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# APPENDICES

## APPENDIX A

### Properties of heavy metals

#### Copper (Cu)

|                             |  |
|-----------------------------|--|
| <b>Atomic number</b>        | : 29   |
| <b>Atomic weight</b>        | : 63.546   |
| <b>Periodic Table</b>       | : group IB   |
| <b>Valences</b>             | : 1, 2; two stable isotopes  |
| <b>Oxidation states</b>     | : +2, +4   |
| <b>Properties</b>           | : Distinctive reddish color, specific gravity 8.96, melting point 1083°C, boiling point 2595°C, dissolves in nitric acid and hot concentrated sulfuric acid, dissolve slowly in hydrochloric and dilute sulfuric acid but only when exposed to the atmosphere.   |
| <b>Hazard</b>               | : The toxicity of metallic copper is very low. However, inhalation of dusts, fumes, mists or salt can cause adverse health effects. Many copper (II) salts are toxic.  |
| <b>Uses</b>                 | : Copper is used in electric cables and wires, switches, plumbing, heating; roofing and building construction; chemical and pharmaceutical machinery; alloys (brass, bronze, and a new alloy with 3% beryllium that is particularly vibration resistant); alloy castings; electroplated protective coatings and undercoats for nickel, chromium, zinc, etc., cooking utensils. |
| <b>Exposure Limits</b>      | : TLV-TWA 1 mg (Cu)/m <sup>3</sup> (dust and mists) (ACGIH and MSHA); 0.2 mg/m <sup>3</sup> (fumes) (ACGIH)  |
| <b>Sampling and storage</b> | : Copper ion tends to be adsorbed on the surface of sample containers. Therefore, analyze samples as soon as possible after collection. To store sample, use 0.5 mL 1+1 HCl/100 mL sample to prevent this adsorption.  |

**Cadmium (Cd)**

|                             |   |
|-----------------------------|---|
| <b>Atomic number</b>        | : 48  |
| <b>Atomic weight</b>        | : 112.4   |
| <b>Periodic Table</b>       | : group IIB   |
| <b>Valences</b>             | : 2   |
| <b>Oxidation states</b>     | : +2  |
| <b>Properties</b>           | : Soft, blue-white, malleable or grayish-white powder. Tarnishes in moist air; corrosion resistance poor in industrial atmospheres. Becomes brittle at 80°C. Resistant to alkalis; high neutron absorber. Specific gravity 8.642, melting point 320.9°C, boiling point 767°C, soluble in acids, especially nitric and ammonium nitrate solutions. |
| <b>Hazard</b>               | : Highly toxic, especially by inhalation of dust or fumes. It is a known carcinogen (OSHA).   |
| <b>Uses</b>                 | : Electrodeposits and dipped coating on metals; bearing and low-melting alloys; brazing alloys; fire-protection systems; nickel cadmium storage batteries; power transmission wire; TV phosphors; basis of pigments used in ceramic glazes.   |
| <b>Exposure Limits</b>      | : TLV-TWA 0.15 mg/m <sup>3</sup> (ACGIH and MSHA); 0.05 mg/m <sup>3</sup> (OSHA); 10hr TWA 0.1 mg(inorganic lead)/m <sup>3</sup> (NIOSH)  |
| <b>Sampling and storage</b> | : Cadmium ion tends to be adsorbed on the surface of sample containers. Therefore, analyze samples as soon as possible after collection. To store sample, use 0.5 mL 1+1 HCl/100 mL sample to prevent this adsorption.  |



**Source:**

Clesceri, S.L. 1989 Standard Methods for the Examination of Water and Wastewater. 17th ed. Washington: American Public Health Association.

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**APPENDIX B****Table B1** Data from elemental analysis for total nitrogen and sulfur content**Total Nitrogen content**

| Name  | TN (mg) | Weight (g) | TN (g/g) | %N     |
|-------|---------|------------|----------|--------|
| A-HMS | 1.5531  | 0.1100     | 0.0141   | 1.4419 |

**Total Sulfur content**

| Name  | Mass of S (g) | Weight (g) | TS (g/g) | %S     |
|-------|---------------|------------|----------|--------|
| M-HMS | 0.0105        | 0.1057     | 0.0992   | 9.9243 |

Table B2 Data from calculation of surface charge of HMS

| Sample | pH   | Surface charge (C/g) |
|--------|------|----------------------|
| 1      | 3.39 | 20.6894              |
| 2      | 3.6  | 8.8539               |
| 3      | 3.78 | 7.3326               |
| 4      | 4.06 | 2.1769               |
| 5      | 4.37 | 1.5538               |
| 6      | 4.99 | -0.0495              |
| 7      | 5.42 | -0.8257              |
| 8      | 4.97 | -2.0218              |
| 9      | 6.7  | -8.4018              |
| 10     | 7.24 | -20.5957             |
| 11     | 8.23 | -33.4557             |
| 12     | 8.56 | -54.58               |
| 13     | 8.94 | -115.072             |

Table B3 Data from calculation of surface charge of A-HMS

| Sample | pH   | Surface charge (C/g) |
|--------|------|----------------------|
| 1      | 9.67 | -21.6759             |
| 2      | 9.6  | -7.612               |
| 3      | 9.58 | -2.9676              |
| 4      | 9.57 | -0.6363              |
| 5      | 9.53 | 1.6316               |
| 6      | 9.51 | 3.561                |
| 7      | 9.5  | 5.339                |
| 8      | 9.4  | 9.0818               |
| 9      | 9.38 | 19.9328              |

Table B4 Data from calculation of surface charge of M-HMS

| Sample | pH   | Surface charge (C/g) |
|--------|------|----------------------|
| 1      | 8.63 | -24.0164             |
| 2      | 7.56 | -9.5771              |
| 3      | 7.01 | -4.7963              |
| 4      | 6.62 | -2.3749              |
| 5      | 6.14 | -0.0338              |
| 6      | 4.96 | 1.4146               |
| 7      | 4.4  | 1.9738               |
| 8      | 3.97 | 2.5858               |
| 9      | 3.45 | 2.3544               |

**Table B5** Data from calculation of surface charge of OD-HMS

| Sample | pH   | Surface charge (C/g) |
|--------|------|----------------------|
| 1      | 8.75 | -21.0023             |
| 2      | 7.42 | -9.3215              |
| 3      | 6.96 | -8.7532              |
| 4      | 6.54 | -7.3215              |
| 5      | 5.83 | -2.1132              |
| 6      | 4.76 | -0.0321              |
| 7      | 4.31 | 1.9758               |
| 8      | 3.88 | 2.5953               |
| 9      | 3.21 | 3.0154               |

**Table B6** Data from calculation of surface charge of PAC

| Sample | pH   | Surface charge (C/g) |
|--------|------|----------------------|
| 1      | 9.78 | -21.0795             |
| 2      | 9.63 | -7.6424              |
| 3      | 9.51 | -3.3454              |
| 4      | 9.47 | -1.0167              |
| 5      | 9.38 | 1.1597               |
| 6      | 9.3  | 2.8946               |
| 7      | 9.21 | 4.6074               |
| 8      | 9.08 | 8.4962               |
| 9      | 8.3  | 19.7073              |

## APPENDIX C

Table C1 Data for adsorption kinetic of Cd(II) at pH 5, Ionic Strength 0.1 M, 25°C on all adsorbents.

| HMS    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|-----------|---------------|------------------|-----------------|-----------------------|------------|
|        | 1         | 0.0615        | 21.8600          | 21.7590         | 0.1010                | 0.3285     |
| 3      | 0.0615    | 21.8600       | 21.7210          | 0.1390          | 0.4520                |            |
| 6      | 0.0615    | 21.8600       | 21.6980          | 0.1620          | 0.5268                |            |
| 9      | 0.0615    | 21.8600       | 21.6850          | 0.1750          | 0.5691                |            |
| 12     | 0.0615    | 21.8600       | 21.6830          | 0.1770          | 0.5756                |            |
| A-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0610        | 21.8600          | 21.7950         | 0.0650                | 0.2131     |
| 3      | 0.0610    | 21.8600       | 21.7560          | 0.1040          | 0.3410                |            |
| 6      | 0.0610    | 21.8600       | 21.7530          | 0.1070          | 0.3508                |            |
| 9      | 0.0610    | 21.8600       | 21.7420          | 0.1180          | 0.3869                |            |
| 12     | 0.0610    | 21.8600       | 21.7400          | 0.1200          | 0.3934                |            |
| M-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0616        | 21.8600          | 20.8510         | 1.0090                | 3.2760     |
| 3      | 0.0616    | 21.8600       | 20.7630          | 1.0970          | 3.5617                |            |
| 6      | 0.0616    | 21.8600       | 20.7540          | 1.1060          | 3.5909                |            |
| 9      | 0.0616    | 21.8600       | 20.7490          | 1.1110          | 3.6071                |            |
| 12     | 0.0616    | 21.8600       | 20.7410          | 1.1190          | 3.6331                |            |
| OD-HMS | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0613        | 21.8600          | 21.7550         | 0.1050                | 0.3426     |
| 3      | 0.0613    | 21.8600       | 21.7020          | 0.1580          | 0.5155                |            |
| 6      | 0.0613    | 21.8600       | 21.6450          | 0.2150          | 0.7015                |            |
| 9      | 0.0613    | 21.8600       | 21.6390          | 0.2210          | 0.7210                |            |
| 12     | 0.0613    | 21.8600       | 21.6350          | 0.2250          | 0.7341                |            |
| PAC    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.2004        | 21.8600          | 21.7880         | 0.0720                | 0.0719     |
| 3      | 0.2004    | 21.8600       | 21.1690          | 0.6910          | 0.6896                |            |
| 6      | 0.2004    | 21.8600       | 21.1630          | 0.6970          | 0.6956                |            |
| 9      | 0.2004    | 21.8600       | 21.1540          | 0.7060          | 0.7046                |            |
| 12     | 0.2004    | 21.8600       | 21.1320          | 0.7280          | 0.7265                |            |

Table C2 Data for adsorption kinetic of Cu(II) at pH 5, Ionic Strength 0.1 M, 25°C on all adsorbents.

| HMS    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|-----------|---------------|------------------|-----------------|-----------------------|------------|
|        | 1         | 0.0635        | 21.8050          | 21.2530         | 0.5570                | 1.7543     |
| 3      | 0.0635    | 21.8050       | 21.2960          | 0.5140          | 1.6189                |            |
| 6      | 0.0635    | 21.8050       | 21.3050          | 0.5050          | 1.5906                |            |
| 9      | 0.0635    | 21.8050       | 21.3110          | 0.4990          | 1.5717                |            |
| 12     | 0.0635    | 21.8050       | 21.2980          | 0.5120          | 1.6126                |            |
| A-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0617        | 21.8050          | 21.7780         | 0.0320                | 0.1037     |
| 3      | 0.0617    | 21.8050       | 21.6830          | 0.1270          | 0.4117                |            |
| 6      | 0.0617    | 21.8050       | 21.7250          | 0.0850          | 0.2755                |            |
| 9      | 0.0617    | 21.8050       | 21.7330          | 0.0770          | 0.2496                |            |
| 12     | 0.0617    | 21.8050       | 21.7220          | 0.0880          | 0.2853                |            |
| M-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0615        | 21.8050          | 15.5320         | 6.2780                | 20.4163    |
| 3      | 0.0615    | 21.8050       | 15.6320          | 6.1780          | 20.0911               |            |
| 6      | 0.0615    | 21.8050       | 15.4230          | 6.3870          | 20.7707               |            |
| 9      | 0.0615    | 21.8050       | 15.3230          | 6.4870          | 21.0959               |            |
| 12     | 0.0615    | 21.8050       | 15.5690          | 6.2410          | 20.2959               |            |
| OD-HMS | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0612        | 21.8050          | 20.8770         | 0.9330                | 3.0490     |
| 3      | 0.0612    | 21.8050       | 20.9630          | 0.8470          | 2.7680                |            |
| 6      | 0.0612    | 21.8050       | 20.9870          | 0.8230          | 2.6895                |            |
| 9      | 0.0612    | 21.8050       | 20.9740          | 0.8360          | 2.7320                |            |
| 12     | 0.0612    | 21.8050       | 21.0020          | 0.8080          | 2.6405                |            |
| FAC    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.2027        | 21.8050          | 18.4360         | 3.3740                | 3.3291     |
| 3      | 0.2027    | 21.8050       | 18.4540          | 3.3560          | 3.3113                |            |
| 6      | 0.2027    | 21.8050       | 18.5030          | 3.3070          | 3.2630                |            |
| 9      | 0.2027    | 21.8050       | 18.5110          | 3.2990          | 3.2551                |            |
| 12     | 0.2027    | 21.8050       | 18.5070          | 3.3030          | 3.2590                |            |

