Synthesis, Thermal Behaviour, and Anti-microbial Activity of Polyetherketones Based on \( p \)-Chloroanisole

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ABSTRACT

Low molecular weight Friedel-Crafts polyetherketones were synthesized from \( p \)-chloroanisole, 1,4-phenylenedioxy diacetylchloride, chloroacetylchloride, 1,2-dichloroethane, and dichloromethane in the presence of anhydrous aluminium chloride and carbon disulfide. The polymer samples were characterized by IR spectral study. The percentage of chlorine content of the resins was determined by the method of Carius. The molecular weights and polydispersities of the resins were obtained by gel permeation chromatography. Thermogravimetric analysis and differential scanning calorimetry were employed to study the thermal properties. All the polyetherketones were tested for their biological activity against bacteria, fungi, and yeast. It was observed that polyetherketones could inhibit the growth of the microorganisms to a considerable extent.

INTRODUCTION

The polyetherketones obtained by Friedel-Crafts reaction are a desirable class of polymers which are drawing increasing interest at the present time. They are stiff, tough, and resist wear, abrasion, and fatigue. They possess low flammability and on burning emit low levels of smoke and toxic gas. And are resistant to radiation. The key application areas are coating, electrical, bearing film, composites, oil industry. Their development has been the subject of many researches [1-6].
Polyetherketone blends have become important components in specific sectors of the polymer industry [7]. Rao et al. [8] synthesized polyetherketone and polyetherketonesulfone by nucleophilic substitution reaction of 4,4'-difluorobenzophenone with 4,4'-dihydroxybenzophenone and 4,4'-dihydroxiphenyl sulfone using benzophenone/sulfolane solvent mixture in presence of K$_2$CO$_3$. These authors have investigated the thermal properties of the polymers.

Khalaf et al. [9] synthesized a new class of polyketones based on diarylidene derivative by Friedel-Crafts reaction of 2,7-dibenzylidene cycloheptanone monomer and dibenzylideneacetone monomer with different diacid chloride in dry dichloromethane as solvent and AlCl$_3$ as catalyst. Polymers were characterized by $^1$H NMR, IR and elemental analysis. The polyketones were insoluble in most organic solvents but dissolve easily in concentrated sulfuric acid. The crystallinity of some polymers were tested by X-ray analysis.

Surgical instruments are made from carbon-fiber-reinforced polyetherketones [10]. Hunter et al. [11] prepared poly(aryl ether ketone)s containing carboxylic acid functionality by Friedel-Crafts polymerization of benzene-1,2,4,5 tetracarboxylic dianhydride with diphenylether. The aromatic polyether-polyketones thus prepared were soluble in polar solvents such as NMP, DMF, etc. and were thermally stable upto 400°C.

It is possible to synthesize low molecular weight resins containing various functional groups that are gaining prominence because of their various microbial and pharmacological properties [12-13]. In the present investigation polyetherketones from p-chloro anisole, 1,4-phenylenedioxy diacetylchloride, chloroacety chloride, 1,2-dichloroethane and dichloromethane were prepared by Friedel-Crafts reaction and tested for their biocidal properties using Escheriachi coli, Bacillius subtilis, Stamphylococcus citreus, Aspergillus niger, Sporotitchum pulverdentum, Trichoderma lignorum, Candida utilis, Sacehatomyces cerevisiae, Pichia stipitis.

EXPERIMENTAL

Materials

p-chloroanisole, chloroacetyl chloride (CAC), 1,2-

dichloroethane (DCE), dichloromethane (DCM), acetone, carbon disulfide (CS$_2$) and anhydrous AlCl$_3$ were of analytical grade (i.e., 98 % purity) and obtained from chiti chem India, baroda, India.

Synthesis of 1,4-Phenylenedioxy diacetylchloride

1,4-Phenylenedioxy diacetylchloride (1,4-PDC) was synthesized from 1,4-phenylenedioxy diacetic acid (1,4-PDA). The product obtained was recrystallized from dry methylene chloride-hexane mixture (80:20) to obtain pure white crystalline needles of 1,4-PDC, having a melting point of 85°C [14].

Synthesis of Polyetherketones

p-Chloroanisole, (1,4-PDC), and anhydrous AlCl$_3$ were slowly added one by one to CS$_2$ in a round bottom flask kept at 0°C for 1 h. After an hour the appropriate reagent (i.e., CAC, DCE, or DCM) was added (Table 1) to the mixture and the reaction mixture was heated at 60°C for 6 h in a reflux condensor. The reaction mixture was then poured into 1:1 H$_2$O/HCl mixture (200 mL) while stirring. The slightly sticky product separated out. The product was heated on a water bath for the removal of CS$_2$. The dark brown solid thus obtained was futher purified with acetone as a solvent and with distilled water as a non solvent. Brown colour is the characteristic of Friedel-Crafts products obtained from aromatic compounds [15]. Conditions of preparation of all these polyetherketones are shown in Table 1 and the reaction scheme is shown in Figures 1 and 2.

