THE CHARACTERIZATION OF RECYCLED ACRYLONITRILE-DIVINYLBENZENE POLYMER FOR POSSIBLE ANTIMICROBIAL TESTS

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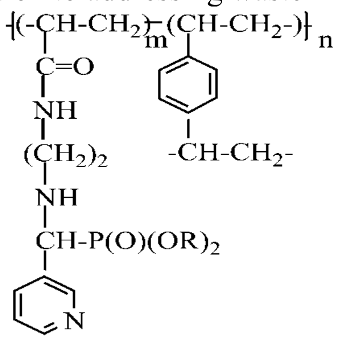
Abstract

This work presented the analysis of acrylonitrile-divinylbenzene copolymers with functional groups (by aminophosphonate type) recovered from a biological medium for possible future use in an antimicrobial test study. Their stability was confirmed by Fourier transform infrared spectroscopy, energy dispersive X-ray analysis (EDX) and scanning electron microscopy (SEM).

Introduction

Bacteria play an important part in our lives. They are found in soil, water, and the air. They could lead to a variety of health issues. Certain materials were used as antimicrobial agents to stop bacterial infections. It is clear that new materials with antibacterial properties are needed. The creation of polymers with antibacterial properties, or polymeric biocides, is a topic of great contemporary interest in polymer research, which has not received sufficient attention. The problem of creating polymeric biocides can often be solved if the bactericide is covalently grafted onto polymeric carriers or other insoluble support materials [1].
The potential antibacterial properties of acrylonitrile-divinylbenzene (AN-DVB) polymers with aminophosphonate groups (see Figure 1) [2] make them worthy of study, as they can improve water purification and other biological applications. The biological activity of these polymers, especially their antibacterial properties, can be enhanced by the addition of aminophosphonate groups [3-5]. Aminophosphonates not only directly inhibit bacterial growth, but also enhance the immune response, making them valuable in fighting infections.
One area that is expanding to reduce their environmental impact is the use of recycled materials. Recycling acrylonitrile-divinylbenzene offers a sustainable source for the synthesis of antimicrobial compounds, in addition to addressing waste management concerns.



where: R= Bz or Et

Figure 1. The structure of the functionalized copolymers: Bz-DVB-AN and Et-DVB-AN.

In water treatment, the most usual treatment method to disinfect and sterilize water is to use chlorine and other related chemicals. But their residues can grow to be concentrated in the food chain and in the environment as well as the possible formation of halomethane analogues that are suspected of being carcinogenic should lead to the prevention of their use [6]. Due to the associated problems result from the use of conventional antimicrobial agents, the idea for using of polymeric antimicrobial agents appeared to be an attractive choice.
This study concerns the characterization of recycled AN-DVB grafted with aminophosphonate groups (see Figure 1) [2] for possible future use in an antimicrobial assay. The efficacy of the copolymers was investigated by Fourier transform infrared spectroscopy (FTIR), Optical image, energy dispersive X-ray analysis (EDX) and scanning electron microscopy (SEM).

Experimental

Instruments

Fourier transform infrared spectroscopy (FTIR) using a JASCO-FT/IR-4200 spectrophotometer, ZEISS Stemi 508 Stereo Microscope, Energy dispersive X-ray (EDX) analysis and scanning electron microscopy (SEM) were performed using an Energy-Dispersive X-ray (EDX) analyzer (Octane Elect Super SDD detector, Ametek, Berwyn, PA, USA) equipped on a Verios G4 UC (Thermo Scientific, Brno, Czech Republic) SEM device.

Working method

All four samples (Bz-AN-DVB-*S. aureus*, Et-AN-DVB-*S. aureus,* Bz-AN-DVB-*E. coli* and Et-AN-DVB-*E.coli*) were recovered from antibacterial solutions where they were tested against a Gram-positive bacterial species (Staphylococcus aureus) (code: Bz-AN-DVB-*S. aureus* and Et-AN-DVB-*S. aureus*) and a Gram-negative bacterial species (Escherichia coli) (code: Bz-AN-DVB-*E. coli* and Et-AN-DVB-*E.coli*). Then, the samples were filtered, autoclaved at a pressure of 1 atm and a temperature of 120 °C for 30 minutes. These recovered samples were characterized by FTIR, Optical Image, SEM and EDX.