**Table C3** Data for adsorption kinetic of MB at pH 5, Ionic Strength 0.1 M, 25°C on all adsorbents.

| HMS    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|-----------|---------------|------------------|-----------------|-----------------------|------------|
|        | 1         | 0.0675        | 48.0557          | 42.1737         | 5.8819                | 17.5058    |
| 3      | 0.0675    | 48.0557       | 37.0657          | 10.9900         | 32.7082               |            |
| 6      | 0.0675    | 48.0557       | 37.8396          | 10.2160         | 30.4048               |            |
| 9      | 0.0675    | 48.0557       | 38.7684          | 9.2873          | 27.6407               |            |
| 12     | 0.0675    | 48.0557       | 37.9944          | 10.0612         | 29.9441               |            |
| A-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0674        | 48.0557          | 45.7338         | 2.3218                | 6.5774     |
| 3      | 0.0674    | 48.0557       | 45.5790          | 2.4766          | 7.0159                |            |
| 6      | 0.0674    | 48.0557       | 45.4243          | 2.6314          | 7.4544                |            |
| 9      | 0.0674    | 48.0557       | 45.7338          | 2.3218          | 6.5774                |            |
| 12     | 0.0674    | 48.0557       | 45.2695          | 2.7862          | 7.8929                |            |
| M-HMS  | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0670        | 48.0557          | 20.5034         | 27.5523               | 82.7395    |
| 3      | 0.0670    | 48.0557       | 18.9555          | 29.1001         | 87.3878               |            |
| 6      | 0.0670    | 48.0557       | 18.4911          | 29.5645         | 88.7823               |            |
| 9      | 0.0670    | 48.0557       | 19.7295          | 28.3262         | 85.0637               |            |
| 12     | 0.0670    | 48.0557       | 19.2651          | 28.7906         | 86.4582               |            |
| OD-HMS | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.0672        | 48.0557          | 18.3364         | 29.7193               | 85.5232    |
| 3      | 0.0672    | 48.0557       | 12.9188          | 35.1369         | 101.1133              |            |
| 6      | 0.0672    | 48.0557       | 13.5379          | 34.5177         | 99.3316               |            |
| 9      | 0.0672    | 48.0557       | 12.4544          | 35.6012         | 102.4496              |            |
| 12     | 0.0672    | 48.0557       | 13.0736          | 34.9821         | 100.6679              |            |
| PAC    | Time (hr) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1         | 0.2014        | 222.4977         | 163.1623        | 59.3357               | 178.4532   |
| 3      | 0.2014    | 222.4977      | 165.2262         | 57.2718         | 172.2461              |            |
| 6      | 0.2014    | 222.4977      | 168.8379         | 53.6601         | 161.3838              |            |
| 9      | 0.2014    | 222.4977      | 166.7740         | 55.7240         | 167.5909              |            |
| 12     | 0.2014    | 222.4977      | 165.4841         | 57.0139         | 171.4703              |            |

Table C4 Data for adsorption kinetic of TX-100 at pH 5, Ionic Strength 0.1 M, 25°C on all adsorbents.

| HMS    | Time (min) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|------------|---------------|------------------|-----------------|-----------------------|------------|
|        | 1          | 0.1203        | 408.6089         | 159.36446       | 249.2445              | 414.3715   |
| 10     | 0.1203     | 408.6089      | 38.85066         | 369.7583        | 614.7269              |            |
| 30     | 0.1203     | 408.6089      | 33.92055         | 374.6884        | 622.9233              |            |
| 60     | 0.1203     | 408.6089      | 33.37276         | 375.2362        | 623.8340              |            |
| 90     | 0.1203     | 408.6089      | 33.92055         | 374.6884        | 622.9233              |            |
| A-HMS  | Time (min) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1          | 0.1207        | 408.6089         | 386.6973        | 21.9116               | 36.3075    |
| 10     | 0.1207     | 408.6089      | 381.7672         | 26.8417         | 44.4767               |            |
| 30     | 0.1207     | 408.6089      | 385.6017         | 23.0072         | 38.1229               |            |
| 60     | 0.1207     | 408.6089      | 385.0539         | 23.5550         | 39.0306               |            |
| 90     | 0.1207     | 408.6089      | 394.9142         | 13.6948         | 22.6922               |            |
| M-HMS  | Time (min) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1          | 0.1210        | 408.6089         | 347.7945        | 60.8144               | 100.5197   |
| 10     | 0.1210     | 408.6089      | 199.6324         | 208.9765        | 345.4157              |            |
| 30     | 0.1210     | 408.6089      | 198.3321         | 210.2768        | 347.5650              |            |
| 60     | 0.1210     | 408.6089      | 200.3659         | 208.2430        | 344.2033              |            |
| 90     | 0.1210     | 408.6089      | 201.3478         | 207.2611        | 342.5803              |            |
| OD-HMS | Time (min) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1          | 0.1210        | 408.6089         | 379.0536        | 29.5553               | 48.8518    |
| 10     | 0.1210     | 408.6089      | 209.6162         | 198.9927        | 328.9136              |            |
| 30     | 0.1210     | 408.6089      | 210.6548         | 197.9541        | 327.1969              |            |
| 60     | 0.1210     | 408.6089      | 211.6325         | 196.9764        | 325.5808              |            |
| 90     | 0.1210     | 408.6089      | 209.6347         | 198.9742        | 328.8830              |            |
| PAC    | Time (min) | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 1          | 0.1204        | 408.6089         | 290.3589        | 118.2500              | 196.4286   |
| 10     | 0.1204     | 408.6089      | 219.0125         | 189.5964        | 314.9442              |            |
| 30     | 0.1204     | 408.6089      | 219.3269         | 189.2820        | 314.4219              |            |
| 60     | 0.1204     | 408.6089      | 219.5579         | 189.0510        | 314.0382              |            |
| 90     | 0.1204     | 408.6089      | 218.9657         | 189.6432        | 315.0219              |            |



## APPENDIX D

**Table D1** Data for adsorption isotherm in Cd(II) at pH 3, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
| HMS    | 0.0103        | 2.0715           | 1.9602          | 0.1113                | 0.3242     |
|        | 0.0115        | 5.0682           | 4.6630          | 0.4052                | 1.0570     |
|        | 0.0118        | 10.7090          | 10.2090         | 0.5000                | 1.2712     |
|        | 0.0119        | 15.7016          | 15.0574         | 0.6443                | 1.6242     |
|        | 0.0109        | 20.4530          | 19.7350         | 0.7180                | 1.9761     |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0106        | 2.0715           | 1.9672          | 0.1043                | 0.2951     |
|        | 0.0104        | 5.0682           | 4.7047          | 0.3635                | 1.0486     |
|        | 0.0120        | 10.7090          | 10.1610         | 0.5480                | 1.3700     |
|        | 0.0115        | 15.7016          | 15.0739         | 0.6277                | 1.6376     |
| 0.0122 | 20.4530       | 19.8750          | 0.5780          | 1.4213                |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0103        | 2.0715           | 1.8226          | 0.2489                | 0.7248     |
|        | 0.0105        | 5.0682           | 4.0362          | 1.0320                | 2.9486     |
|        | 0.0120        | 10.7090          | 9.6742          | 1.0348                | 2.5870     |
|        | 0.0114        | 15.7016          | 14.4500         | 1.2516                | 3.2937     |
| 0.0102 | 20.4530       | 19.1850          | 1.2680          | 3.7294                |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0113        | 2.0715           | 1.9342          | 0.1372                | 0.3643     |
|        | 0.0116        | 5.0682           | 4.4985          | 0.5697                | 1.4734     |
|        | 0.0118        | 10.7090          | 10.1830         | 0.5260                | 1.3373     |
|        | 0.0111        | 15.7016          | 15.0124         | 0.6893                | 1.8628     |
| 0.0129 | 20.4530       | 19.6670          | 0.7860          | 1.8279                |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0113        | 2.0715           | 1.9336          | 0.1379                | 0.3661     |
|        | 0.0112        | 5.0682           | 4.8339          | 0.2343                | 0.6275     |
|        | 0.0107        | 10.7090          | 9.5062          | 1.2028                | 3.3723     |
|        | 0.0115        | 15.7016          | 14.5018         | 1.1999                | 3.1300     |
| 0.0107 | 20.4530       | 19.4322          | 1.0208          | 2.8621                |            |

**Table D2** Data for adsorption isotherm in Cd(II) at pH 5, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | 0.0133        | 2.3150           | 2.253           | 0.062                 | 0.14066    |
| 0.0130 | 5.3925        | 5.177            | 0.216           | 0.49840               |            |
| 0.0126 | 10.8800       | 10.672           | 0.208           | 0.49506               |            |
| 0.0124 | 16.2850       | 16.081           | 0.204           | 0.49466               |            |
| 0.0109 | 21.8620       | 21.679           | 0.183           | 0.50334               |            |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0113        | 2.3150           | 2.2369          | 0.078                 | 0.20743    |
| 0.0104 | 5.3925        | 5.2631           | 0.129           | 0.37327               |            |
| 0.0100 | 10.8800       | 10.7570          | 0.123           | 0.36900               |            |
| 0.0125 | 16.2850       | 16.1295          | 0.155           | 0.37314               |            |
| 0.0107 | 21.8620       | 21.7296          | 0.132           | 0.37112               |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0121        | 2.3150           | 1.7859          | 0.529                 | 1.31178    |
| 0.0115 | 5.3925        | 4.2570           | 1.135           | 2.96207               |            |
| 0.0128 | 10.8800       | 9.6078           | 1.272           | 2.98182               |            |
| 0.0102 | 16.2850       | 15.2930          | 0.992           | 2.91753               |            |
| 0.0108 | 21.8620       | 20.8143          | 1.048           | 2.91024               |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0109        | 2.3150           | 2.2626          | 0.106                 | 0.29119    |
| 0.0105 | 5.3925        | 4.5245           | 0.187           | 0.53314               |            |
| 0.0114 | 10.8800       | 9.4500           | 0.227           | 0.59789               |            |
| 0.0101 | 16.2850       | 14.1730          | 0.201           | 0.59703               |            |
| 0.0130 | 21.8620       | 19.2100          | 0.256           | 0.59077               |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0308        | 2.3150           | 1.8563          | 0.459                 | 0.44675    |
| 0.0306 | 5.3925        | 4.7088           | 0.684           | 0.67032               |            |
| 0.0335 | 10.8800       | 10.0553          | 0.825           | 0.73850               |            |
| 0.0308 | 16.2850       | 15.5071          | 0.778           | 0.75768               |            |
| 0.0306 | 21.8620       | 21.1182          | 0.744           | 0.72925               |            |

**Table D3** Data for adsorption isotherm in Cu(II) at pH 3, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | 0.0108        | 1.9371           | 1.930           | 0.008                 | 0.02083    |
| 0.0122 | 4.8028        | 4.578            | 0.225           | 0.55230               |            |
| 0.0126 | 10.6890       | 10.003           | 0.686           | 1.63333               |            |
| 0.0124 | 16.5430       | 15.864           | 0.679           | 1.64274               |            |
| 0.0104 | 21.8230       | 21.252           | 0.571           | 1.64712               |            |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0102        | 1.9371           | 1.9340          | 0.003                 | 0.00912    |
| 0.0113 | 4.8028        | 4.7996           | 0.003           | 0.00850               |            |
| 0.0107 | 10.6890       | 10.6856          | 0.003           | 0.00953               |            |
| 0.0104 | 16.5430       | 16.5397          | 0.003           | 0.00952               |            |
| 0.0115 | 21.8230       | 21.8199          | 0.003           | 0.00809               |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0107        | 1.9371           | 0.0228          | 1.914                 | 5.36722    |
| 0.0103 | 4.8028        | 0.2013           | 4.602           | 13.40243              |            |
| 0.0103 | 10.6890       | 3.1552           | 7.534           | 21.94311              |            |
| 0.0103 | 16.5430       | 9.0036           | 7.539           | 21.95942              |            |
| 0.0116 | 21.8230       | 12.1740          | 9.649           | 24.95431              |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0110        | 1.9618           | 1.7398          | 0.222                 | 0.60562    |
| 0.0104 | 4.9295        | 4.4367           | 0.493           | 1.42154               |            |
| 0.0129 | 9.5184        | 8.2640           | 1.254           | 2.91721               |            |
| 0.0110 | 15.1310       | 14.0030          | 1.128           | 3.07636               |            |
| 0.0101 | 19.5355       | 18.5570          | 0.979           | 2.90644               |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0309        | 1.9371           | 0.4961          | 1.441                 | 1.39902    |
| 0.0311 | 4.8028        | 2.3625           | 2.440           | 2.35399               |            |
| 0.0312 | 10.6890       | 7.6022           | 3.087           | 2.96808               |            |
| 0.0323 | 16.5430       | 13.2360          | 3.307           | 3.07152               |            |
| 0.0333 | 21.8230       | 18.3090          | 3.514           | 3.16577               |            |

