FULL LENGTH ARTICLE

Synthesis and evaluation of new anti-microbial additive based on pyrimidine derivative incorporated physically into polyurethane varnish for surface coating and into printing ink paste

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KEYWORDS
Pyrimidine derivatives; Hetero cycle compounds; Biocides; Anti-microbial; Polyurethane coating; Printing ink paste

Abstract In this study, heterocyclic compounds containing 3-((4-bromophenyl)diazenyl)-5-(methylthio)-6-(phenylsulfonyl)pyrazolo-[1,5-a]pyrimidine-2,7-diamine (compound II) and 4-(methylthio)-3-phenylsulfonyl)benzo[4,5]imidazo[1,2-a]pyrimidin-2-amine (compound III) were prepared and their chemical structures were confirmed by spectral data. The new compounds were screened for antimicrobial activity against six different microbial strains when physically incorporated into polyurethane varnish formula and printing ink paste. Experimental coatings were manufactured on laboratory scale and applied by brush onto glass and steel panels. Results of the biological activity indicated that polyurethane varnishes and printing ink paste containing compounds II and III exhibit a very good antimicrobial effect. The physical and mechanical resistances of the polyurethane varnish formulations were also studied to evaluate any drawbacks associated with this addition. The studies revealed that the physical incorporation of compounds II and III enhances slightly the physical and mechanical properties.

1. Introduction

Pyrazole, pyrimidine, phenylsulfone and their derivative products are some of the oldest and best known classes of nitrogen and sulfur containing compounds. In recent years there has been considerable interest in the phenylsulfonl pyrazol...
derivatives, which incorporated three important pharmacophore groups the phenylsulfonyl ring, pyrazol and pyrimidine heterocycles and the amine group. They have been reported to exhibit significant biological activities and are widely used as pharmaceuticals. They are capable of imparting antimicrobial activity properties when incorporated into polymers and their composites [1–2]. Biocide additives have been used to prolong the life of surface coatings. They prevent or slow down the growth of organisms on the surface coating. Without biocide additives, the biological species start to adhere on the coating surface and lead to disbonding and blistering of coatings under various service conditions. Biocides in paint fall into two main categories; those used for wet state protection and those for film protection. Wet state (in-can) biocides may be bactericides and fungicides, which were used to protect the coating material until it can be applied. Film biocides, which can be fungicide or algaeceide, are incorporated to prevent the growth of fungi and algae on applied surface coatings [3–5]. Sharif Ahmad et al. have successfully used it as a starting material for the development of polyethers. Polyurethanes, polyester and polyesteramide are susceptible to microbials, polyesters, and polymer materials with desirable properties, such as high abrasion resistance, tear strength, excellent shock absorption, flexibility and elasticity [13–15]. The attractiveness of polyurethanes stems from their excellent bonding to different substrates, relatively low price and fast reaction time [16]. Polyurethane top-coats, recommended for paint systems commonly utilized for corrosion protection of steel structures, are used in highly corrosive atmospheres (C5 category) [17]. Polyurethane, polyester and polyurethanes are transparent to microbial attack, when they are exposed to the atmosphere or used as an adhesive or a coating material. Generally microorganisms have been found to cause disbonding and blistering of coatings under various service conditions [18–20]. Marine biofouling is a natural phenomenon representing one of the greatest problems in marine technology and navigation, since the accumulation of organisms such as barnacle, tube worms and algae on the submerged surfaces of the vessels results in important speed reduction and considerably higher fuel consumption. To circumvent these problems, antifouling paints, i.e. paint formulations traditionally containing biocidal species, are used to protect the submerged surfaces from marine biofouling [21]. Till the end of 1990s, the most effective antifouling paints were based on organotin compounds, mostly tributyltin compounds (TBT-based paints). TBT and its derivitives were found to be harmful molecules to marine ecosystems by Alzieu [22]. And so it is completely prohibited by 1 January 2008 [23–25]. This short-dated restriction promotes research for new ecological paints. One of the methods to overcome such a problem is to develop polymers having biocidal activities [26]. A large number of naturally occurring compounds contain heterocyclic rings as an important part of their structure such as coumarin (IUPAC name: 2H-Chromen-2-one) compounds and their derivatives are used as medicines [27]. Coumarin compounds and their derivatives form a group of more than 40 drugs, which are widely used in medicine as anticoagulant, hypertensive, antiarhythmic, and immunomodulating agents [28] and possess remarkable activities against bacteria [29] and fungi [30]. Furthermore, pyrimidine derivatives having various substituted thiazole rings at carbon-3 exhibit promising biological activities [31]. Heterocyclic compounds based on sulfur have attracted continuing interest because of their varied biological activities [32], which have found applications in the treatment of microbial infections [33–34]. Thiazole and pyrazol are parent materials for various chemical compounds including sulfur drugs, biocides, fungicides, dyes, and chemical reaction accelerators. In addition, 2-amino thiazole derivatives are reported to exhibit significant biological activities and are widely used as pharmaceuticals [35]. On the basis of all of this evidence, this study reports the synthesis, characterization and antimicrobial activities of new structure hybrids incorporating the phenylsulfonyl and pyrazol ring system. This combination was anticipated to influence on the biological activities. The heterocyclic compound based on phenylsulfonyl moiety 3,3-bis(methylthio)-2-(phenylperoxythio)acrylonitrile, 3-(4-bromophenyl)diazanyl)-5-(methylthio)-6-(phenylsulfonyl)pyrazolo[1,5-a]pyrimidine-2,7-diamine and 4-(methylthio)-3-(phenylsulfonyl)benzo[4,5]imidazo[1,2-a]pyrimidin-2-amine were physically added to the polyurethane varnish and printing ink paste, to make it antimicrobial. The biological activity test was used to assess the biological activity of the additive. The physical and mechanical resistances were also studied to evaluate any drawbacks associated with the additive.

