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APPLICATION OF COALESCENCE FILTRATION IN SUSTAINABLE ENVIRONMENTAL PRACTICE

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Abstract

This paper presents how coalescence filtration could be applied in sustainable environmental practice. The coalescence filtration is a separation method that could be used in a wide range of industries (petrochemical, chemical, food, pharmaceutical, power plants, etc.) mostly for the separation of liquid/liquid and gas/liquid dispersed systems, like oily wastewater and metalworking fluid (MWF) aerosols. Filter media in coalescence filtration could be varied from different polymers up to stainless steel. It is very important to point out that the latest literature review shows that waste polymer materials (like polypropylene bags, waste from the carpet industry, etc.) could be efficiently used as filter media in coalescence filtration. Optimal design of coalescence filtration could provide highly efficient separation treatment of oily wastewater and MWF aerosols after which the wastewater could be reused, as well as collected MWF. In addition, this method could be designed to work continuously without the need for filter washing or frequent filter change, i.e. there is no waste generation (wastewater or waste filter). The continuous mode of coalescence filtration provides much lower energy consumption than when the mode is discontinuous. By optimization of working parameters, like fluid velocity, porosity, and permeability of filter media, etc., a mobile coalescer could be designed. Mobile coalescer is small, and light, and as such, it could be easily moved, transported, and used for oily wastewater treatment outside of industry, for example at carwash stations and on ships where bilge water is generated.

Key words*: coalescence filtration, sustainable development, oily wastewater, MWF aerosol, water reuse, energy efficiency*

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1. Introduction

Very small droplets that are dispersed in the fluid (gas or liquid) could not settle, because they are very light. However, if they coalesce i.e. merge in one bigger droplet, they could become heavy enough to settle and separate from the fluid in which they are dispersed. Coalescence filtration is separation method in which this phenomenon is applied and coalescers are devices in which coalescence filtration occurs (Govedarica & Sokolović 2014).

The coalescence filtration is widely used method for separation of liquid/liquid and gas/liquid dispersed systems in many industries like, petrochemical, chemical, food, pharmaceutical, power plants, etc, as well many other nonindustrial activities, where this kind of separation is need. For example, at car wash station, at ships, in kitchen, etc.

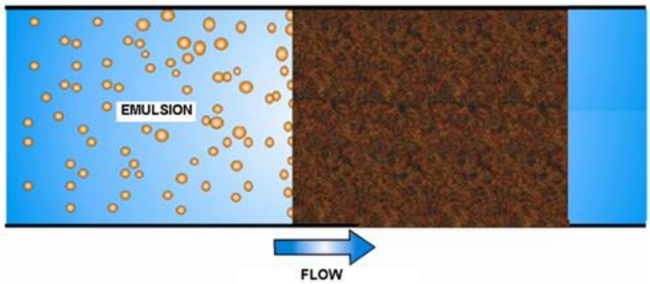
The filters that are used in coalescence filtration could be of very different kind and construction. They could be surface filters or filters made from packing materials that form filter bed. Surface filters are usually constructed as lamellae or porous surface of stainless steel or some other material. Filters made as bed material are constructed like deep bed filters and could be made from different materials. Coalescence on surface filter occurs on surface of filter, afterwards the drainage of liquid from the surface occurs. However, in filter beds coalescence occur in the volume of the bed, afterwards the droplets could settle.

In this paper is presented how coalescence filtration by filter bed coalescer could be applied in sustainable environmental practice. Firstly, the operating mode that is sustainable, key parameters and its optimization are described. Secondly, the filter bed materials that are eco-friendly are presented. And finally, application of sustainable operating mode of bed coalescer with eco-friendly filter bed material in sustainable environmental practice is presented.

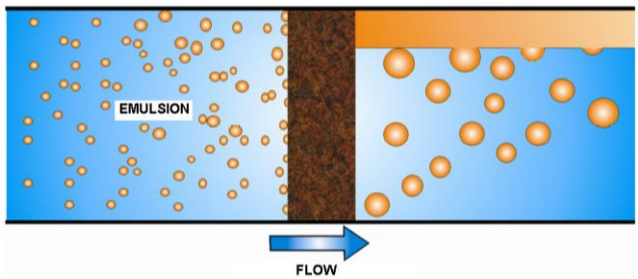
2. Sustainable operating mode and key parameters of bed coalescer

2.1 Operating mode of bed coalescer

The bed coalescers could operate discontinuously and continuously, Figure 1. a) and b).



a) Discontinuous mode of bed coalescer



b) Continuous mode of bed coalescer

Figure 1. Modes of bed coalescer for liquid/liquid dispersed system (Šećerov Sokolović et al 2016)

When bed coalescer operates discontinuously, Figure 1. a), the pressure drop rise until some maximal value, after which the bed cannot accumulate, i.e. merge any new amount of upcoming droplets of dispersed phase (Šećerov Sokolović et al 2016) i.e. coalescence is no longer possible. At that point filtration cycle if over, coalescence filtration ends and washing cycle of filter bed begins. This is a huge disadvantage of discontinuous operating mode of bed coalescers, due to generation of extra oily wastewater during the filter bed washing (Šećerov Sokolović et al., 2016). This has a negative impact on the sustainable development practice.