**Table D4** Data for adsorption isotherm in Cu(II) at pH 5, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | 0.0112        | 2.1143           | 2.0462          | 0.0681                | 0.1824     |
| 0.0126 | 5.2857        | 5.1155           | 0.1702          | 0.4052                |            |
| 0.0103 | 10.7930       | 10.4290          | 0.3640          | 1.0602                |            |
| 0.0109 | 16.0478       | 15.6435          | 0.4043          | 1.1126                |            |
| 0.0105 | 21.2080       | 20.7720          | 0.4360          | 1.2457                |            |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0108        | 2.1143           | 2.1103          | 0.0040                | 0.0110     |
| 0.0105 | 5.2857        | 5.1369           | 0.1488          | 0.4251                |            |
| 0.0112 | 10.7930       | 10.2440          | 0.5490          | 1.4705                |            |
| 0.0104 | 16.0478       | 15.3660          | 0.6818          | 1.9666                |            |
| 0.0113 | 21.2080       | 20.4750          | 0.7330          | 1.9460                |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0102        | 2.1143           | 0.0099          | 2.1044                | 6.1893     |
| 0.0111 | 5.2857        | 0.0248           | 5.2609          | 14.2186               |            |
| 0.0103 | 10.7930       | 1.9794           | 8.8136          | 25.6707               |            |
| 0.0116 | 16.0478       | 5.8769           | 10.1708         | 26.3039               |            |
| 0.0112 | 21.2080       | 11.7130          | 9.4950          | 25.4330               |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0104        | 2.1143           | 2.1121          | 0.0022                | 0.0063     |
| 0.0123 | 5.2857        | 5.2796           | 0.0061          | 0.0149                |            |
| 0.0128 | 10.7930       | 10.6870          | 0.1060          | 0.2484                |            |
| 0.0103 | 16.0478       | 15.6103          | 0.4375          | 1.2741                |            |
| 0.0133 | 21.2080       | 20.6670          | 0.5410          | 1.2203                |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0115        | 2.1143           | 2.0912          | 0.0231                | 0.0603     |
| 0.0128 | 5.2857        | 5.2279           | 0.0578          | 0.1355                |            |
| 0.0128 | 10.7930       | 10.4510          | 0.3420          | 0.8016                |            |
| 0.0116 | 16.0478       | 15.6836          | 0.3641          | 0.9417                |            |
| 0.0124 | 21.2080       | 20.8563          | 0.3517          | 0.8509                |            |

**Table D5** Data for adsorption isotherm in MB at pH 5, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | HMS           | 0.0108           | 8.0000          | 1.9337                | 6.0663     |
| 0.0104 |               | 10.0000          | 2.6309          | 7.3691                | 21.2571    |
| 0.0111 |               | 15.0000          | 3.2681          | 11.7319               | 31.7078    |
| 0.0107 |               | 20.0000          | 6.5795          | 13.4205               | 37.6275    |
| 0.0118 |               | 30.0000          | 15.7427         | 14.2573               | 36.2474    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | A-HMS         | 0.0110           | 6.0000          | 4.6134                | 1.3866     |
| 0.0101 |               | 8.0000           | 6.5850          | 1.4150                | 4.2031     |
| 0.0103 |               | 10.0000          | 8.3060          | 1.6940                | 4.9339     |
| 0.0111 |               | 20.0000          | 18.1936         | 1.8064                | 4.8822     |
| 0.0118 |               | 30.0000          | 28.1060         | 1.8940                | 4.8152     |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | M-HMS         | 0.0124           | 8.0000          | 0.8553                | 7.1447     |
| 0.0110 |               | 10.0000          | 1.2911          | 8.7089                | 23.7517    |
| 0.0129 |               | 20.0000          | 4.3410          | 15.6590               | 36.4162    |
| 0.0109 |               | 30.0000          | 8.6600          | 21.3400               | 58.7338    |
| 0.0113 |               | 50.0000          | 28.4328         | 21.5672               | 57.2580    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | OD-HMS        | 0.0128           | 8.0000          | 0.1691                | 7.8309     |
| 0.0102 |               | 10.0000          | 0.4251          | 9.5749                | 28.1615    |
| 0.0110 |               | 20.0000          | 0.8989          | 19.1011               | 52.0939    |
| 0.0103 |               | 30.0000          | 7.9466          | 22.0534               | 64.2333    |
| 0.0105 |               | 50.0000          | 27.1257         | 22.8743               | 65.3552    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | PAC           | 0.0102           | 70.0000         | 2.1267                | 67.8733    |
| 0.0110 |               | 80.0000          | 6.5927          | 73.4073               | 200.2016   |
| 0.0105 |               | 100.0000         | 30.1212         | 69.8788               | 199.6537   |
| 0.0116 |               | 150.0000         | 72.3308         | 77.6692               | 200.8686   |
| 0.0109 |               | 200.0000         | 127.1864        | 72.8136               | 200.4043   |

**Table D6** Data for adsorption isotherm in MB at pH 7, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | HMS           | 0.0110           | 8.0000          | 1.9283                | 6.0717     |
| 0.0101 |               | 10.0000          | 2.6200          | 7.3800                | 21.9209    |
| 0.0103 |               | 15.0000          | 3.2790          | 11.7210               | 34.1389    |
| 0.0111 |               | 20.0000          | 6.5904          | 13.4096               | 36.2422    |
| 0.0118 |               | 30.0000          | 15.7972         | 14.2028               | 36.1089    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | A-HMS         | 0.0124           | 6.0000          | 4.6188                | 1.3812     |
| 0.0110 |               | 8.0000           | 6.6122          | 1.3878                | 3.7849     |
| 0.0129 |               | 10.0000          | 8.3333          | 1.6667                | 3.8762     |
| 0.0109 |               | 20.0000          | 18.4659         | 1.5341                | 4.2223     |
| 0.0113 |               | 30.0000          | 28.3783         | 1.6217                | 4.3053     |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | M-HMS         | 0.0128           | 8.0000          | 0.8989                | 7.1011     |
| 0.0102 |               | 10.0000          | 1.3237          | 8.6763                | 25.5184    |
| 0.0110 |               | 20.0000          | 4.3574          | 15.6426               | 42.6617    |
| 0.0103 |               | 30.0000          | 8.6873          | 21.3127               | 62.0759    |
| 0.0105 |               | 50.0000          | 28.5962         | 21.4038               | 61.1537    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | OD-HMS        | 0.0102           | 8.0000          | 0.2018                | 7.7982     |
| 0.0110 |               | 10.0000          | 0.4087          | 9.5913                | 26.1580    |
| 0.0105 |               | 20.0000          | 0.9207          | 19.0793               | 54.5123    |
| 0.0116 |               | 30.0000          | 7.9030          | 22.0970               | 57.1474    |
| 0.0109 |               | 50.0000          | 28.5962         | 21.4038               | 58.9095    |
|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | PAC           | 0.0110           | 70.0000         | 2.1267                | 67.8733    |
| 0.0101 |               | 80.0000          | 11.7668         | 68.2332               | 202.6728   |
| 0.0103 |               | 100.0000         | 30.1212         | 69.8788               | 203.5305   |
| 0.0111 |               | 150.0000         | 71.6228         | 78.3772               | 211.8304   |
| 0.0118 |               | 200.0000         | 116.2936        | 83.7064               | 212.8128   |

**Table D7** Data for adsorption isotherm in MB at pH 9, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        |               |                  |                 |                       |            |
|--------|---------------|------------------|-----------------|-----------------------|------------|
| HMS    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0116        | 8.0000           | 1.9337          | 6.0663                | 15.6886    |
|        | 0.0114        | 10.0000          | 2.6363          | 7.3637                | 19.3781    |
|        | 0.0119        | 15.0000          | 3.2844          | 11.7156               | 29.5350    |
|        | 0.0115        | 20.0000          | 6.6176          | 13.3824               | 34.9105    |
| 0.0117 | 30.0000       | 16.6141          | 13.3859         | 34.3228               |            |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0111        | 6.0000           | 4.5589          | 1.4411                | 3.8949     |
|        | 0.0113        | 8.0000           | 6.6721          | 1.3279                | 3.5254     |
|        | 0.0104        | 10.0000          | 8.4476          | 1.5524                | 4.4780     |
|        | 0.0106        | 20.0000          | 18.4114         | 1.5886                | 4.4959     |
| 0.0112 | 30.0000       | 28.3239          | 1.6761          | 4.4896                |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0108        | 8.0000           | 0.9044          | 7.0956                | 19.7101    |
|        | 0.0112        | 10.0000          | 1.3673          | 8.6327                | 23.1233    |
|        | 0.0116        | 20.0000          | 4.3193          | 15.6807               | 40.5537    |
|        | 0.0112        | 30.0000          | 8.7472          | 21.2528               | 56.9272    |
| 0.0105 | 50.0000       | 30.8292          | 19.1708         | 54.7736               |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0112        | 8.0000           | 0.2181          | 7.7819                | 20.8443    |
|        | 0.0109        | 10.0000          | 0.4414          | 9.5586                | 26.3080    |
|        | 0.0114        | 20.0000          | 0.9207          | 19.0793               | 50.2087    |
|        | 0.0115        | 30.0000          | 7.9139          | 22.0861               | 57.6160    |
| 0.0119 | 50.0000       | 27.7248          | 22.2752         | 56.1560               |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0101        | 70.0000          | 2.6713          | 67.3287               | 199.9861   |
|        | 0.0113        | 80.0000          | 5.7213          | 74.2787               | 197.2000   |
|        | 0.0105        | 100.0000         | 31.2105         | 68.7895               | 196.5415   |
|        | 0.0111        | 150.0000         | 71.6228         | 78.3772               | 211.8304   |
| 0.0116 | 200.0000      | 119.0168         | 80.9832         | 209.4392              |            |

**Table D8** Data for adsorption isotherm in TX-100 at pH 5, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | HMS           | 0.0102           | 75.0000         | 21.4049               | 53.5951    |
| 0.0108 |               | 100.0000         | 22.3736         | 77.6264               | 179.6907   |
| 0.0109 |               | 200.0000         | 32.0604         | 167.9396              | 385.1825   |
| 0.0100 |               | 400.0000         | 139.5839        | 260.4161              | 651.0403   |
| 0.0124 |               | 600.0000         | 269.8714        | 330.1286              | 665.5819   |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0106        | 75.0000          | 79.2272         | -4.2272               | -9.9698    |
|        | 0.0114        | 100.0000         | 97.5977         | 2.4024                | 5.2683     |
|        | 0.0109        | 200.0000         | 179.2441        | 20.7560               | 47.6054    |
|        | 0.0115        | 400.0000         | 380.8086        | 19.1914               | 41.7204    |
| 0.0112 | 600.0000      | 580.3320         | 19.6680         | 43.9018               |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0107        | 75.0000          | 23.8266         | 51.1734               | 119.5639   |
|        | 0.0099        | 100.0000         | 28.6700         | 71.3300               | 180.1262   |
|        | 0.0115        | 200.0000         | 94.5403         | 105.4597              | 229.2603   |
|        | 0.0112        | 400.0000         | 225.7964        | 174.2036              | 388.8473   |
|        | 0.0099        | 600.0000         | 449.0772        | 150.9228              | 381.1183   |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0102        | 75.0000          | 1.6526          | 73.3474               | 215.7276   |
|        | 0.0108        | 100.0000         | 3.6848          | 96.3152               | 267.5423   |
|        | 0.0107        | 200.0000         | 70.2380         | 129.7620              | 363.8186   |
|        | 0.0130        | 400.0000         | 238.9073        | 161.0927              | 371.7524   |
| 0.0133 | 600.0000      | 436.5349         | 163.4651        | 368.7184              |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0115        | 75.0000          | 8.8072          | 66.1928               | 143.8974   |
|        | 0.0115        | 100.0000         | 10.8484         | 89.1517               | 193.8079   |
|        | 0.0110        | 200.0000         | 83.3095         | 116.6905              | 265.2056   |
|        | 0.0111        | 400.0000         | 251.1949        | 148.8051              | 335.1465   |
| 0.0106 | 600.0000      | 454.8007         | 145.1994        | 342.4513              |            |