Characterization of Polyetherketones

IR spectra of the resins were scanned on Perkin-Elmer-983 spectrophotometer. The percentage chlorine content of the resins was determined by the Carius method [16]. The results are shown in Table 1. The number average molecular weight ($M_n$), weight average molecular weight ($M_w$), and polydispersity ($M_w/M_n$) values of the polyetherketones were determined with a Waters gel permeation chromatography (GPC) instrument equipped with a 600E multisolvent delivery system and a U6K manual injector series connected to Ultrastyragal columns (7.6 × 300 mm) packed with styrene-divinyl/benzene (DVB) cross-linked copolymers with gel porosities of $10^3$ and $10^6$ and molecular weight exclusion limits of $2 \times 10^2$ to $3 \times 10^4$ and $2 \times 10^5$ to $10^7$, respectively.
A 410 refractive index detector and NEC Powermat 386/25 data acquisition and processing unit were used for analysis. Tetrahydrofuran at a 1.0 mL/min flow rate was used as a mobile phase throughout the analysis. All

Table 1. Condition of the preparation of polyetherketones.

<table>
<thead>
<tr>
<th>Resin No.</th>
<th>p-chloroanisole (mol)</th>
<th>1,4-PDC (mol)</th>
<th>CAC (mol)</th>
<th>DCE (mol)</th>
<th>DCM (mol)</th>
<th>AlCl₃ (mol)</th>
<th>Yield (%)</th>
<th>Physical state and softening range a (°C)</th>
<th>Chlorine (%)</th>
<th>Remarks b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.03</td>
<td>0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>35.3</td>
<td>Reddish brown Powder</td>
<td>17.1</td>
<td>1,4-PDC + CS₂ + AlCl₃, was mixed and p-chloro anisole was added within 10 min.</td>
</tr>
<tr>
<td>2</td>
<td>0.03</td>
<td>0.015</td>
<td>0.015</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>33.6</td>
<td>Dark brown Powder</td>
<td>18.3</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this CAC was added</td>
</tr>
<tr>
<td>3</td>
<td>0.03</td>
<td>0.015</td>
<td>-</td>
<td>0.015</td>
<td>-</td>
<td>0.06</td>
<td>30.9</td>
<td>Blackish brown Powder</td>
<td>17.7</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this DCM was added</td>
</tr>
<tr>
<td>4</td>
<td>0.03</td>
<td>0.015</td>
<td>-</td>
<td>-</td>
<td>0.015</td>
<td>0.06</td>
<td>34.5</td>
<td>Blackish brown Powder</td>
<td>17.8</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this CAC was added</td>
</tr>
<tr>
<td>5</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>32.3</td>
<td>Black Powder</td>
<td>17.9</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this CAC was added. After 1h., DCE was added</td>
</tr>
<tr>
<td>6</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>0.06</td>
<td>33.8</td>
<td>Black Powder</td>
<td>18.1</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this DCM was added</td>
</tr>
<tr>
<td>7</td>
<td>0.03</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>0.01</td>
<td>0.06</td>
<td>31.6</td>
<td>Blackish brown Powder</td>
<td>17.5</td>
<td>1,4-PDC + CS₂ + AlCl₃, p-chloro anisole was added, content was kept at 0°C for 1h. and to this DCE was added. After 1h., DCM was added</td>
</tr>
</tbody>
</table>

Reaction temperature: 60°C; Reaction time: 6h; Solvent: CS₂ (25 mL).
(a) From DSC thermograms; (b) The general method of preparation is already given in the text. Here specific changes for each preparation are indicated.
Resin No. 1

\[
\begin{align*}
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{AlCl}_3 \\
\text{Cl} & \hspace{1cm} \text{Solvent CS}_2 \hspace{1cm} \rightarrow \\
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{AlCl}_3 \\
\text{Cl} & \hspace{1cm} \text{Solvent CS}_2 \hspace{1cm} \rightarrow \\
\end{align*}
\]

Resin No. 2

\[
\begin{align*}
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{ClICH}_2\text{COCl} \\
\text{Cl} & \hspace{1cm} \text{AlCl}_3 \hspace{1cm} \rightarrow \\
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{AlCl}_3 \\
\text{Cl} & \hspace{1cm} \text{Solvent CS}_2 \hspace{1cm} \rightarrow \\
\end{align*}
\]

