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Template-assisted synthesis of molecularly imprinted polymers for the removal of methyl red from aqueous media

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Abstract

This study entails the synthesis of molecularly imprinted polymers (MIPs) with good selectivity coefficients for azo dye as a potential sorbent material to extract azo dye from polluted aqueous media. A series of MIPs for methyl red (MR) as a template, were synthesized by changing the molar ratio of functional monomers, via precipitation polymerization format of non-covalent approach. Water-soluble functional monomer; acrylic acid (AA) was used to weave the frame work of polymers while ethylene glycol dimethacrylate (EGDMA) was utilized as crosslinking monomer. The impact of different experimental parameters, such as mole ratio of monomer (functional) to crosslinking monomer on the molecular recognition was investigated. The highly efficient and selective MR-MIP was used for the removal of spiked MR dye from different water samples. The selected imprinted polymer, MR1-MIP was able to selectively remove the MR molecules from aqueous media. A significant amount of dye was removed by MR1-MIP from the river water samples with a high degree of removal efficiency i.e. 92.25%. The imprinting factor of 3.75 for MR1-MIP indicated that the high selectivity in terms of adsorption for MR. A minimum loss of only ~ 3.35% in the removal efficiency within ten sequential cycles of adsorption–desorption study evidenced that MR-MIPs could be used as the most cost effective and best sorbent for the removal of MR from polluted water. Furthermore, the structural properties of MR-MIPs were characterized by FTIR and EDX, whereas TGA, SEM and BET were used to describe the thermal, morphological and surface structures of the particles, respectively.

Keywords Methyl red, Removal, Molecularly imprinted polymers, Precipitation polymerization, And aqueous media

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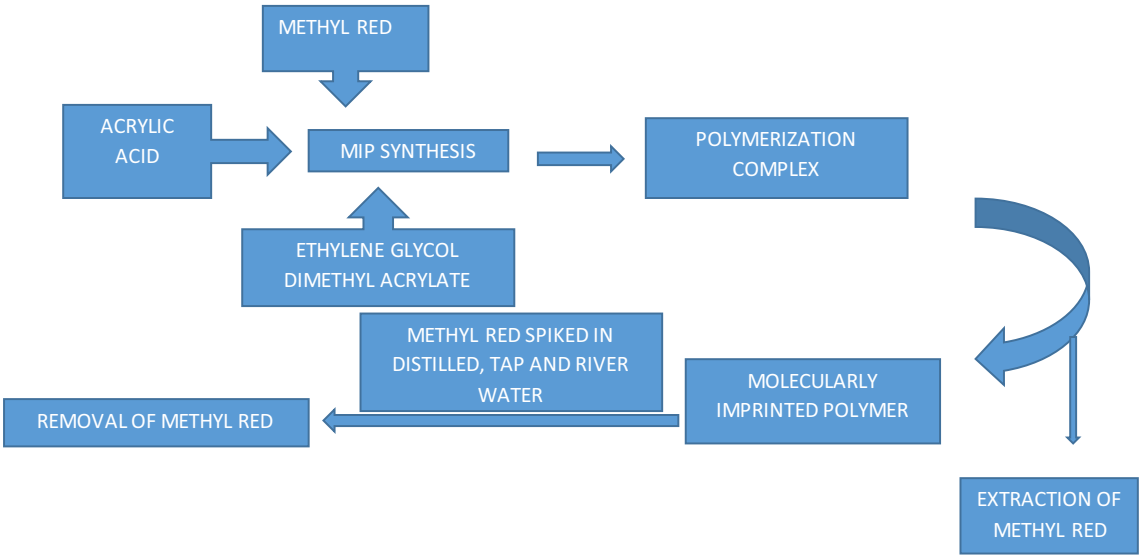
Graphical Abstract



Introduction

The color index reveals that the dying process is coupled with about 8000 commercial products [1, 2] and the use of synthetic dyes had been a significant part of nearly all industries. Dyes belonging to the recalcitrant class of pollutants and their color contamination can easily be identified [3]. Dye waste (10–15% of total dyes production) is a major part of a complex industrial sewage from these industries and could never be recommended for any household or industrial usage [4]. Paper and pulp industries [5], craft bleaching industries [6], tanneries [7], fabric industries [8], pharmaceutical industries, rubber, textile, leather, cosmetics and dyestuff manufacturing industries are amongst the source of generating immensely toxic colored effluents [9]. About 72% of the total dyes used and manufactured in the world are azo dyes [10] and 2/3 part of this is utilized in textile industries [11]. The inefficiency in textile processing of dying creates a huge amount of water stacked with azo dye stuff. These residues are directly transmitted into the water bodies and water with this unfavorable condition is potentially distressing for both toxicological and aesthetical reasons [12]. Azo dyes are capable of remaining persistent in the environment due to the presence of aromatic rings, azo and amino groups. The presence of dyes is undesirable in water even at very low concentrations. Due to their complex structure many of these are very difficult to degrade. Therefore, it is extremely necessary to remove the azo dyes from industrial waste before it is disposed into the water stream which may disrupt the aquatic biota [13]. Methyl red is a well-known dye being used in paper printing and textile dying sector. Potentially it is carcinogenic and also responsible for long term adverse effects in aquatic environment. It is toxic both by ingestion and inhalation and its contact may cause skin and eye irritation [14]. Therefore its removal owes population health and environmental protection.

Various biological and chemical methods have been reported in literature for the removal of azo dyes [15–24]. A wide range of physical techniques are also available for the elimination of dyes from contaminated aqueous media [25, 26]. Amongst all the employed approaches and the methods reported in the literature, adsorption has been proven as one of the most effective technique and the best equilibrium process [27]. Although the reported methods have satisfactory results for the removal of dyes but they lack specificity and have been used for the non-specific adsorption process which in turn results in poor selectivity. Therefore, a method which is highly specific and selective is required to remove dyes from the waste water effluents. Molecularly imprinted polymers (MIPs) are the solution for the selective removal of toxic materials such as dyes from waste water. MIPs are economical adsorbents/sorbents and offere a plenty of potential applications for future commercial purposes. MIPs have environmental safe procedure than any other current practices and can withstand