**Table D9** Data for adsorption isotherm in TX-100 at pH 7, Ionic Strength 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
| HMS    | 0.0112        | 75.0000          | 14.4767         | 60.5233               | 135.0967   |
|        | 0.0110        | 100.0000         | 15.5096         | 84.4904               | 192.0237   |
|        | 0.0108        | 200.0000         | 25.8388         | 174.1612              | 403.1510   |
|        | 0.0114        | 400.0000         | 166.3159        | 233.6841              | 614.9582   |
|        | 0.0109        | 600.0000         | 331.0666        | 268.9334              | 616.8196   |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0110        | 75.0000          | 67.8176         | 7.1825                | 19.5885    |
|        | 0.0106        | 100.0000         | 93.6065         | 6.3935                | 18.0947    |
|        | 0.0111        | 200.0000         | 189.4743        | 10.5257               | 28.4479    |
|        | 0.0114        | 400.0000         | 379.5278        | 20.4722               | 53.8741    |
| 0.0115 | 600.0000      | 580.2334         | 19.7666         | 51.5651               |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0103        | 75.0000          | 16.2396         | 58.7604               | 171.1468   |
|        | 0.0102        | 100.0000         | 25.7703         | 74.2297               | 218.3226   |
|        | 0.0126        | 200.0000         | 91.3640         | 108.6360              | 258.6571   |
|        | 0.0112        | 400.0000         | 278.6144        | 121.3856              | 325.1399   |
| 0.0137 | 600.0000      | 447.3641         | 152.6359        | 334.2393              |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0107        | 75.0000          | 2.1607          | 72.8393               | 204.2224   |
|        | 0.0106        | 100.0000         | 4.7009          | 95.2991               | 269.7145   |
|        | 0.0104        | 200.0000         | 73.2863         | 126.7137              | 365.5204   |
|        | 0.0113        | 400.0000         | 262.2771        | 137.7229              | 365.6359   |
| 0.0116 | 600.0000      | 460.9208         | 139.0792        | 359.6876              |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0105        | 75.0000          | 5.0270          | 69.9730               | 199.9229   |
|        | 0.0099        | 100.0000         | 21.2853         | 78.7147               | 238.5295   |
|        | 0.0111        | 200.0000         | 75.6664         | 124.3336              | 336.0368   |
|        | 0.0114        | 400.0000         | 269.6444        | 130.3557              | 343.0412   |
| 0.0116 | 600.0000      | 470.3499         | 129.6501        | 335.3020              |            |

**Table D10** Data for adsorption isotherm in TX-100 at pH 9, Ionic Strength 0.1 M, 25°C; 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|--------|---------------|------------------|-----------------|-----------------------|------------|
|        | 0.0106        | 75.0000          | 50.4653         | 24.5347               | 57.8648    |
| 0.0113 | 100.0000      | 61.6052          | 38.3948         | 84.9443               |            |
| 0.0104 | 200.0000      | 68.3859          | 131.6141        | 316.3800              |            |
| 0.0115 | 400.0000      | 120.2103         | 279.7897        | 608.2385              |            |
| 0.0104 | 600.0000      | 347.8501         | 252.1499        | 606.1296              |            |
| A-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0108        | 75.0000          | 83.3095         | -8.3095               | -19.2350   |
| 0.0107 | 100.0000      | 97.0874          | 2.9126          | 6.8052                |            |
| 0.0117 | 200.0000      | 181.7955         | 18.2045         | 38.8985               |            |
| 0.0109 | 400.0000      | 382.3395         | 17.6605         | 40.5058               |            |
| 0.0113 | 600.0000      | 582.3732         | 17.6269         | 38.9975               |            |
| M-HMS  | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0107        | 75.0000          | 30.6074         | 44.3926               | 103.7210   |
| 0.0118 | 100.0000      | 29.1544          | 70.8456         | 150.0967              |            |
| 0.0109 | 200.0000      | 69.8389          | 130.1611        | 298.5345              |            |
| 0.011  | 400.0000      | 265.5123         | 134.4877        | 305.6539              |            |
| 0.0105 | 600.0000      | 472.8098         | 127.1902        | 302.8338              |            |
| OD-HMS | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0116        | 75.0000          | 4.7009          | 70.2991               | 181.8081   |
| 0.0104 | 100.0000      | 8.2571           | 91.7429         | 264.6429              |            |
| 0.0109 | 200.0000      | 79.3827          | 120.6173        | 331.9741              |            |
| 0.0112 | 400.0000      | 259.2289         | 140.7711        | 377.0654              |            |
| 0.0105 | 600.0000      | 467.5253         | 132.4747        | 378.4991              |            |
| PAC    | Adsorbent (g) | Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Int.-Eq. Conc. (mg/L) | ADS (mg/g) |
|        | 0.0101        | 75.0000          | 13.9101         | 61.0899               | 151.2126   |
| 0.0104 | 100.0000      | 16.4615          | 83.5385         | 200.8136              |            |
| 0.0118 | 200.0000      | 81.2684          | 118.7316        | 251.5501              |            |
| 0.0108 | 400.0000      | 275.6889         | 124.3111        | 287.7573              |            |
| 0.0106 | 600.0000      | 475.7225         | 124.2775        | 293.1072              |            |

## APPENDIX E

**Table E1** Data for adsorption isotherm in Bi-solute of fixed Cd(II) and varied TX-100 concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|-------------------|
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 0.0000            |
| 0.0112 | 2.0000        | 1.7447                  | 0.3521          | 572.2742          |                   |
| 0.0108 | 5.0000        | 3.9430                  | 1.5434          | 529.6023          |                   |
| 0.0120 | 10.0000       | 7.9534                  | 2.9969          | 505.5089          |                   |
| 0.0109 | 15.0000       | 12.1770                 | 2.9697          | 504.6944          |                   |
| 0.0111 | 20.0000       | 20.1154                 | 3.0556          | 508.4275          |                   |
| A-HMS  | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0115        | 0.0000                  | 0.0000          | 0.0000            | 53.9018           |
| 0.0122 | 2.0000        | 1.7463                  | 0.3620          | 45.5816           |                   |
| 0.0118 | 5.0000        | 3.8796                  | 0.9420          | 5.0000            |                   |
| 0.0130 | 10.0000       | 7.7575                  | 2.6064          | 4.3000            |                   |
| 0.0119 | 15.0000       | 11.7510                 | 2.7650          | 3.9000            |                   |
| 0.0121 | 20.0000       | 19.0420                 | 2.6885          | 4.1000            |                   |
| M-HMS  | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0118        | 0.0000                  | 0.0000          | 0.0000            | 385.1183          |
| 0.0125 | 2.0000        | 1.7620                  | 2.8636          | 283.4931          |                   |
| 0.0121 | 5.0000        | 4.5691                  | 3.6764          | 263.4548          |                   |
| 0.0133 | 10.0000       | 7.6394                  | 4.2525          | 284.9721          |                   |
| 0.0122 | 15.0000       | 11.9300                 | 4.2588          | 275.9671          |                   |
| 0.0124 | 20.0000       | 19.1620                 | 4.1900          | 291.5452          |                   |
| OD-HMS | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0106        | 0.0000                  | 0.0000          | 0.0000            | 368.7184          |
| 0.0110 | 2.0000        | 1.9074                  | 0.4464          | 344.7688          |                   |
| 0.0104 | 5.0000        | 4.1449                  | 1.0223          | 281.6945          |                   |
| 0.0102 | 10.0000       | 8.2859                  | 2.2519          | 278.0211          |                   |
| 0.0104 | 15.0000       | 11.6360                 | 2.3060          | 275.8997          |                   |
| 0.0111 | 20.0000       | 17.1170                 | 2.3675          | 275.8044          |                   |
| PAC    | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 337.2654          |
| 0.0104 | 2.0000        | 1.5873                  | 0.2338          | 262.9009          |                   |
| 0.0108 | 5.0000        | 3.8055                  | 0.7906          | 233.6863          |                   |
| 0.0120 | 10.0000       | 7.8813                  | 1.4846          | 239.8186          |                   |
| 0.0106 | 15.0000       | 11.9690                 | 1.6601          | 235.3568          |                   |
| 0.0114 | 20.0000       | 19.0980                 | 1.6378          | 231.2412          |                   |

**Table E2** Data for adsorption isotherm in Bi-solute of fixed TX-100 and varied Cd(II) concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cd(II) ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|-------------------|
|        | HMS           | 0.0105                  | 50.0000         | 25.1029           | 103.5494          |
| 0.0112 |               | 75.0000                 | 50.0000         | 161.9935          | 2.5304            |
| 0.0108 |               | 100.0000                | 80.0000         | 254.3446          | 2.5699            |
| 0.0120 |               | 200.0000                | 120.0000        | 507.0000          | 2.6783            |
| 0.0109 |               | 400.0000                | 330.0000        | 512.0000          | 2.9745            |
| 0.0111 |               | 600.0000                | 480.0000        | 508.0000          | 2.9310            |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | A-HMS         | 0.0115                  | 50.0000         | 49.9767           | 0.7543            |
| 0.0122 |               | 75.0000                 | 74.4124         | 1.5800            | 2.3604            |
| 0.0118 |               | 100.0000                | 96.2487         | 3.2000            | 2.8532            |
| 0.0130 |               | 200.0000                | 178.3944        | 4.9000            | 3.1937            |
| 0.0119 |               | 400.0000                | 377.0001        | 5.2000            | 3.1609            |
| 0.0121 |               | 600.0000                | 573.5260        | 5.0000            | 3.1872            |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | M-HMS         | 0.0118                  | 50.0000         | 8.3839            | 113.4986          |
| 0.0125 |               | 75.0000                 | 8.9038          | 187.0648          | 3.5964            |
| 0.0121 |               | 100.0000                | 22.9413         | 201.0226          | 3.7370            |
| 0.0133 |               | 200.0000                | 57.7753         | 280.0000          | 3.8149            |
| 0.0122 |               | 400.0000                | 270.9384        | 280.0000          | 3.8413            |
| 0.0124 |               | 600.0000                | 454.4666        | 280.0000          | 3.9000            |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | OD-HMS        | 0.0106                  | 50.0000         | 2.6649            | 136.5437019       |
| 0.0110 |               | 75.0000                 | 15.2644         | 201.1604          | 2.6214            |
| 0.0104 |               | 100.0000                | 40.7843         | 270.4146          | 2.7646            |
| 0.0102 |               | 200.0000                | 120.6626        | 265.6548          | 2.8387            |
| 0.0104 |               | 400.0000                | 251.8790        | 265.6687          | 2.9596            |
| 0.0111 |               | 600.0000                | 464.5222        | 266.5743          | 2.9287            |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | PAC           | 0.0105                  | 50.0000         | 5.0332            | 37.3754           |
| 0.0104 |               | 75.0000                 | 20.0000         | 60.2478           | 1.5819            |
| 0.0108 |               | 100.0000                | 60.0000         | 180.2495          | 1.6646            |
| 0.0120 |               | 200.0000                | 140.0000        | 235.1967          | 1.7209            |
| 0.0106 |               | 400.0000                | 330.0000        | 232.0000          | 1.8117            |
| 0.0114 |               | 600.0000                | 450.0000        | 233.0000          | 1.8626            |

**Table E3** Data for adsorption isotherm in Bi-solute of fixed Cu(II) and varied TX-100 concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Cu(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|-------------------|
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 0.0000            |
| 0.0112 | 2.0000        | 1.6306                  | 0.6713          | 542.7373          |                   |
| 0.0108 | 5.0000        | 3.9011                  | 1.7936          | 463.3442          |                   |
| 0.0120 | 10.0000       | 5.6904                  | 2.9942          | 422.5316          |                   |
| 0.0109 | 15.0000       | 12.9870                 | 3.2376          | 430.3516          |                   |
| 0.0111 | 20.0000       | 18.8630                 | 3.2565          | 425.2818          |                   |
| A-HMS  | Adsorbent (g) | Cu(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0115        | 0.0000                  | 0.0000          | 0.0000            | 50.9018           |
|        | 0.0122        | 2.0000                  | 1.5967          | 0.5888            | 42.9030           |
|        | 0.0118        | 5.0000                  | 3.8333          | 1.8684            | 2.0000            |
|        | 0.0130        | 10.0000                 | 7.9100          | 2.6062            | 1.8000            |
|        | 0.0119        | 15.0000                 | 11.8700         | 2.7196            | 1.9000            |
|        | 0.0121        | 20.0000                 | 18.1170         | 2.7046            | 2.1000            |
| M-HMS  | Adsorbent (g) | Cu(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0118        | 0.0000                  | 0.0000          | 0.0000            | 391.1183          |
|        | 0.0125        | 2.0000                  | 0.8857          | 7.4866            | 327.3293          |
|        | 0.0121        | 5.0000                  | 3.1374          | 16.5094           | 271.9797          |
|        | 0.0133        | 10.0000                 | 7.4723          | 28.3847           | 274.0402          |
|        | 0.0122        | 15.0000                 | 12.9500         | 28.5735           | 267.2367          |
|        | 0.0124        | 20.0000                 | 18.3490         | 28.6981           | 267.4581          |
| OD-HMS | Adsorbent (g) | Cu(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0106        | 0.0000                  | 0.0000          | 0.0000            | 368.7184          |
|        | 0.0110        | 2.0000                  | 1.9464          | 0.3043            | 318.6821          |
|        | 0.0104        | 5.0000                  | 4.6373          | 1.3966            | 255.6278          |
|        | 0.0102        | 10.0000                 | 9.1802          | 5.0123            | 248.7280          |
|        | 0.0104        | 15.0000                 | 13.7420         | 5.0239            | 239.3498          |
|        | 0.0111        | 20.0000                 | 18.5630         | 5.0703            | 240.0483          |
| PAC    | Adsorbent (g) | Cu(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 347.2654          |
|        | 0.0104        | 2.0000                  | 1.2769          | 1.3148            | 313.5469          |
|        | 0.0108        | 5.0000                  | 3.4462          | 3.3873            | 270.8358          |
|        | 0.0120        | 10.0000                 | 8.0049          | 4.9375            | 263.5210          |
|        | 0.0106        | 15.0000                 | 12.5100         | 5.0365            | 263.1877          |
|        | 0.0114        | 20.0000                 | 18.5320         | 5.0058            | 264.7596          |