Results and discussion

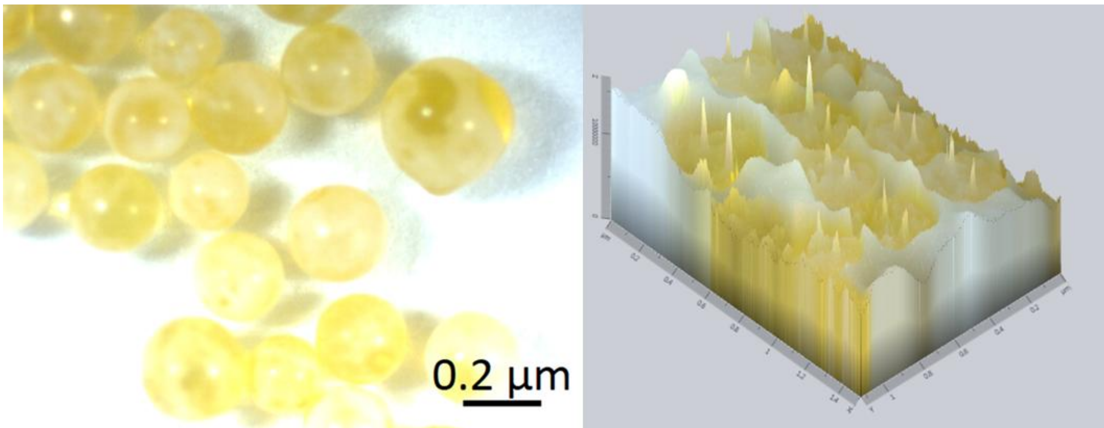


Figure 1. Optical Image of Et-AN-DVB *S.aureus* sample after autoclaved and sterilized.

The variation regarding the number of total germs (CFU/mL) and percentage of microbial reduction at contact times with the two antimicrobial materials are presented in Table 1 [2].
We considered that the antibacterial activity is the result of hydrogen bonding between the organic phosphorus groups (P=O) from aminophosphonat groups and the OH groups in the cell walls of the bacteria, as we described in our previous study [2]. Because of this, it is thought that the copolymers' antibacterial action occurred more quickly for gram-positive bacteria than gram-negative bacteria.

Table 1. The antimicrobial activity of functionalized copolymers [2].

Sample	in the start moment (0 h)	after 18 h of contact	
	CFU/mL	CFU/mL	Percentage of microbial reduction, %
Escherichia coli			
BzDVB-AN	1.337.216	371.475	72.2
EtDVB-AN	1.269.800	196.850	84.4
Staphylococcus aureus			
BzDVB-AN	2.952.770	726.381	75.4
EtDVB-AN	2.572.250	133.757	94.8