2. Experimental

2.1. Materials

All chemicals used during this study were sourced either internationally, or from local companies, and are of pure grade. Sodium benzenesulfinate, 2-chloroacetonitrile and dimethylformamide were purchased from Aldrich Chemical Co.

Carbon disulfide was purchased from Merck Co., Germany. Methyl iodide was purchased from British Drug Houses (BDH).

Ethanol and potassium hydroxide were purchased from El-Nasr Pharmaceutical and Chemical Co. (ADWIC), EGYPT.

Aniline and its substituted derivatives, hydrazine hydrate and pyridine were purchased from Aldrich Chemical Co.

Malononitrile and piperidine were purchased from Across Organics Co. (Belgium).

Hydrochloric acid and sodium nitrite were purchased from El-Nasr Pharmaceutical and Chemical Co. (ADWIC), EGYPT.

2-Aminobenzimidazole was purchased from Merck Co., Germany.

2.2. Methods and techniques

New anti-microbial additives based on pyrimidine derivative (compounds II & III) were prepared as presented in Scheme 1.

2.2.1. Synthesis of 3,3-bis(methylthio)-2-(phenylperoxythio)-acrylonitrile as starting material (compound I)

A solution of 2-(phenylsulfonyl) acetonitrile (0.01 mol) and sodium ethoxide (0.46 g, 0.02 mol) in 20 ml absolute ethanol was refluxed for 20 min, after cooling; carbon disulfide...
2.2.2. Synthesis of 3-((4-Bromophenyl)diazenyl)-5-(methylthio)-6-(phenylsulfonyl)-pyrazolo[1,5-a]pyrimidine-2,7-diamine (compound II)

To a mixture of 10 mmol of both compound I and 4-(4-bromophenyl)diazenyl)-1H-pyrazole-3,5-diamine, in ethanol (25 ml), a few drops of piperidine were added and the reaction mixture was refluxed for 3 h. The solid product was filtered off, washed with ethanol and recrystallized from ethanol/DMF to afford the title compound. The pure product was obtained as an orange powder.