Table E4 Data for adsorption isotherm in Bi-solute of fixed Cu(II) and varied TX-100 concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cu(II) ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|-------------------|
|        | 0.0105        | 50.0000                 | 25.1029         | 113.0319          | 1.6250            |
| 0.0112 | 75.0000       | 50.0000                 | 157.7402        | 2.1184            |                   |
| 0.0108 | 100.0000      | 80.0000                 | 235.1648        | 3.0534            |                   |
| 0.0120 | 200.0000      | 120.0000                | 415.6242        | 3.0952            |                   |
| 0.0109 | 400.0000      | 330.0000                | 416.7743        | 3.0561            |                   |
| 0.0111 | 600.0000      | 480.0000                | 417.3659        | 3.1415            |                   |
| A-HMS  | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cu(II) ADS (mg/g) |
|        | 0.0115        | 50.0000                 | 47.4125         | 0.2692            | 1.4422            |
|        | 0.0122        | 75.0000                 | 70.7497         | 0.6480            | 2.8439            |
|        | 0.0118        | 100.0000                | 94.6172         | 1.2919            | 2.9278            |
|        | 0.0130        | 200.0000                | 181.6012        | 1.7588            | 3.0565            |
|        | 0.0119        | 400.0000                | 377.8455        | 1.7489            | 3.0660            |
| 0.0121 | 600.0000      | 582.0456                | 1.8329          | 3.1744            |                   |
| M-HMS  | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cu(II) ADS (mg/g) |
|        | 0.0118        | 50.0000                 | 8.6940          | 114.7388          | 22.2389           |
|        | 0.0125        | 75.0000                 | 24.0754         | 151.2613          | 24.5218           |
|        | 0.0121        | 100.0000                | 33.6224         | 182.6907          | 26.3661           |
|        | 0.0133        | 200.0000                | 84.5398         | 264.8914          | 28.4818           |
|        | 0.0122        | 400.0000                | 237.8225        | 279.8397          | 29.3077           |
| 0.0124 | 600.0000      | 445.2050                | 280.6294        | 28.9464           |                   |
| OD-HMS | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cu(II) ADS (mg/g) |
|        | 0.0106        | 50.0000                 | 2.6649          | 38.8465           | 2.8806            |
|        | 0.0110        | 75.0000                 | 15.2644         | 98.9170           | 3.0750            |
|        | 0.0104        | 100.0000                | 40.7843         | 157.8720          | 3.3659            |
|        | 0.0102        | 200.0000                | 120.6626        | 262.3201          | 4.9131            |
|        | 0.0104        | 400.0000                | 251.8790        | 264.1891          | 5.1147            |
| 0.0111 | 600.0000      | 464.5222                | 263.0157        | 5.0663            |                   |
| PAC    | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | Cu(II) ADS (mg/g) |
|        | 0.0105        | 50.0000                 | 5.0332          | 68.0653           | 3.0840            |
|        | 0.0104        | 75.0000                 | 20.0000         | 172.7209          | 3.4179            |
|        | 0.0108        | 100.0000                | 60.0000         | 206.8887          | 4.8879            |
|        | 0.0120        | 200.0000                | 140.0000        | 257.3182          | 4.7817            |
|        | 0.0106        | 400.0000                | 330.0000        | 263.8079          | 4.8036            |
| 0.0114 | 600.0000      | 450.0000                | 263.4589        | 4.9109            |                   |

**Table E5** Data for adsorption isotherm in Bi-solute of fixed Cd(II) and varied MB concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

| HMS    | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | MB ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|---------------|
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0112 | 2.0000        | 1.8750                  | 0.3217          | 33.1658           |               |
| 0.0108 | 5.0000        | 4.7520                  | 0.3287          | 32.2688           |               |
| 0.0120 | 10.0000       | 9.7240                  | 0.3554          | 31.2311           |               |
| 0.0109 | 15.0000       | 14.7650                 | 0.3505          | 31.3969           |               |
| 0.0111 | 20.0000       | 19.5330                 | 0.3491          | 31.4902           |               |
| A-HMS  | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | MB ADS (mg/g) |
|        | 0.0115        | 0.0000                  | 0.0000          | 0.0000            | 4.8152        |
|        | 0.0122        | 2.0000                  | 1.9720          | 0.0450            | 2.2294        |
|        | 0.0118        | 5.0000                  | 4.8230          | 0.0552            | 2.0223        |
|        | 0.0130        | 10.0000                 | 9.8110          | 0.0550            | 2.0329        |
|        | 0.0119        | 15.0000                 | 14.8720         | 0.0657            | 2.1899        |
|        | 0.0121        | 20.0000                 | 19.6440         | 0.0661            | 2.2692        |
| M-HMS  | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | MB ADS (mg/g) |
|        | 0.0118        | 0.0000                  | 0.0000          | 0.0000            | 48.7338       |
|        | 0.0125        | 2.0000                  | 0.7805          | 1.5432            | 42.7363       |
|        | 0.0121        | 5.0000                  | 3.8430          | 2.5512            | 38.8508       |
|        | 0.0133        | 10.0000                 | 8.5690          | 2.5540            | 37.6930       |
|        | 0.0122        | 15.0000                 | 13.5740         | 2.5357            | 37.5113       |
|        | 0.0124        | 20.0000                 | 18.5510         | 2.5334            | 37.5892       |
| OD-HMS | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | MB ADS (mg/g) |
|        | 0.0106        | 0.0000                  | 0.0000          | 0.0000            | 54.2333       |
|        | 0.0110        | 2.0000                  | 1.9110          | 0.2108            | 51.2439       |
|        | 0.0104        | 5.0000                  | 4.7560          | 0.2301            | 50.6277       |
|        | 0.0102        | 10.0000                 | 9.7510          | 0.2653            | 50.0711       |
|        | 0.0104        | 15.0000                 | 14.7990         | 0.2654            | 50.0917       |
|        | 0.0111        | 20.0000                 | 19.5570         | 0.2651            | 50.1328       |
| PAC    | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cd(II) ADS (mg/g) | MB ADS (mg/g) |
|        | 0.0105        | 0.0000                  | 0.0000          | 0.0000            | 200.8686      |
|        | 0.0104        | 2.0000                  | 1.7320          | 0.3073            | 157.8063      |
|        | 0.0108        | 5.0000                  | 4.5810          | 0.5168            | 146.6793      |
|        | 0.0120        | 10.0000                 | 9.5720          | 0.5150            | 144.5392      |
|        | 0.0106        | 15.0000                 | 14.5980         | 0.5132            | 145.2575      |
|        | 0.0114        | 20.0000                 | 19.4020         | 0.5125            | 146.2581      |

**Table E6** Data for adsorption isotherm in Bi-solute of fixed MB and varied Cd(II) concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | Cd(II) ADS (mg/g) |
|--------|---------------|---------------------|-----------------|---------------|-------------------|
|        | HMS           | 0.0105              | 0.0000          | 0.0000        | 0.0000            |
| 0.0112 |               | 5.0000              | 1.4316          | 15.5582       | 0.3766            |
| 0.0108 |               | 10.0000             | 3.3097          | 19.0710       | 0.3881            |
| 0.0120 |               | 15.0000             | 7.4322          | 32.0186       | 0.3532            |
| 0.0109 |               | 20.0000             | 12.2520         | 32.9282       | 0.3515            |
| 0.0111 |               | 30.0000             | 22.7260         | 32.6058       | 0.3517            |
|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | A-HMS         | 0.0115              | 0.0000          | 0.0000        | 0.0000            |
| 0.0122 |               | 5.0000              | 4.8988          | 0.5469        | 0.1469            |
| 0.0118 |               | 10.0000             | 8.2990          | 1.0124        | 0.0589            |
| 0.0130 |               | 15.0000             | 13.2284         | 2.1904        | 0.0525            |
| 0.0119 |               | 20.0000             | 18.0268         | 2.2654        | 0.0516            |
| 0.0121 |               | 30.0000             | 28.0880         | 2.2658        | 0.0517            |
|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | M-HMS         | 0.0118              | 0.0000          | 0.0000        | 0.0000            |
| 0.0125 |               | 5.0000              | 2.0000          | 13.4283       | 2.8314            |
| 0.0121 |               | 10.0000             | 5.0000          | 28.4988       | 2.6212            |
| 0.0133 |               | 15.0000             | 8.0207          | 39.2177       | 2.2892            |
| 0.0122 |               | 20.0000             | 13.0000         | 40.8882       | 2.3036            |
| 0.0124 |               | 30.0000             | 25.0000         | 40.2915       | 2.3074            |
|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | OD-HMS        | 0.0106              | 0.0000          | 0.0000        | 0.0000            |
| 0.0110 |               | 5.0000              | 2.0000          | 13.2979       | 0.4077            |
| 0.0104 |               | 10.0000             | 5.0000          | 36.4271       | 0.3185            |
| 0.0102 |               | 15.0000             | 8.0000          | 50.2950       | 0.3072            |
| 0.0104 |               | 20.0000             | 11.0000         | 50.3325       | 0.2897            |
| 0.0111 |               | 30.0000             | 26.0000         | 50.8969       | 0.2891            |
|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | Cd(II) ADS (mg/g) |
|        | PAC           | 0.0105              | 0.0000          | 0.0000        | 0.0000            |
| 0.0104 |               | 80.0000             | 15.0000         | 147.3309      | 0.6284            |
| 0.0108 |               | 100.0000            | 41.5925         | 160.3300      | 0.5213            |
| 0.0120 |               | 120.0000            | 56.8746         | 160.4884      | 0.5207            |
| 0.0106 |               | 150.0000            | 94.5396         | 158.4582      | 0.5209            |
| 0.0114 |               | 200.0000            | 140.7181        | 161.6780      | 0.5196            |



**Table E7** Data for adsorption isotherm in Bi-solute of fixed Cu(II) and varied MB concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | MB ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|---------------|
|        | HMS           | 0.0105                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0112 |               | 2.0000                  | 1.0051          | 0.6890            | 23.0156       |
| 0.0108 |               | 5.0000                  | 4.7512          | 1.0564            | 24.3650       |
| 0.0120 |               | 10.0000                 | 9.5531          | 1.0742            | 20.8729       |
| 0.0109 |               | 15.0000                 | 15.2023         | 1.0877            | 22.8106       |
| 0.0111 |               | 20.0000                 | 20.2348         | 1.0693            | 22.1262       |
|        | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | MB ADS (mg/g) |
|        | A-HMS         | 0.0115                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0122 |               | 2.0000                  | 1.4415          | 0.0045            | 3.2700        |
| 0.0118 |               | 5.0000                  | 5.1568          | 0.0056            | 3.1083        |
| 0.0130 |               | 10.0000                 | 9.9901          | 0.0066            | 3.3502        |
| 0.0119 |               | 15.0000                 | 15.6931         | 0.0063            | 3.6059        |
| 0.0121 |               | 20.0000                 | 20.7757         | 0.0060            | 3.5294        |
|        | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | MB ADS (mg/g) |
|        | M-HMS         | 0.0118                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0125 |               | 2.0000                  | 0.5943          | 3.8951            | 50.5636       |
| 0.0121 |               | 5.0000                  | 2.4088          | 11.4489           | 43.6589       |
| 0.0133 |               | 10.0000                 | 5.6500          | 12.6920           | 50.7879       |
| 0.0122 |               | 15.0000                 | 10.8100         | 12.5718           | 49.3475       |
| 0.0124 |               | 20.0000                 | 18.3890         | 12.7512           | 48.5063       |
|        | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | MB ADS (mg/g) |
|        | OD-HMS        | 0.0106                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0110 |               | 2.0000                  | 0.7532          | 0.1126            | 42.8518       |
| 0.0104 |               | 5.0000                  | 4.4180          | 1.0928            | 44.3246       |
| 0.0102 |               | 10.0000                 | 9.1532          | 1.9102            | 42.6625       |
| 0.0104 |               | 15.0000                 | 14.9010         | 1.9113            | 42.2161       |
| 0.0111 |               | 20.0000                 | 20.1130         | 1.9112            | 42.4233       |
|        | Adsorbent (g) | Cd(II) Int.Conc. (mg/L) | Eq.Conc. (mg/L) | Cu(II) ADS (mg/g) | MB ADS (mg/g) |
|        | PAC           | 0.0105                  | 0.0000          | 0.0000            | 0.0000        |
| 0.0104 |               | 2.0000                  | 0.5478          | 0.5508            | 185.2098      |
| 0.0108 |               | 5.0000                  | 4.2135          | 1.8379            | 167.8425      |
| 0.0120 |               | 10.0000                 | 9.1547          | 2.1303            | 156.3771      |
| 0.0106 |               | 15.0000                 | 14.7875         | 2.1408            | 156.3430      |
| 0.0114 |               | 20.0000                 | 19.8547         | 2.1415            | 155.8061      |