Resin No. 3 and 4

\[
\begin{align*}
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{Cl-R-Cl} \\
\text{Cl} & \hspace{1cm} \text{AlCl}_3 \hspace{1cm} \rightarrow \\
\text{OCH}_3 & + \text{Cl-C-H}_2\text{-O-Cl} + \text{Cl-R-Cl} \\
\text{Cl} & \hspace{1cm} \text{Solvent CS}_2 \hspace{1cm} \rightarrow \\
\end{align*}
\]

For resin No. 3: R = -CH\text{=CH}_2-
For resin No. 4: R = -CH\text{=CH}_2-

Figure 1. Reaction scheme for resins 1-4.
the measurements were carried out at room temperature. The TGA thermograms were recorded on DuPont model 951 thermogravimetric analyzer at a heating rate of 10°C/min under nitrogen atmosphere. The differential scanning calorimetry (DSC) data were obtained from DuPont 900 thermal analyzer.

**Antimicrobial Activity**

The polyetherketones thus synthesized, were tested with different microorganisms that are commonly employed for biodegradability tests. Bacteria strains (*Escheriachi coli*, *Bacillus subtilis*, *Stamphylococcs citreus*), fungal (*Aspergillus niger*, *Sporotichum pulverulentum*, *Trichoderma lignorum*), and yeast (*Candida utilis*, *Sacchatomyces cerevisiae*, *Pichia stipitis*) were selected and grown in N-broth, Sabourand s dextrose broth and YEPD (Yeast extract peptone dextrose) medium, respectively with and without the indicated resins.
to study the antimicrobial properties. The content of the flasks were incubated in a shaker at room temperature. At specific time intervals (20-48 h), the optical density was measured at 660 nm for bacteria and yeast cultures. Percent inhibition (I) is obtained from the relation.

$$ I = \frac{100 (X-Y)}{X} $$  \hspace{1cm} (1)

Where,

$X$ = optical density of bacterial suspension in control set

$Y$ = optical density of bacterial suspension in test set

The percent inhibition was found to be maximum after 48 h. The fungal cultures were harvested after 48 h, and the dry cell mass was determined gravimetrically. The percentage inhibition (I) for fungal cultures is also calculated using equation (1) but here;

$X$ = Weight of dry fungal cell mass in control set

$Y$ = Weight of dry fungal cell mass in test set.

The details of experimental procedures have already been reported [17-18].

RESULTS AND DISCUSSION

The polyetherketones prepared under different experimental conditions are presented in Table 1. All the polyetherketones are highly coloured compounds ranging from brown to black and are soluble in acetone, dimethylformamide, and dioxane. All polyetherketones were soften in the range of 112-130°C. The number average molecular weight ($M_n$) and weight average molecular weight ($M_w$) of polyetherketones obtained from gel permeation chromatography vary from 3275 to 8580 and 4585 to 8830, respectively. The polydispersity index of polyetherketones lies in the range of 1.40 to 2.58. Molecular weight data is presented in Table 2.

Characterization of Resins by IR Spectra

The IR spectra (Figure 3) confirmed the structure of polyetherketones in all aspects. The important IR frequencies and their assignment are listed in Table 3. A broad band in the region of 2960-2800 cm$^{-1}$ could be due to C-H stretching vibration of methylene groups, where as bands at 1345 and 1455 cm$^{-1}$ could be assigned to the C-H bending vibration of methyl or methylene group. The 835 cm$^{-1}$ peak in all the resins may be due to the C-H out of plane bending vibration of tetra substituted aromatic ring, where as C-H in

### Table 2. Average molecular weights of polyetherketones by GPC.

<table>
<thead>
<tr>
<th>Resin No.</th>
<th>$M_n$</th>
<th>$M_w$</th>
<th>Polydispersity $M_w / M_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8580</td>
<td>12540</td>
<td>1.46</td>
</tr>
<tr>
<td>2</td>
<td>4330</td>
<td>8670</td>
<td>2.00</td>
</tr>
<tr>
<td>3</td>
<td>3275</td>
<td>4585</td>
<td>1.40</td>
</tr>
<tr>
<td>4</td>
<td>4710</td>
<td>6775</td>
<td>1.83</td>
</tr>
<tr>
<td>5</td>
<td>4125</td>
<td>7935</td>
<td>1.92</td>
</tr>
<tr>
<td>6</td>
<td>3420</td>
<td>8830</td>
<td>2.58</td>
</tr>
<tr>
<td>7</td>
<td>3570</td>
<td>6685</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Figure 3. FT IR Spectra of resins 1-7.
plane bending vibration is observed around 1150 cm\(^{-1}\). A sharp band at 670 cm\(^{-1}\) has been assigned to C-Cl stretching in the monomer 1,4-PDC [19]. This band as expected disappear on formation of polymers. The C=O stretching vibration in polymers appears around 1710 cm\(^{-1}\) [20]. In all the polymers the fairly strong absorption around 1235 cm\(^{-1}\) is attributed to C-O-C stretching band [21]. The vibration due to aromatic ring are assigned to absorptions in the range of 1500-1600 cm\(^{-1}\).

