# MICROFLUIDICS TRANSPORT PHENOMENA FOR BIOMEDICAL APPLICATIONS

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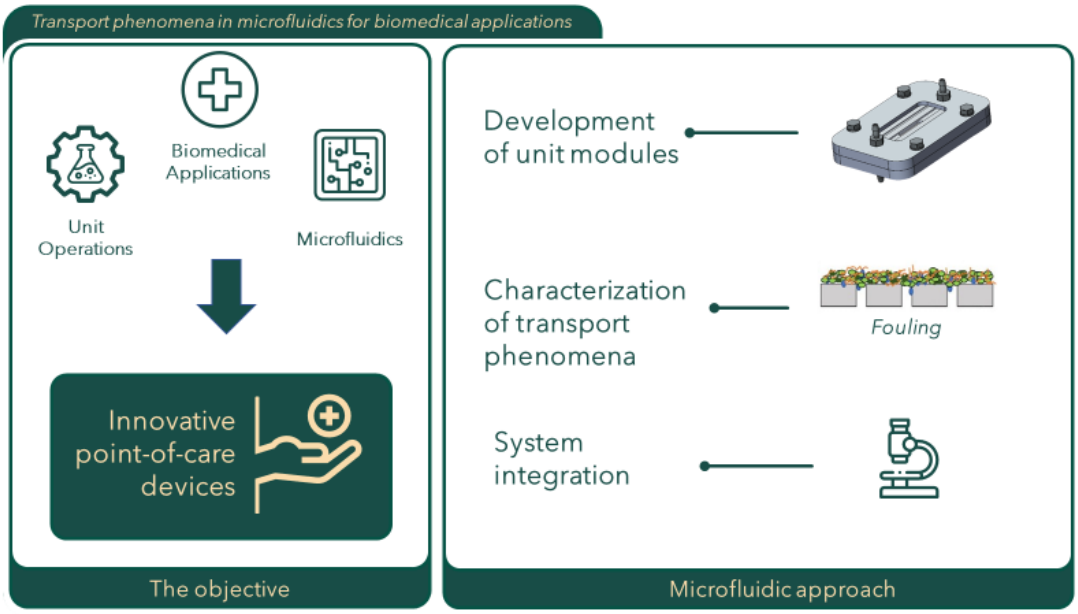


Many biomedical applications make use of common chemical engineering processes, such as membrane filtration, which can be described in terms of unit operations. An in depth comprehension of the governing transport phenomena is crucial for the development of innovative devices and the optimization of already existing ones. Microfluidics, the science and technology of systems processing low amounts of fluids in microchannels [1], represents a very useful tool for this purpose.

Compared to standard equipment, microfluidics offers a large number of benefits [2]. The most important advantage of microfluidic systems is that the use of small fluid volumes allows to reduce the consumption of reagents, resulting in a significant decrease in both costs and safety risks. In parallel, waste products are reduced too. Moreover, thanks to the small dimensions, multiple functions can be integrated on a single device, forming the so called lab-on-chip (LOC) architectures. Another relevant gain of miniaturized components is associated with the characteristic high surface-to-volume ratios. Indeed, microchannels facilitate rapid heat and mass transfer, enabling not only quick and precise temperature control but also reduced power consumption and process time. Similar features are extremely useful for processes such as PCR (Polymerase Chain Reaction), where temperature cycling can be achieved by flowing a fluid in a microchannel through different temperature regions, rather than heating and cooling it in place [3]. All the cited advantages, together with the increasing number of publications and commercially available devices, clearly show the versatility of microfluidic technologies and justify the interest from different disciplines in research and development of innovative applications. The biomedical sector is one of the most thriving areas in which microfluidics is exploited for multiple purposes, from diagnostic application to drug delivery and cell identification [4].

Microfluidics has been proven to be a key tool for research on the main problem affecting membrane processes, that is fouling or rather the flux decline and throughput loss which affects every filtration device [5-7]. This phenomenon is of high relevance in biomedical application dealing with complex multiphase fluids like blood, such as hemodiafiltration

devices, as it reduces the lifespan of membrane modules and could be dangerous for patients [8]. Conventional fouling monitoring is based on flux decrease or transmembrane pressure increase monitoring. However, despite the possibility to assess the fouling mechanism by using mathematical models to fit flux and pressure data, no information on the location, composition or amount of foulants is given. It is therefore clear how important the visualization of the fouling phenomena is.

Different techniques are available for fouling visualization, and microfluidics represents a key investigation tool in many of them [9,10]. To study membrane fouling, two microfluidic categories can be identified. The former involves membrane mimicking microfluidic devices (MMM) which reproduce in an ideal way the pore structure of a membrane; the latter includes the embedded membrane microfluidic devices, characterized by specifically designed chips that house a small portion of membrane [11,12]. Among the various investigation techniques, microfluidics find its most common application in direct observation of the fouling phenomena through bright field, fluorescence and confocal microscopy [13-15].

This first year of research was primarily focused on the filtration process applied to biological fluid purification, e.g. plasma or whole blood. A modular microfluidic filtration device was designed and built with the purpose of investigating the main problems affecting membrane processes, i.e. fouling, by combining direct observation of the phenomenon with conventional monitoring strategies. The module's design consists of a central core housing a small membrane sheet, enclosed in an external case whose functions are to seal the device preventing leakage and allow inlet and outlet connections with external pumping and metering systems. The case is also equipped with an inspection window, which enables membrane visualization. The presented module is currently being used to study the behavior of a model fouling solution (e.g. bovine serum albumin (BSA)-water) under different process conditions and a continuous optimization is being carried out in order to study the evolution of fouling via its real-time visualization.

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