**Table E8** Data for adsorption isotherm in Bi-solute of fixed MB and varied Cu(II) concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L)     | MB ADS (mg/g)   | Cu(II) ADS (mg/g) |
|--------|---------------|---------------------|---------------------|-----------------|-------------------|
|        | HMS           | 0.0105              | 0.0000              | 0.0000          | 0.0000            |
| 0.0112 |               | 5.0000              | 1.4729              | 10.3739         | 1.1088            |
| 0.0108 |               | 10.0000             | 3.3613              | 19.9162         | 1.0920            |
| 0.0120 |               | 15.0000             | 7.5148              | 20.7923         | 1.1333            |
| 0.0109 |               | 20.0000             | 10.8590             | 24.7055         | 1.1784            |
| 0.0111 |               | 30.0000             | 21.1782             | 24.9675         | 1.1491            |
| A-HMS  |               | Adsorbent (g)       | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g)     |
|        | 0.0115        | 0.0000              | 0.0000              | 0.0140          | 0.3711            |
|        | 0.0122        | 5.0000              | 1.2467              | 0.0075          | 0.0140            |
|        | 0.0118        | 10.0000             | 3.6275              | 0.0074          | 0.0075            |
|        | 0.0130        | 15.0000             | 3.7543              | 0.0075          | 0.0074            |
|        | 0.0119        | 20.0000             | 3.7437              | 0.0076          | 0.0075            |
|        | 0.0121        | 30.0000             | 3.7622              | 0.0076          | 0.0076            |
| M-HMS  | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L)     | MB ADS (mg/g)   | Cu(II) ADS (mg/g) |
|        | 0.0118        | 0.0000              | 0.0000              | 0.0000          | 20.1722           |
|        | 0.0125        | 5.0000              | 0.0901              | 13.2700         | 18.0135           |
|        | 0.0121        | 10.0000             | 0.9105              | 28.9986         | 12.9267           |
|        | 0.0133        | 15.0000             | 4.0000              | 35.5978         | 11.5205           |
|        | 0.0122        | 20.0000             | 12.0000             | 40.6496         | 12.0579           |
|        | 0.0124        | 30.0000             | 25.0000             | 39.4949         | 11.8216           |
| OD-HMS | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L)     | MB ADS (mg/g)   | Cu(II) ADS (mg/g) |
|        | 0.0106        | 0.0000              | 0.0000              | 0.0000          | 3.2886            |
|        | 0.0110        | 5.0000              | 0.2302              | 11.5744         | 3.0140            |
|        | 0.0104        | 10.0000             | 2.4874              | 37.1789         | 2.1371            |
|        | 0.0102        | 15.0000             | 8.0000              | 43.7801         | 2.0748            |
|        | 0.0104        | 20.0000             | 14.0000             | 46.9362         | 2.1211            |
|        | 0.0111        | 30.0000             | 26.5000             | 46.7579         | 2.1291            |
| PAC    | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L)     | MB ADS (mg/g)   | Cu(II) ADS (mg/g) |
|        | 0.0105        | 0.0000              | 0.0000              | 0.0000          | 3.3751            |
|        | 0.0104        | 80.0000             | 10.0000             | 150.1040        | 2.9394            |
|        | 0.0108        | 100.0000            | 46.0394             | 151.2914        | 2.7841            |
|        | 0.0120        | 120.0000            | 65.6459             | 156.7907        | 2.7577            |
|        | 0.0106        | 150.0000            | 94.5396             | 161.5350        | 2.5223            |
|        | 0.0114        | 200.0000            | 136.0744            | 161.1569        | 2.5992            |

**Table E9**Data for adsorption isotherm in Bi-solute of fixed TX-100 and varied MB concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

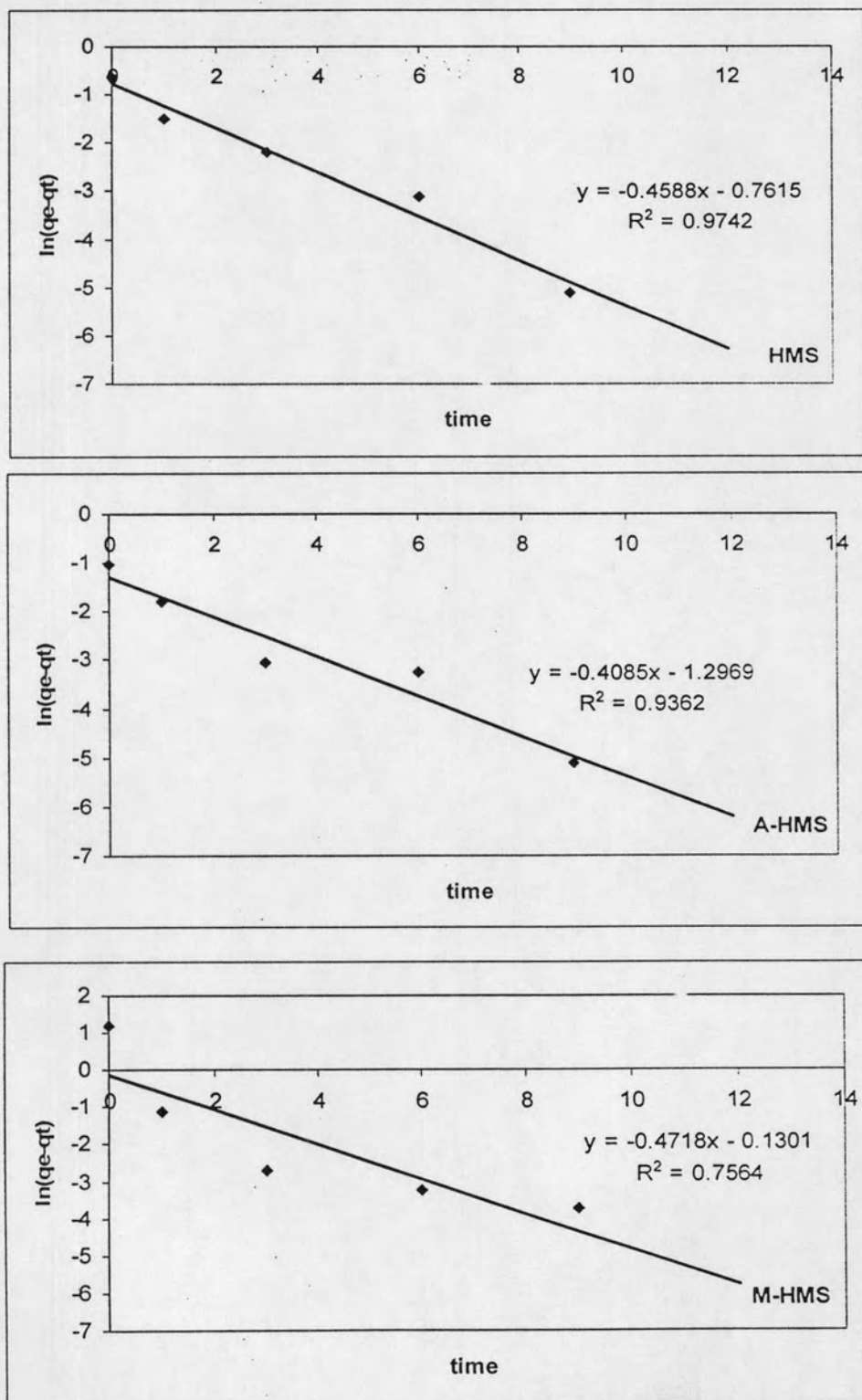
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | MB ADS (mg/g) |
|--------|---------------|-------------------------|-----------------|-------------------|---------------|
|        | HMS           | 0.0105                  | 0.0000          | 0.0000            | 625.5819      |
| 0.0112 |               | 50.0000                 | 20.4393         | 658.8400          | 5.9684        |
| 0.0108 |               | 100.0000                | 21.4881         | 668.6089          | 28.3743       |
| 0.0120 |               | 200.0000                | 40.1459         | 649.1097          | 26.7255       |
| 0.0109 |               | 400.0000                | 142.2587        | 667.3671          | 30.1849       |
| 0.0111 |               | 600.0000                | 424.0000        | 676.6972          | 30.1079       |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | MB ADS (mg/g) |
|        | A-HMS         | 0.0115                  | 0.0000          | 0.0000            | 43.9018       |
| 0.0122 |               | 50.0000                 | 52.5223         | 47.9988           | 0.0200        |
| 0.0118 |               | 100.0000                | 105.9763        | 49.6541           | 0.0500        |
| 0.0130 |               | 200.0000                | 172.9000        | 69.0596           | 0.3000        |
| 0.0119 |               | 400.0000                | 372.8320        | 74.6225           | 0.3200        |
| 0.0121 |               | 600.0000                | 569.2948        | 76.6827           | 0.3110        |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | MB ADS (mg/g) |
|        | M-HMS         | 0.0118                  | 0.0000          | 0.0000            | 381.1183      |
| 0.0125 |               | 50.0000                 | 14.2646         | 444.1074          | 13.9684       |
| 0.0121 |               | 100.0000                | 36.6327         | 521.0135          | 12.9348       |
| 0.0133 |               | 200.0000                | 86.7970         | 510.1696          | 12.6359       |
| 0.0122 |               | 400.0000                | 208.9670        | 494.1809          | 11.8520       |
| 0.0124 |               | 600.0000                | 421.0952        | 520.3978          | 11.1956       |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | MB ADS (mg/g) |
|        | OD-HMS        | 0.0106                  | 0.0000          | 0.0000            | 368.7184      |
| 0.0110 |               | 50.0000                 | 2.4624          | 425.8759          | 7.0234        |
| 0.0104 |               | 100.0000                | 27.1760         | 437.9105          | 21.9545       |
| 0.0102 |               | 200.0000                | 68.3127         | 457.4144          | 23.2157       |
| 0.0104 |               | 400.0000                | 221.6190        | 457.5667          | 22.5000       |
| 0.0111 |               | 600.0000                | 513.9397        | 457.6978          | 22.6817       |
|        | Adsorbent (g) | TX-100 Int.Conc. (mg/L) | Eq.Conc. (mg/L) | TX-100 ADS (mg/g) | MB ADS (mg/g) |
|        | PAC           | 0.0105                  | 0.0000          | 0.0000            | 282.4513      |
| 0.0104 |               | 50.0000                 | 7.4416          | 317.1196          | 30.8406       |
| 0.0108 |               | 100.0000                | 46.2881         | 315.4547          | 28.7054       |
| 0.0120 |               | 200.0000                | 156.2212        | 351.3228          | 31.2598       |
| 0.0106 |               | 400.0000                | 352.5967        | 365.7011          | 36.1446       |
| 0.0114 |               | 600.0000                | 532.9639        | 365.7181          | 34.9913       |

**Table E10** Data for adsorption isotherm in Bi-solute of fixed MB and varied TX-100 concentration at pH 5, IS 0.1 M, 25°C, 30 ml of solution on all adsorbents.