Yield (70%), mp. > 300 °C

- IR (KBr) $v_{\text{max}}$/cm$^{-1}$: 3415, 3312 (NH$_2$), 1527 (C=N), 1546, 1142 (SO$_2$).
- $^1$H NMR (DMSO-d$_6$): $\delta$ 2.71 (s, 6H, 2SCH$_3$), 7.67–7.98 (m, 9H, ArH's).
- MS (m/z): 370(M$^+$).
- Analysis for C$_{17}$H$_{14}$N$_5$O$_2$S$_2$ (370.45):

<table>
<thead>
<tr>
<th>Calcd.</th>
<th>C, 55.12; H, 3.81; N, 15.12; S, 17.31%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found.</td>
<td>C, 55.20; H, 3.87; N, 15.03; S, 17.26%</td>
</tr>
</tbody>
</table>

2.2.3. Synthesis of 4-(methylthio)-3-(phenylsulfonyl)benzo[4,5]imidazo[1,2-a]pyrimidin-2-amine (compound III)

A mixture of 10 mmol of both compound I and 2-aminobenzimidazole (10 mmol) in pyridine (25 ml) was refluxed for 12 h. After the indicated time of reflux, the solvent was evaporated and the crude product was taken in ethanol then collected by filtration, dried and the residue recrystallized from DMF/H$_2$O to afford the title product. The pure product was obtained as an orange powder.

Yield (78%), mp. > 300 °C

- IR (KBr) $v_{\text{max}}$/cm$^{-1}$: 3415, 3312 (NH$_2$), 1527 (C=N), 1346, 1142 (SO$_2$).
- $^1$H NMR (DMSO-d$_6$): $\delta$ 2.76 (s, 6H, 2SCH$_3$), 3.79 (s, 2H, NH$_2$), 7.56–7.85 (m, 9H, Ar'H's).
- MS (m/z): 370(M$^+$).
- Analysis for C$_{19}$H$_{16}$BrN$_7$O$_2$S$_2$ (518.41):

<table>
<thead>
<tr>
<th>Calcd.</th>
<th>C, 44.02; H, 3.11; N, 18.91; S, 12.37%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found.</td>
<td>C, 44.13; H, 3.17; N, 18.84; S, 12.26%</td>
</tr>
</tbody>
</table>

2.3. Characterization studies

Melting points were determined with a Stuart Scientific Co. Ltd., apparatus. Elemental analyses were performed on a Perkin-Elmer 240 microanalyser at the Micro analytical Center of Cairo University. The IR spectra (KBr technique) were recorded on a FTIR 5300 spectrometer (v, cm$^{-1}$). $^1$HNMR spectra (DMSO-d$_6$) were recorded on a Varian Gemini 300 MHz spectrometer and chemical shifts are expressed in $\delta$ ppm units, using TMS as an internal standard.

2.4. Preparation of antimicrobial (biocidal) coating

To understand the anti-microbial activity of new additives based on pyrimidine derivative (compounds II & III). They were incorporated physically in the ratio of 0.5% and 1.0% into commercial reference polyurethane varnish and printing ink paste. The composition of the used polyurethane varnish and the printing ink paste used for the study is tabulated in Tables 1 and 2. The samples of different molar ratios were then applied to both glass and steel panels by means of a brush. All efforts were made to maintain a uniform film thickness of...
2.5. Antimicrobial screening

The anti-microbial activity of the synthesized pyrimidine derivative (compounds II & III) was tested against six different micro-organisms such as; (i) Gram-negative bacteria (G-) [Escherichia coli (E. coli) & Salmonella], (ii) Gram-positive bacteria (G+) [Micrococcus luteus (M. luteus), Staphylococcus aureus (S. aureus)] and (iii) against fungi [Aspergillus flower (A. flower), Candida albicans]. Nutrient agar was used as the medium.

