic hydrogenation reaction by improving gas–liquid MT. According to the authors, this advanced technology is based on a column packed with a commercial elastomeric polyurethane open-cell foam, which also acts as a catalyst support. The authors argue that for the first time the catalytic support parameters (porosity, tortuosity, characteristic length, etc.) have undergone cyclic and controlled changes over time. These dynamic cycles have enabled the intensification of the transfer of gas to liquid at a constant energy level. The authors have investigated the selective hydrogenation of phenylacetylene to styrene in an alcoholic solution using a palladium-based catalyst under hydrogen bubble conditions. The conversion has been observed with this EcFR at 1 Hz as the cycle frequency and has been compared with that observed with a conventional Fixed Catalytic Foam-bed Reactor (FcFR). This article has been viewed 2487 times and one citation has been found in the literature.

The article (Contribution 8) from China has explored the MT enhancement through structured inserts (twisted tapes and multi-blades) and inlet designs (multi-hole injectors and T-mixers). By means of high-speed imaging and water-succinct acid-butanol experiments, the authors have analyzed flow patterns and MT rates. The results have shown that annular and dispersion flows dominate under tested conditions. It has been found that the structured inserts have lowered the threshold for dispersion flow. The authors argue that multi-hole injectors have improved MT by over 40% compared to T-mixers in plain tubes, while C-tape inserts have achieved the highest volumetric MT coefficient (2.43 s^{-1}) due to the increased interfacial area and droplet breakup from energy dissipation. This approach offers scalable solutions to enhance tube-in-tube milli-reactor performance for industrial applications. This article has been viewed 1933 times and two citations have been found in the literature.

In summary, the eight articles in the Special Issue have been viewed 23,705 times and cited 16 times so far. The readers will learn many new aspects of the mass transfer (MT) process in different multiphase reactors.

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List of Contributions

1. Nedeltchev, S. Updated Review on the Available Methods for Measurement and Prediction of the Mass Transfer Coefficients in Bubble Columns. *Fluids* **2025**, *10*, 29. https://doi.org/10.3390/fluids10020029.
2. Nedeltchev, S. Investigation of the Mass Transfer Ratio in a Bubble Column Operated with Various Organic Liquids and Mixtures under Ambient Conditions. *Fluids* **2026**, *11*, 44. https://doi.org/10.3390/fluids11020044.
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Process Transfer Strategies between Stainless Steel and Single-Use Bioreactors. *Fluids* **2024**, *9*, 115. https://doi.org/10.3390/fluids9050115.
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