**Thermal Analysis of the Resins**

The thermal properties of all the resins have been investigated by thermogravimetric analysis (TGA) and DSC measurements. The thermal data and various kinetic parameters of the thermal degradation are presented in Tables 4 and 5. The resins degrade between 200 to 650°C and show moderate thermal stability. Broido method [22] was applied for TGA data to evaluate the energy of activation (E\(_A\)) for the degradation reaction and it was found to be in the range of 114-149 kJ mol\(^{-1}\). The following equation has been employed to evaluate E\(_A\):

\[
\ln \ln(1/Y) = -(E_A/R) \left( \frac{1}{T} \right) + \text{constant}
\]

where, Y is equal to \((W_t-W_\alpha)/(W_0-W_\alpha)\) and \(W_t, W_\alpha, W_0, R, T\) are the active weight at any time \(t\), the weight of the material at the end of pyrolysis, the weight of the material taken initially, gas constant, and

<table>
<thead>
<tr>
<th>Resin No.</th>
<th>Phenyl ring vibration (cm(^{-1}))</th>
<th>PH-O-CH(_2)</th>
<th>Substituted aromatic ring</th>
<th>CH(_3), CH(_2) bending</th>
<th>V(_{C-O}) stretching (cm(^{-1}))</th>
<th>V(_{C-Cl}) stretching (cm(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1610, 1515</td>
<td>1240</td>
<td>1160</td>
<td>840</td>
<td>1350</td>
<td>1460</td>
</tr>
<tr>
<td>2</td>
<td>1612, 1505</td>
<td>1235</td>
<td>1150</td>
<td>833</td>
<td>1338</td>
<td>1442</td>
</tr>
<tr>
<td>3</td>
<td>1605, 1510</td>
<td>1230</td>
<td>1155</td>
<td>835</td>
<td>1322</td>
<td>1450</td>
</tr>
<tr>
<td>4</td>
<td>1615, 1504</td>
<td>1235</td>
<td>1158</td>
<td>830</td>
<td>1335</td>
<td>1461</td>
</tr>
<tr>
<td>5</td>
<td>1607, 1495</td>
<td>1245</td>
<td>1150</td>
<td>840</td>
<td>1374</td>
<td>1450</td>
</tr>
<tr>
<td>6</td>
<td>1608, 1510</td>
<td>1240</td>
<td>1155</td>
<td>845</td>
<td>1360</td>
<td>1445</td>
</tr>
</tbody>
</table>

**Table 3. Assignment of infrared frequencies of polyetherketones prepared from \(p\)-chloroanisole.**

**Table 4. Characteristic temperature for thermal degradation of polyetherketones evaluated from TGA.**

<table>
<thead>
<tr>
<th>Resin No.</th>
<th>Weight loss (%) at temperature up to</th>
<th>IPDT(^a) (°C)</th>
<th>IDT(^b) (°C)</th>
<th>TS(^c) (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250 (\circ)</td>
<td>350 (\circ)</td>
<td>450 (\circ)</td>
<td>550 (\circ)</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>23</td>
<td>34</td>
<td>62</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>24</td>
<td>29</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>25</td>
<td>28</td>
<td>66</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>24</td>
<td>32</td>
<td>47</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>23</td>
<td>33</td>
<td>68</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>28</td>
<td>34</td>
<td>56</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>25</td>
<td>28</td>
<td>47</td>
</tr>
</tbody>
</table>

\(^{a}\) Integral procedural decomposition temperature; \(^{b}\) Initial decomposition temperature; \(^{c}\) Half-volatilization temperature.
temperature in Kelvin, respectively. The slope of a plot of $\ln \ln(1/Y)$ versus $1/T$ provides $E_A$. The energy, obtained in calories, has been converted into kilojoules per mole. The values of characteristic degradation temperatures and integral procedural decomposition temperature (IPDT) were obtained by Doyle’s method [23]. IPDT expresses the overall thermal stability of a resin and it varies in the range of 522-567°C. From the DSC thermogram, the heat of fusion ($\Delta H_f$) is obtained as follows:

$$\Delta H_f = \frac{AEBS60}{M}$$

Where $A$, $B$, $E$, $M$, and $S$ are the peak area (cm$^2$), the
time base (min/cm), the cell calibration constant, the sample mass (mg), and the sensitivity (mW/cm), respectively. The calculation has been carried out by a program built into the instrument itself. The heat of fusion ($\Delta H_f$) evaluated by DSC thermograms was in the range of 28 - 38 Jg$^{-1}$.