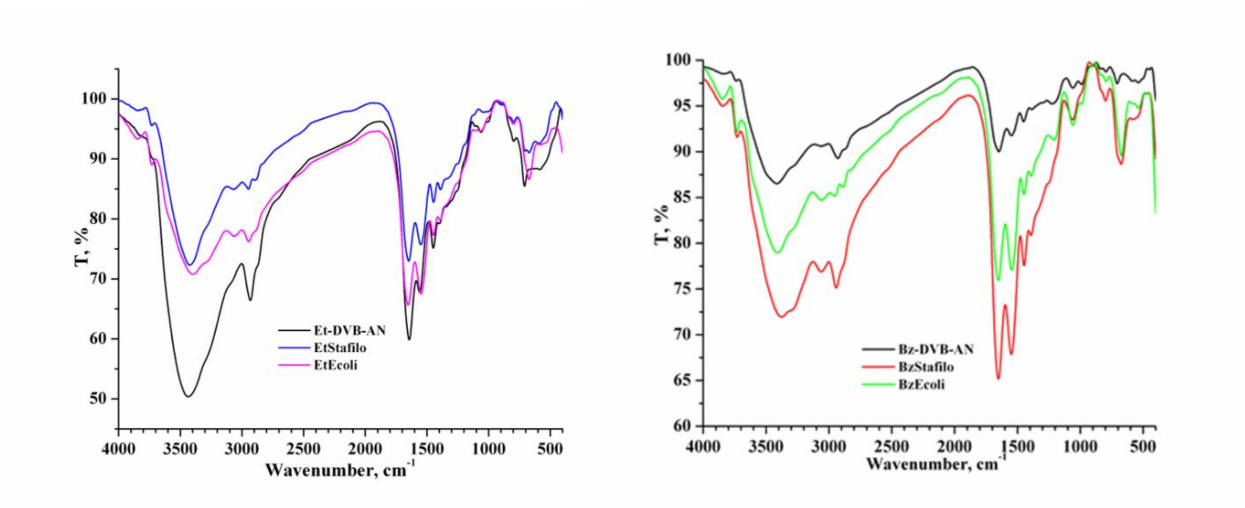


Figure 2. FTIR spectrum for samples obtained after their recovered.

The graphic (see Fig. 2) highlights the characteristic bands of both the phosphonate groups and the amino group, observed at 1170 cm^{-1} and 1570 cm^{-1}, respectively, in the spectra.
The phosphorus content of the recovered copolymers, presented in Tables 2 and 3, is an indication that they can be used in subsequent antibacterial testing.

Table 2. Semi-quantitative EDX-analysis of Bz-DVB-AN- recovered.

Type of analysis/Element	Wt, %			
	C	**N**	**O**	**P**
Bz-AN-DVB- it was recovered after testing with ***S. aureus***				
EDX	**78.08**	**14.05**	**2.85**	**5.01**
Bz-AN-DVB- it was recovered after testing with ***E. coli***				
EDX	**73.05**	**14.76**	**5.81**	**5.34**

Table 3. Semi-quantitative EDX-analysis of Et-DVB-AN- recovered.

Type of analysis/Element	Wt, %			
	C	**N**	**O**	**P**
Et-AN-DVB- it was recovered after testing with ***S. aureus***				
EDX	**68.21**	**20.85**	**7.79**	**3.14**
Et-AN-DVB- it was recovered after testing with ***E.coli***				
EDX	**67.18**	**20.64**	**6.63**	**4.31**

As illustrated in Figure 3 and detailed in Tables 2 and 3, the EDX spectra of the recovered samples confirm that their functionalization is fully preserved.

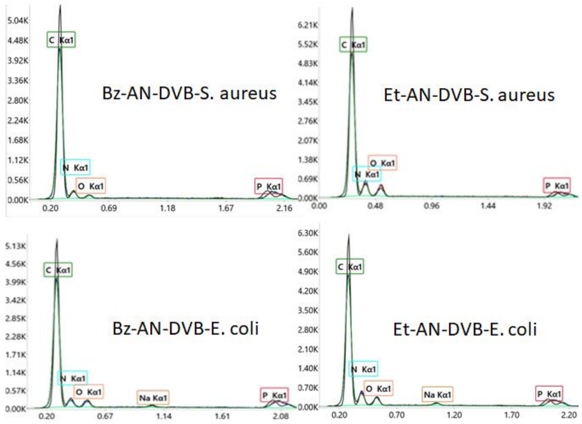


Figure 3. EDX image for samples obtained after their recovered.

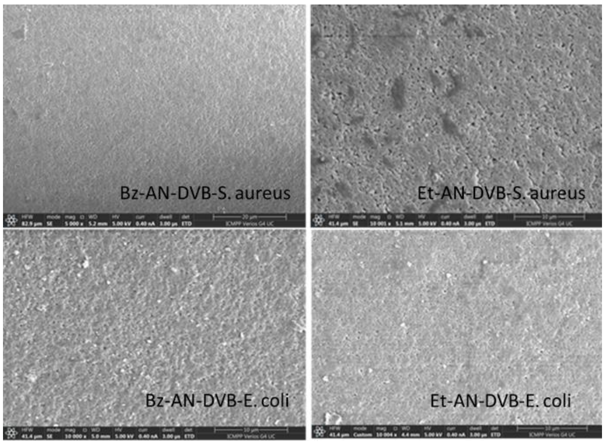


Figure 4. SEM image for samples were obtained after their recovered.

Figure 4 presents SEM images of the recovered samples, revealing that the copolymers exhibit a uniform surface morphology.

Conclusion

The analysis of recycled acrylonitrile-divinylbenzene polymers functionalized with aminophosphonate groups presents a promising approach for developing antimicrobial materials with practical applications.

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