2.5.1. Paper disk diffusion method for the determination of antimicrobial activity

Paper disk diffusion method is used to determine what antibiotics or compounds inhibit bacterial growth, or are bacteriostatic. The paper disks are soaked with a select antibiotic or chemical and then placed on a lawn of bacteria in a petri dish. The zones of inhibition are measured around where the disk was placed to determine whether the bacterium was resistant or susceptible to the particular antibiotic or chemical chosen. The sterilized (autoclaved at 120 °C for 30 min) medium at (40–50 °C) was incubated (1 ml/100 ml of medium) with the suspension (105 cfu ml\(^{-1}\)) of the micro-organism (matched to McFarland barium sulfate standard) and poured into a petri dish to give a depth of 3–4 mm. The paper impregnated with the test compounds (mg/ml\(^{-1}\)) was placed on the solidified medium. The plates were pre-incubated for 1 h at room temperature and incubated at 37 °C for 24 and 48 h for anti-bacterial and anti-fungal activities, respectively. Cefepime (mg/disk) was used as a standard for antibacterial and anti-fungal activities respectively.

2.5.2. Minimum inhibitory concentration (MIC) test for the determination of anti-microbial activity

MIC was determined by the agar streak dilution method. A stock solution for each synthesized compound (100 mg/ml\(^{-1}\)) in dimethyl formamide was prepared and graded quantities of test compounds were incorporated in specified quantities of molten sterile agar (nutrient agar for anti-bacterial activity and sabouraud dextrose agar medium for anti-fungal activity). A specified quantity of the medium at (40–50 °C) containing the compound was poured into a petri dish to give a depth of 3–4 mm and allowed to solidify. Suspension of the micro-organism was prepared to contain approximately (105 cfu ml\(^{-1}\)) and applied to plates with serially diluted compounds in dimethyl formamide to be tested and incubated at 37 °C for 24 and 48 h for bacteria and fungi, respectively. The MIC was considered to be the lowest concentration of the test substance exhibiting no visible growth of bacteria or fungi on the plate.

2.6. Physical and mechanical testing of films

A range of physical and mechanical evaluations of the painted films were undertaken according to appropriate ASTM standard test methods. The color of polyurethane varnish formulations was measured by Gardner standard color scale (ASTM D1544). The prepared steel panels (ASTM D 609-95) were used to measure the film coating thickness (ASTM D 1005-07), the adhesion ‘cross hatch’ test (ASTM D 3359-02) and to measure film hardness by means of the pencil test (ASTM D 3363-00).

3. Results and discussion

On the basis of all of this evidence, we have selected polyurethane to evaluate the antimicrobial activities of new structure hybrids incorporating the phenylsulfonyl and pyrazol derivative based on 3,3-bis(methylthio)-2-(phenylperoxythio)acrylonitrile, 3-(4-bromophenyl)diazeneyl-5-(methylthio)-6-(phenyl sulfonyl)pyrazolo-[1,5-a]pyrimidine-2,7-diamine and 4-(methylthio)-3-(phenylsulfonyl)benzo[4,5]imidazo[1,2-al]pyrimidin-2-amine (compounds II & III).

3.1. Synthesis of new anti-microbial additives based on pyrimidine derivatives (compounds II & III)

Synthesis of new anti-microbial additives based on pyrimidine derivatives (compounds II & III) was prepared in the hope that it might demonstrate enhanced antimicrobial activity properties. The chemical structure of the prepared compounds II and III is represented in Scheme 1. In this series all compounds were prepared and purified as illustrated in the experimental section. The good agreement between the experimental and theoretical values of the C, H and N and spectroscopy study
levels reveals that the methods of synthesis and purification of the products were performed successfully.

3.2. Evaluation of new anti-microbial additives based on pyrimidine derivatives (compounds II & III) as biocide additives incorporated into a polyurethane varnish and printing ink paste