On the other hand, when the bed coalescer operates in continuous mode there in no need for filter bed washing i.e. there is no washing cycle, and therefore there is no generation of an extra amount of oily wastewater. In continuous operation mode the pressure drop rise only until steady-state regime is reached. State-state regime is reached when "capillary-conducted" phase is formed in filter bed (Šećerov Sokolović et al., 2016). When this condition is fulfilled, the bed coalescer could work continuously for a very long time.

In Figure 1. b) it is presented the operating scheme of bed coalescer in continuous working mode. Small droplets that are suspended in the fluid, flow until they reach the filter bed, where they coalesce. Upcoming droplets coalesce in filter bed by three different mechanisms in filter bed. Figure 2. presents the key mechanisms how coalesce occur in filter bed: a) in capillary-conducted" phase i.e. saturated liquid, b.) the adjacent droplets in the pore space and c.) on the filter surface (Spielman et al., 1972a, 1972b, 1973). Afterwards the bigger liquid droplets exit from the filter bed and settle in the settling section of bed coalescer, from where the oil is discontinuously discharged.

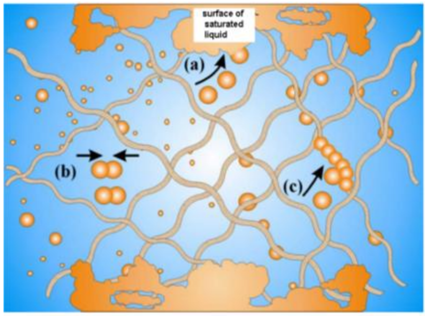


Figure 2. Coalescence mechanisms in filter bed (Govedarica& Sokolović 2014)

Sustainable operation mode of bed coalescer is continuous mode, because under this operating mode of coalescer there is no generation of oily wastewater due to filter wash. On the other hand, it works under constant pressure drop in steady-state regime, and therefore the energy demand is much lower than in discontinuous operating mode.

2.2. Key parameters of bed coalescer

Bed coalescence operating in steady-state mode is affected by many factors. However, the key parameters are fluid flow orientation, fluid velocity, bed properties, etc.

Bed coalescer could work at vertical up, vertical down, and horizontal fluid flow orientation. A long time ago, Šećerov-Sokolović et. al has shown that horizontal fluid flow orientation is the most effective fluid flow orientation for steady-state regime of bed coalescer (Šećerov-Sokolović et al., 2006), although today there are still many coalescers in vertical fluid mode.

Fluid velocity is for sure the key parameter of the coalescer because it determines not only its capacity but also its size. When it is necessary to construct small portable coalescers then the fluid velocity must be very high. However, there is critical velocity, the maximal velocity under which the emission limit value (ELV) could be obtained. After the critical velocity, coalescer could not treat wastewater any more effectively, because the ELV will be exceeded. Therefore, it is very important to determine critical velocity for every coalescer. This is determined by increasing of fluid velocity i.e. its optimization, until the value at which concentration of oil in effluent exceeds ELV.

Filter bed properties that affect the coalescence filtration are bed length, bed porosity and bed permeability. Bed length depends on construction of coalescer, and for every coalescer there is one the most effective bed length under which there is no redispersion of coalesced liquid. Bed porosity and bed permeability depends on each other. If the bed porosity is changed bed permeability will be changed as well. However, bed permeability has direct influence on critical velocity (Šećerov Sokolović et al., 1997). Therefore, it is obvious that bed porosity, bed permeability and critical velocity are key parameters of bed coalescer that affect one on other (Hadnađev et al., 2022).

Variations in bed properties influence the modification of energy consumption and pressure drop of coalescer. By increasing the bed permeability, the critical velocity increases and the size of coalescer is reducing as well as its weight (Šećerov Sokolović et al., 2016; Šećerov-Sokolović et al., 1997). Therefore, the coalescer is portable, less space for its accommodation and less material for its contraction and foundation is needed (Šećerov Sokolović et al., 2016). All this has positive impact on sustainable development.