### Antimicrobial Activity

Polyetherketones have been prepared using different monomers as shown in Table 1. When tested for their response against microorganisms interesting results were obtained. Figures 4, 5, and 6 provide a comparative account of the effect of polyetherketones on the growth of bacteria, fungi, and yeast. These results indicate that the polyetherketones inhibit significantly the growth of microorganisms. During the period of 48 h

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**Table 5.** Kinetic parameters of the decomposition of polyetherketones (prepared from p-chloroanisole) found by TGA and DSC.

<table>
<thead>
<tr>
<th>Resin No.</th>
<th>Temperature range at step-1 (°C)</th>
<th>Weight loss at step-1 (%)</th>
<th>Temperature range at step-2 (°C)</th>
<th>Weight loss at step-2 (%)</th>
<th>Decomposition temperature range (°C)</th>
<th>$\Delta T$</th>
<th>Energy of activation$^a$ ($E_A$) (kJmol$^{-1}$)</th>
<th>Order of reaction (n)</th>
<th>Heat of fusion$^b$ ($H_f$) (Jg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>255-460</td>
<td>35</td>
<td>460-610</td>
<td>93</td>
<td>255-610</td>
<td>355</td>
<td>114</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>185-390</td>
<td>24</td>
<td>390-620</td>
<td>95</td>
<td>185-620</td>
<td>435</td>
<td>128</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>205-440</td>
<td>30</td>
<td>440-640</td>
<td>97</td>
<td>205-640</td>
<td>435</td>
<td>132</td>
<td>1</td>
<td>35</td>
</tr>
<tr>
<td>4</td>
<td>245-470</td>
<td>32</td>
<td>470-650</td>
<td>85</td>
<td>245-650</td>
<td>405</td>
<td>119</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>250-475</td>
<td>35</td>
<td>450-640</td>
<td>94</td>
<td>250-640</td>
<td>390</td>
<td>139</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>210-465</td>
<td>34</td>
<td>465-630</td>
<td>78</td>
<td>210-630</td>
<td>420</td>
<td>149</td>
<td>1</td>
<td>38</td>
</tr>
<tr>
<td>7</td>
<td>255-490</td>
<td>29</td>
<td>490-650</td>
<td>91</td>
<td>255-650</td>
<td>395</td>
<td>136</td>
<td>1</td>
<td>33</td>
</tr>
</tbody>
</table>

Rate of heating: 10°C/min.

$^a$ Broido method; $^b$ by DSC thermograms.
control culture (without resin) exhibited maximum growth.

Resin 1 appears to be the least effective one to prevent the growth of bacteria, fungi, and yeast. Resin 2 is the most effective antimicrobial agent. The presence of chlorine in the resins has been assigned as the important component to prevent the growth of microorganisms [24-27]. Interestingly resin 1 has lowest percentage of chlorine and resin 2 has highest percentage of it. The remaining resins have more or less equal chlorine content which are not significantly different from the percent of chlorine in the resin 2. Thus, the variation in antimicrobial activity may not be just a linear function of amount of chlorine, which though it appears to be essential for antimicrobial activity.

Interestingly all the resins have the repeating unit \( \text{O} \overset{\|}{} \text{Ph} = \overset{\|}{} \text{C} = \overset{\|}{} \text{CH}_2 \) and resin 2 has the maximum amount of this moiety. From the feed composition it is apparent that the percentage of this moiety decreases in the resins in the following order:

Resin 7 < resin 3 ≈ resin 4 < resin 5 ≈ resin 6 < resin 2.

and the biocidal activity follows the same trend.

CONCLUSION

Seven polyetherketones were synthesized and characterized. All the resin showed two-step decomposition. For antimicrobial activity it appears that:

1. Chlorine presence is important for antimicrobial activity.

2. Antimicrobial activity increases with increase in the percentage of \( \text{O} \overset{\|}{} \text{Ph} = \overset{\|}{} \text{C} = \overset{\|}{} \text{CH}_2 \) moiety.

REFERENCES