|        |               |                     |                 |               |                   |
|--------|---------------|---------------------|-----------------|---------------|-------------------|
| HMS    | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0105        | 0.0000              | 0.0500          | 56.2474       | 0.0000            |
|        | 0.0112        | 5.0000              | 1.1185          | 45.8343       | 84.1138           |
|        | 0.0108        | 10.0000             | 3.2000          | 38.6153       | 204.1572          |
|        | 0.0120        | 15.0000             | 11.8576         | 39.4757       | 427.4825          |
|        | 0.0109        | 20.0000             | 16.5533         | 34.1608       | 696.9511          |
|        | 0.0111        | 30.0000             | 26.6783         | 32.0509       | 698.3236          |
| A-HMS  | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0115        | 0.0000              | 0.0000          | 6.8152        | 0.0000            |
|        | 0.0122        | 5.0000              | 0.2653          | 6.1024        | 5.0000            |
|        | 0.0118        | 10.0000             | 1.5859          | 3.2657        | 20.3000           |
|        | 0.0130        | 15.0000             | 6.8685          | 0.2001        | 64.2369           |
|        | 0.0119        | 20.0000             | 13.3902         | 0.5000        | 81.5937           |
|        | 0.0121        | 30.0000             | 20.2870         | 0.4000        | 80.7421           |
| M-HMS  | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0118        | 0.0000              | 0.0000          | 58.7338       | 0.0000            |
|        | 0.0125        | 5.0000              | 0.5118          | 55.3940       | 93.2421           |
|        | 0.0121        | 10.0000             | 1.2653          | 38.1259       | 169.0600          |
|        | 0.0133        | 15.0000             | 5.5370          | 33.0163       | 429.9056          |
|        | 0.0122        | 20.0000             | 13.9120         | 13.5451       | 488.0889          |
|        | 0.0124        | 30.0000             | 27.4120         | 11.9311       | 491.5372          |
| OD-HMS | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0106        | 0.0000              | 0.0000          | 44.2333       | 0.0000            |
|        | 0.0110        | 5.0000              | 2.0496          | 40.1331       | 122.7477          |
|        | 0.0104        | 10.0000             | 5.3023          | 42.4951       | 247.9619          |
|        | 0.0102        | 15.0000             | 12.9301         | 40.5244       | 383.2257          |
|        | 0.0104        | 20.0000             | 19.0958         | 20.7140       | 430.0070          |
|        | 0.0111        | 30.0000             | 27.8054         | 23.4508       | 431.5994          |
| PAC    | Adsorbent (g) | MB Int.Conc. (mg/L) | Eq.Conc. (mg/L) | MB ADS (mg/g) | TX-100 ADS (mg/g) |
|        | 0.0105        | 0.0000              | 0.0000          | 170.8686      | 0.0000            |
|        | 0.0104        | 80.0000             | 28.6758         | 100.4836      | 123.7006          |
|        | 0.0108        | 100.0000            | 52.3714         | 88.0820       | 185.9159          |
|        | 0.0120        | 120.0000            | 104.8714        | 17.0871       | 362.3577          |
|        | 0.0106        | 150.0000            | 137.3985        | 21.2909       | 382.9606          |
|        | 0.0114        | 200.0000            | 173.3496        | 16.0621       | 382.7625          |

## APPENDIX F

Figure F1 The pseudo first order for Cd(II) adsorption kinetic.



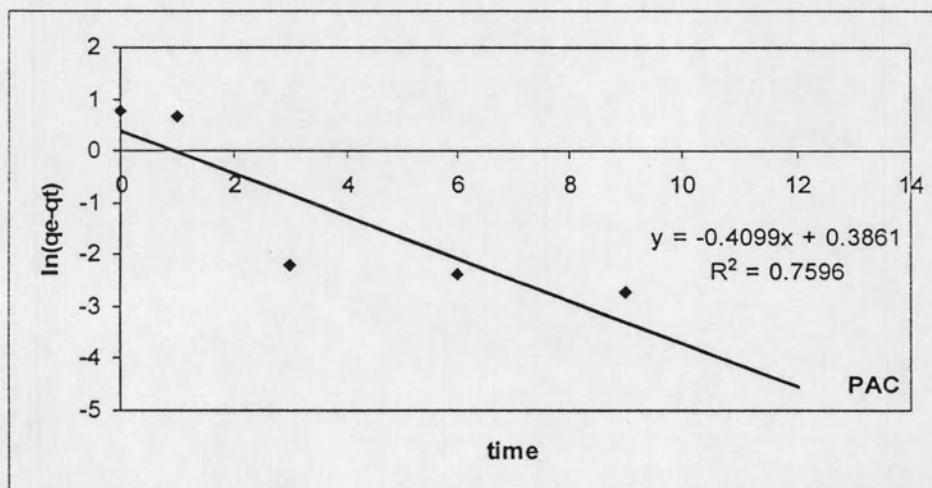
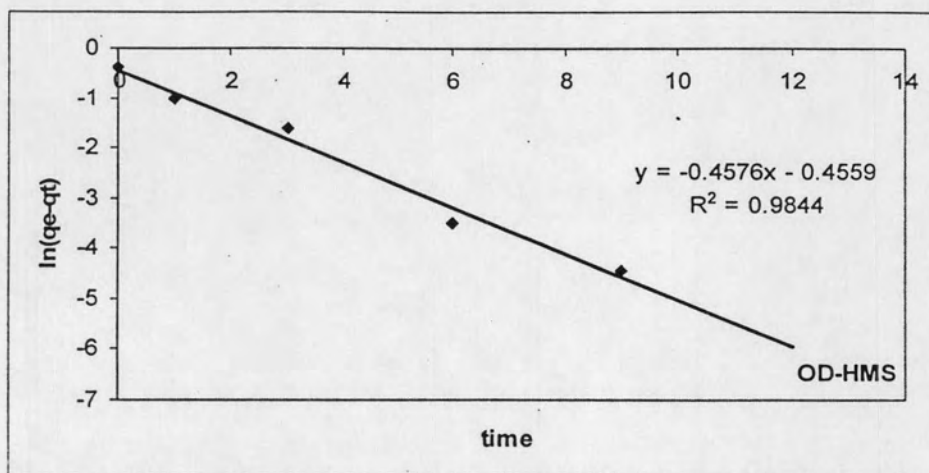
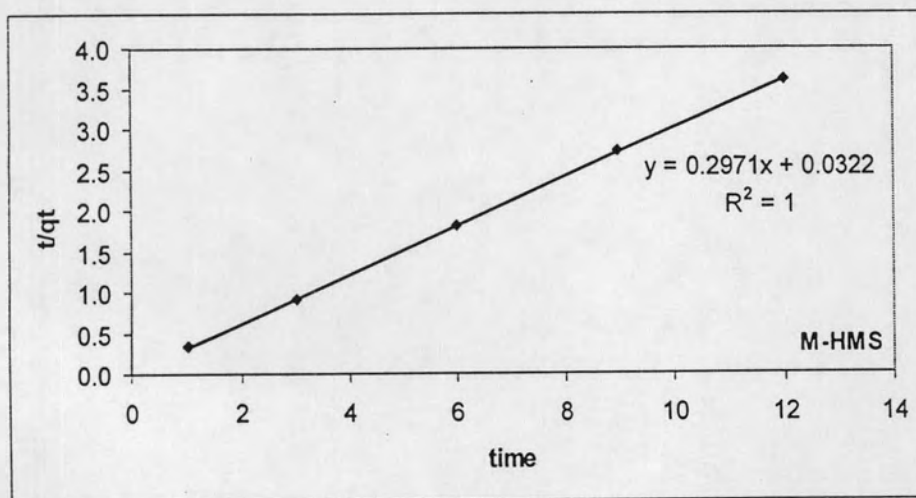
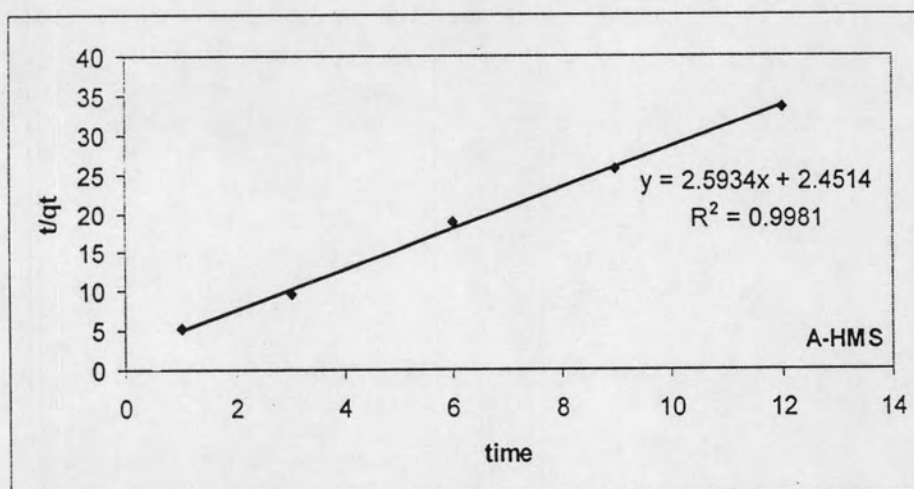
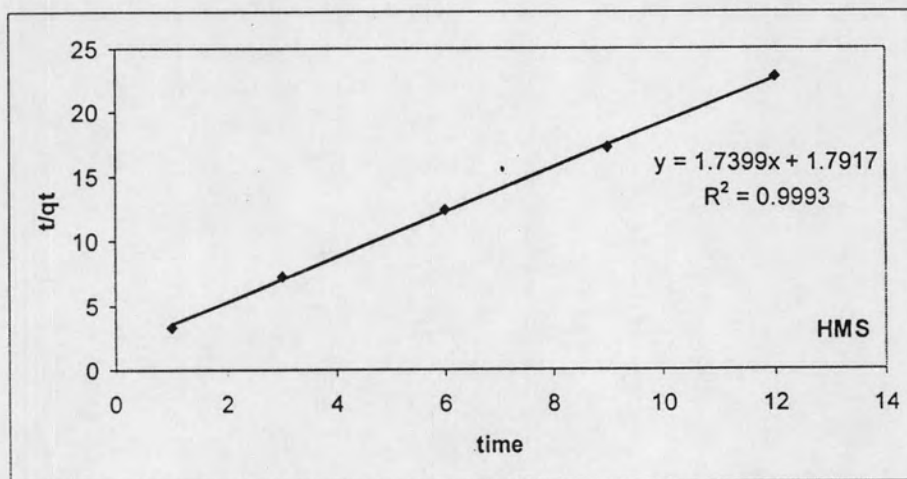


Figure F2 The pseudo second order for Cd(II) adsorption kinetic.