It is clear that the incorporation of 3,3-bis(methylthio)-2-(phenylperoxythio)acrylonitrile, 3-(4-bromophenyl)diazonel-5-(methylthio)-6-(phenylsulfonyl)pyrazolo-[1,5-a]pyrimidine-2,7-diamine and 4-(methylthio)-3-(phenylsulfonyl)benzo[4,5]imidazo-[1,2-a]pyrimidin-2-amine (compounds II and III), physiologically added into polyurethane varnish and printing ink paste in the ratios mentioned in the experimental section, results in excellent antimicrobial activity when compared alongside a blank polyurethane and printing ink paste sample. The results obtained from the antimicrobial activity are shown in Tables 3 and 4 and Figs. 1 and 2. The antimicrobial activity of the blank and blended polyurethane varnish formulations and printing ink paste was evaluated by testing it against six different micro-organisms such as Gram-negative bacteria (G-), Gram-positive (G+) bacteria and fungi. Compounds II and III were found to possess (i) moderate antimicrobial activity against Gram-negative bacteria (G-) [E. coli], show higher sensitivity than salmonella (ii) high antimicrobial activity against Gram-positive bacteria (G+) [compounds II and III were very effective against M. luteus and S. aureus], and (iii) mild antimicrobial activity against fungi [A. flower and C. albicans] showed the highest sensitivity. It can be observed that the antimicrobial activity against the target micro-organisms increases with the increase in the biocide additive percent and it gives better results with polyurethane than printing ink paste. This is due to the incorporation of compound II and III into the polyurethane varnish formulations and printing ink paste.

### Table 3 Anti-microbial activity of polyurethane varnish incorporated new pyrimidine derivative (compound II & III) as a biocide additive.

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Blank</th>
<th>Compound II%</th>
<th>Compound III%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Micrococcus luteus (ATCC 9341)</td>
<td>−Ve</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + + Ve</td>
<td>+ + + + Ve</td>
</tr>
<tr>
<td>Staphylococcus aureus (NCTC 7447)</td>
<td>−Ve</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + + Ve</td>
<td>+ + + + Ve</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>−Ve</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + Ve</td>
</tr>
<tr>
<td>Salmonella</td>
<td>−Ve</td>
<td>24</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + Ve</td>
</tr>
<tr>
<td>Candida albicans (IMRU 3669)</td>
<td>−Ve</td>
<td>22</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + + Ve</td>
</tr>
<tr>
<td>Aspergillus flavus</td>
<td>−Ve</td>
<td>20</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + + Ve</td>
</tr>
</tbody>
</table>

Rating the results according to the following:

- Ve = No Inhibition Zone.
- + Ve = Weak Inhibition Zone (10–19 mm).
- ++ Ve = Moderate Inhibition Zone (20–26 mm).
- +++ Ve = Good Inhibition Zone (27–35 mm).
- ++++ Ve = Very Good Inhibition Zone More than 35 mm.

### Table 4 Anti-microbial activity of printing ink paste incorporated new pyrimidine derivative (compound II & III) as a biocide additive.

<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Blank</th>
<th>Compound II%</th>
<th>Compound III%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Micrococcus luteus (ATCC 9341)</td>
<td>−Ve</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + + Ve</td>
<td>+ + + + Ve</td>
</tr>
<tr>
<td>Staphylococcus aureus (NCTC 7447)</td>
<td>−Ve</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + + Ve</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>−Ve</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ Ve</td>
<td>+ + Ve</td>
</tr>
<tr>
<td>Salmonella</td>
<td>−Ve</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + Ve</td>
</tr>
<tr>
<td>Candida albicans (IMRU 3669)</td>
<td>−Ve</td>
<td>26</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + Ve</td>
</tr>
<tr>
<td>Aspergillus flavus</td>
<td>−Ve</td>
<td>31</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ + Ve</td>
<td>+ + + + Ve</td>
</tr>
</tbody>
</table>

Rating the results according to the following:

- Ve = No Inhibition Zone.
- + Ve = Weak Inhibition Zone (10–19 mm).
- ++ Ve = Moderate Inhibition Zone (20–26 mm).
- +++ Ve = Good Inhibition Zone (27–35 mm).
- ++++ Ve = Very Good Inhibition Zone More than 35 mm.
enhancement may be attributed to the introduction of a bio-
cide compound containing three functional groups; (i) phenyl-
sulfone, pyrazol, and the primidine ring and free NH2
possesses remarkable activities against bacteria and fungi, (ii)
pyrazoline and pyrimidine rings are also a familiar group of
heterocyclic compounds possessing remarkable activities
against bacteria due to the presence of 😂N–C–N and 😂N–
C–S moieties in addition to (iii) free amino groups that are
reported to exhibit significant biological activities. We believe
that antimicrobial activity results contribute to circumvent
the accumulation of organisms on the coating surfaces and
contribute to the hazardous materials and ecological coating
chemistry.