Unfortunately, the optimization of key parameters that will have the highest operation efficiency and that will be sustainable could be done only be performing experiments. The reason is that there are many parameters that are interconnected, and all of them are influenced by the nature of filter bed material.

3. Eco-friendly filter bed materials

There are many different materials that could be used as filter bed materials, from different polymers up to stainless steel. They could be in the form of globules or fibres. The most frequently used form of filter bed materials in coalescers are fibres. Because the fibres are compressible, and therefore filter beds of different porosity and permeability in the wide range could be easily formed.

The latest literature review shows that waste polymer materials for example polypropylene bags, waste from the carpet and furniture industry could be efficiently used as filter media in bed coalescers (Sokolović et al., 2016; Sokolović et al., 2019; Hadnađev et al., 2022; Sokolović et al., 2024). This waste materials are usually from polyethylene terephthalate, polypropylene, polyurethane, etc.

Since this waste is not disposed on landfills, due to its application as filter bed materials the concept of circular economy and sustainable development is reached. This application of waste fibres has also an impact on environmental pollution reduction. Also, it is very important to point out that filter bed materials formed from this waste fibres, could operate very long without need for its washing or changing, so therefore there is no generation of any waste or wastewater. Therefore, this waste fibres represents eco-friendly bed materials.

Beside these materials, materials that have unlimited life-time like for example expanded polystyrene (EPS) are also economically and eco-friendly, because there is no need to wash or change them (Sokolović & Šećerov Sokolović, 2024).

All these materials are very light and therefore, the coalescers with filter beds made from these materials could be easily moved from one place to another if needed.

4. Application of bed coalescers in Sustainable Development

In many industrial processes and activities oily wastewater is generated. For example, in petrochemical and chemical industry, food industry, petroleum refining, leather production, metal finishing (Govedarica & Sokolović, 2014). Oly wastewater is also generated in some non- industrial activities, like at households, at carwash stations, on ships, etc.

There are many published papers that have shown effective treatment of oily wastewater (liquid/liquid dispersed system) by bed coalescers.

Šević has shown that oil-reservoir water separation could be effectively done by coalescent filtration (Šević, 1992). On the other hand, Šećerov Sokolović et. al has shown that formation water and wastewater from hardening shop could also be effectively treated by coalescence filtration (Šećerov Sokolović & Sokolović, 2009). Newly published paper confirms effective treatment of car wash wastewater by combined methods in which one of the methods is coalescence filtration (Sokolović & Šećerov Sokolović, 2024). In some cases after the treatment of oily wastewater by bed coalescers, the treated water is of high quality that it could be reused in process.

The bed coalescers could be also effectively used for Metal Working Fluid (MWF) aerosols (liquid/gas dispersed system) that are generated in metal working industry because of MWF applications for cooling and lubrication of machine working paces (Sokolović & Laminger, 2021).

All this confirms that coalesce filtration has a great positive impact in sustainable environmental practice.

5. Summary

Coalescence filtration could be used in sustainable environmental practice for efficient treatment of oily wastewater treatment on one hand, and for MWF aerosol removal from the working atmosphere on the other hand.

Application of coalescence filtration for oily wastewater has a huge positive impact on Environment Protection and Sustainable Development, because when the bed coalescers is well optimized, oily concentration in treated water could reach values low below emission level limits (ELV), sometimes so low, that the water could even be reused in process (Sokolović & Šećerov Sokolović, 2024).

On the other hand, application of bed coalescers for MWF aerosol removal has a great impact on Occupational Health and Safety, as well as on Environment Protection (Mead-Hunter & King Mullins 2014; Sokolović & Laminger, 2021). MWF aerosols are generated in metal working industries, and if they are not properly removed from the working environment the workers would be exposed to this mist, and that could cause serious disease (Sokolović & Laminger, 2021). On the other hand, if they are discharged in the atmosphere without previous treatment they could cause huge environmental problems in atmosphere.

Furthermore, if bed coalescer is designed to work in continuous mode, its contribution in sustainable environmental practice is even greater. Because in continuous operating mode of bed coalescers there is no need for filter wash so there is no generation of oily wastewater consequently. On the other hand, the energy demand is much lower than in discontinuous operating mode, because the coalescers works under constant pressure.

Last, but not least, if the eco-friendly filter bed materials are used, like waste fibres from carpet and furniture production, or waste polypropylene bags, the concept of circular economy and sustainable development could be fulfilled, because this waste fibres are not disposed on landfills, instead of that they are used as filter bed in coalescer. Also, it is important to say that most of these materials has unlimited lifetime, so there is no need for their change i.e. there is no generation of exhaust filter media that would represent waste.

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