3.3. Evaluation of the physical and mechanical properties of
polyurethane varnish formulations containing the new
antimicrobial as biocide additive

The effects of adding antimicrobial additives to the polyur-
ethane varnish, in respect to the physical and mechanical prop-
erties, were evaluated as per the standard test methods. This
was done to ascertain any negative aspects that might arise
due to the presence of additives. The color, gloss, scratch hard-
ness, adhesion and flexibility all are measured. The resulting
data are shown in Table 5. All modified and unmodified poly-
urethane varnish compositions showed very clear transparent
and homogenous appearance after adding the antimicrobial
additives.

(a) Color:
Color was measured using the Gardner standard colors,
which consists of 18 colors numbered from 1 to 18. The
method determines the color by comparison with stan-
dards of definite color compositions. It could be seen that
the antimicrobial additive actually increased the color
levels. This is obviously a negative result which may be
attributed to the introduction of sulfur and nitrogenous
base into polyurethane varnish formulations.

Table 5  
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Blank</th>
<th>Compound II%</th>
<th>Compound III%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color “Gardner”</td>
<td>14</td>
<td>&gt;18</td>
<td>&gt;18</td>
</tr>
<tr>
<td>Gloss at 20 °C</td>
<td>83</td>
<td>88</td>
<td>95</td>
</tr>
<tr>
<td>Scratch hardness (kg)</td>
<td>&gt;1.5</td>
<td>&gt;2</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Adhesion</td>
<td>4B</td>
<td>5B</td>
<td>5B</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
</tbody>
</table>

Figure 1  Anti-microbial activity of blank and blended polyurethane with a biocide additive (compounds II & III).

Figure 2  Anti-microbial activity of blank and blended printing ink paste with a biocide additive (compounds II & III).
Synthesis and evaluation of new anti-microbial additives

(b) Gloss:
It was measured by using a glossmeter (Sheen UK). On watching the films at 20° angle, it was observed that the flame retardant additives increased the gloss. This is a positive result which may be attributed to the introduction of aromatic rings and a lone pair of electrons in the additives structure.

c) Scratch hardness test:
It was determined by using a scratch hardness tester (Sheen UK). The scratch hardness varies from 1000 to 2000 g. It is clear from the data that as we added the additives percentage the scratch hardness of the film goes on increasing.

(d) Cross-hatch adhesion test:
It was measured by using a crosscut adhesion tester (Sheen U.K.). In this test method a lattice with six cuts in each direction is made in the film to the substrate (space the cuts 1 mm), pressure-sensitive tape is applied over the lattice and then removed. All the coating films demonstrated good cross-hatch adhesion. The additive did not change the adhesion properties of polyurethane varnish formula.

(e) Flexibility (bend) test:
Flexibility was determined by using a inch Mandrel bend tester (Sheen U.K.), in such a way that the surface of the panel was directed outside. Films of all the coating compositions passed the inch mandrel bend test. The varnish was considered satisfactory if no marks for cracking or dislodging are observed after bending. Based on this qualitative measurement, it can be said that all the films had reasonably good flexibility.

4. Conclusion

In this study new antimicrobial additives 3,3-bis(methylthio)-2-(phenylperoxythio)-acrylonitrile, 3-((4-Bromophenyl)diazene-5-(methylthio)-6-(phenylsulfonyl)pyrazolo[1,5-a]pyrimidine-2,7-diamine and 4-(methylthio)-3-(phenylsulfonyl)benzo[4,5][2-(phenylperoxythio)-acrylonitrile, 3-((4-Bromophenyl)diazeno[1,2-a]pyrimidin-2-amine (compounds II and III), were demonstrated good cross-hatch adhesion. The additive did not change the adhesion properties of polyurethane varnish formula.

References