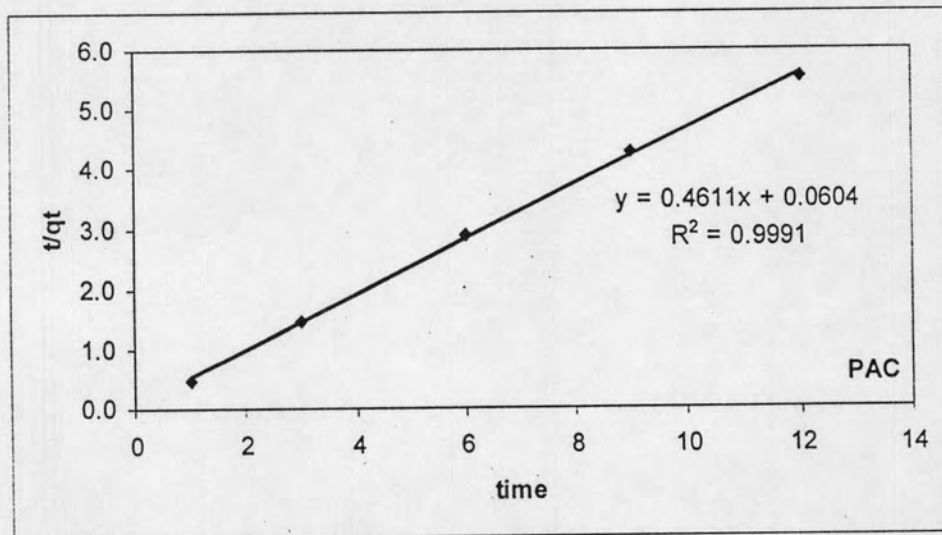
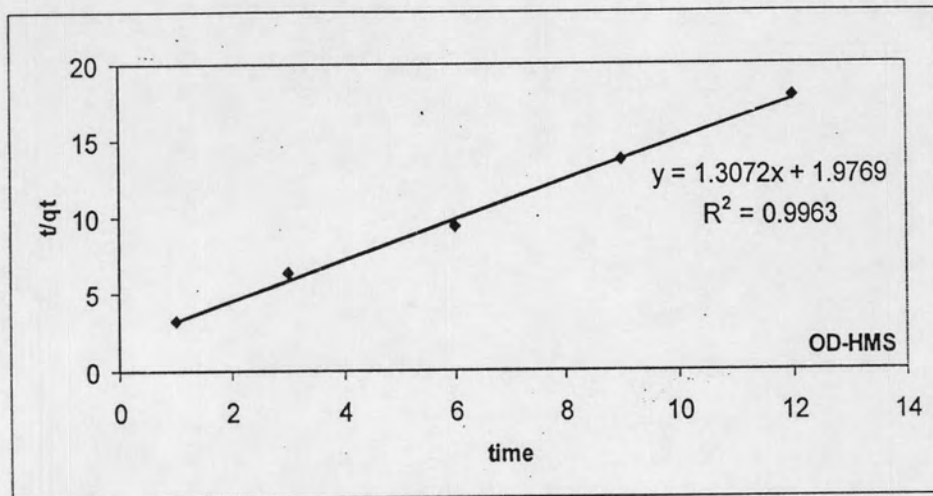
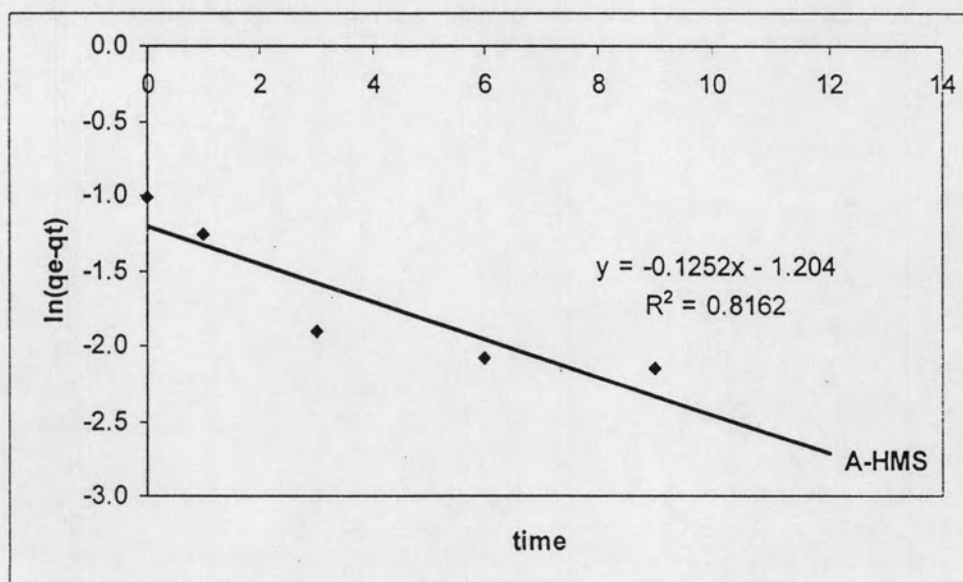
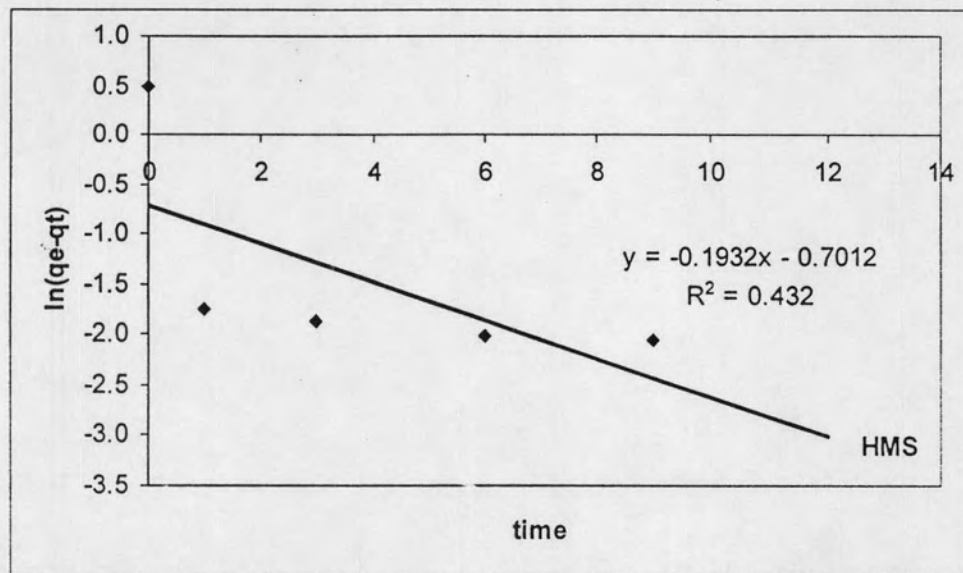




Figure F3 The pseudo first order for Cu(II) adsorption kinetic.



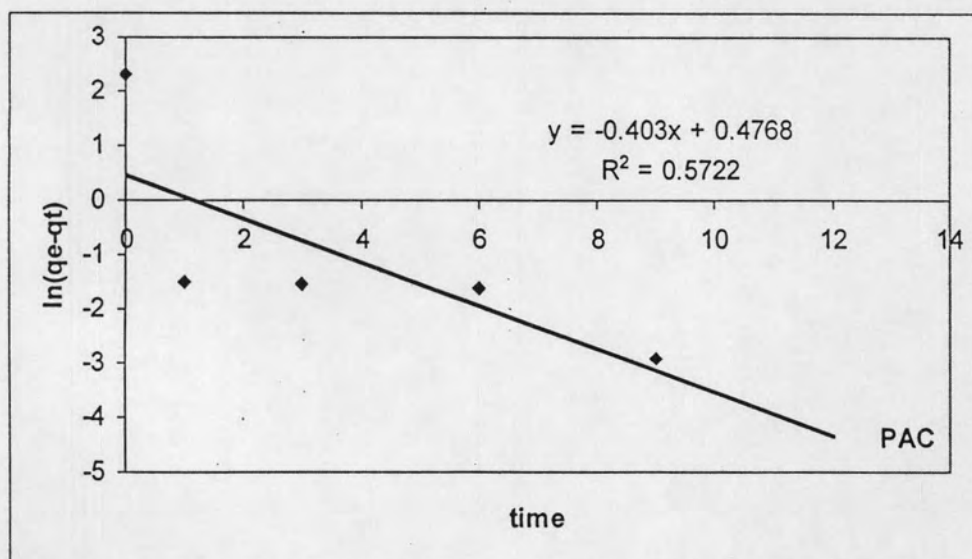
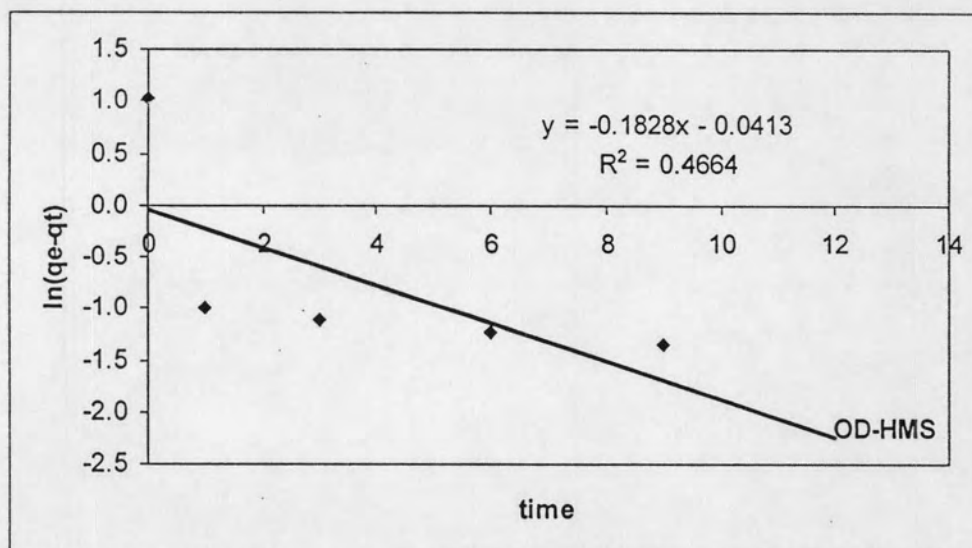
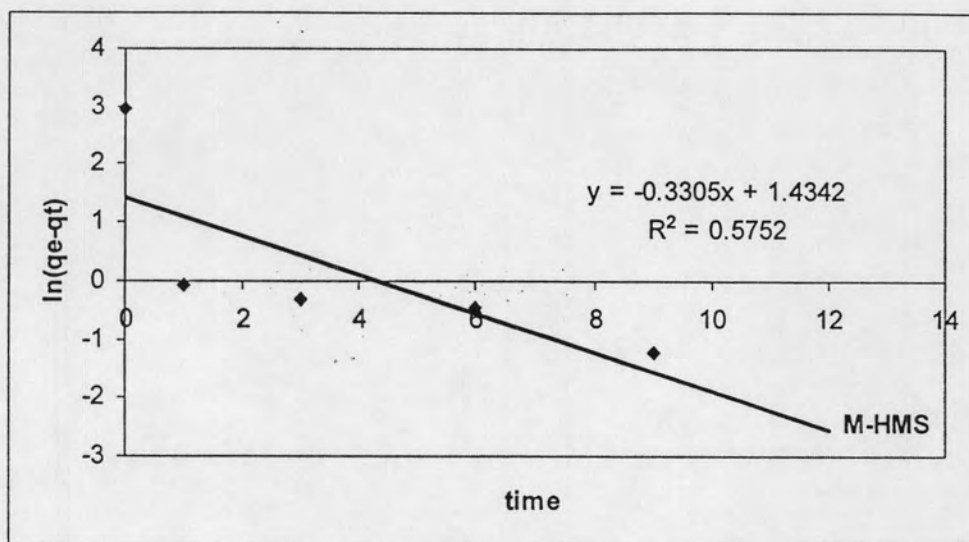
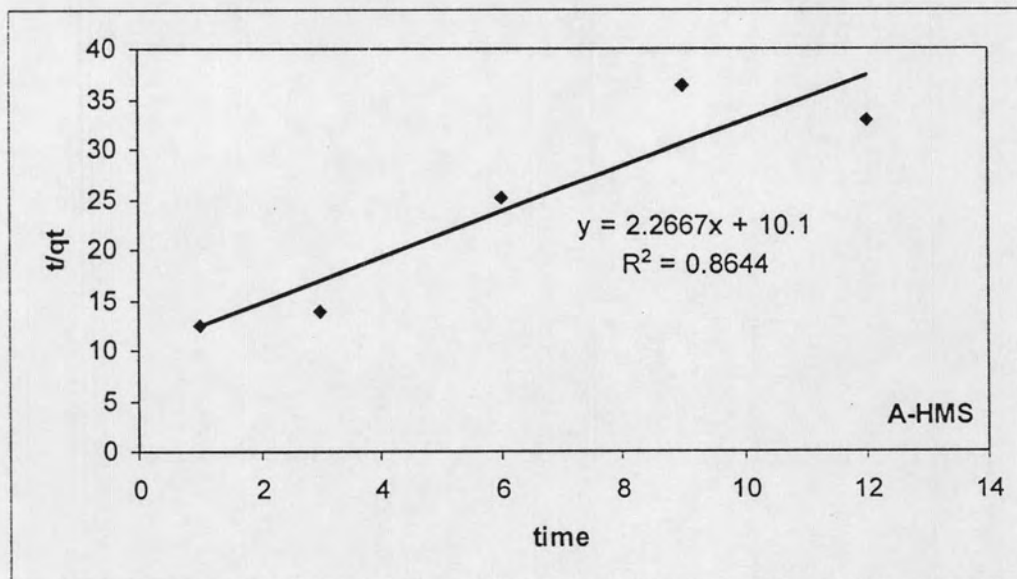
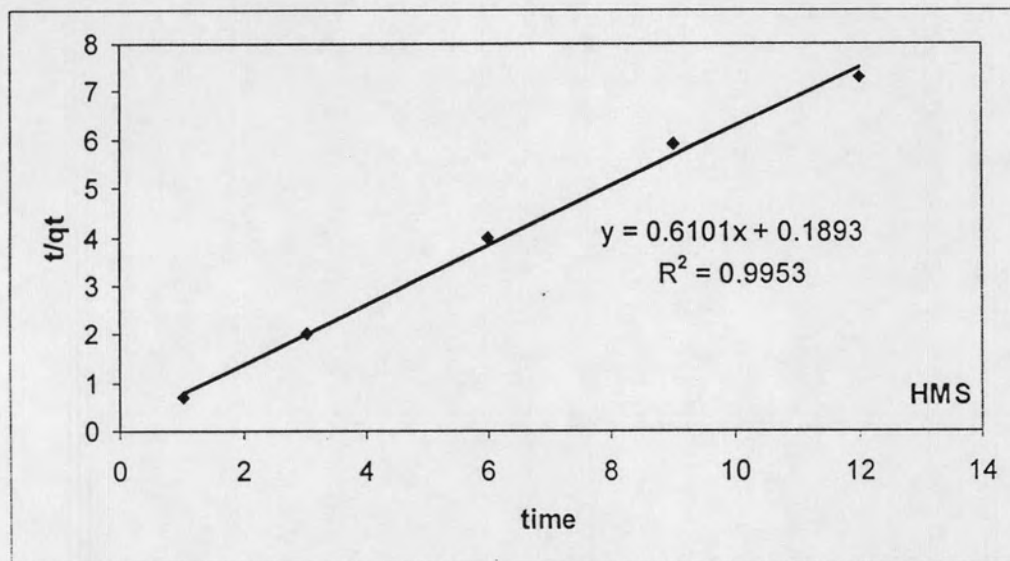


Figure F4 The pseudo second order for Cu(II) adsorption kinetic.



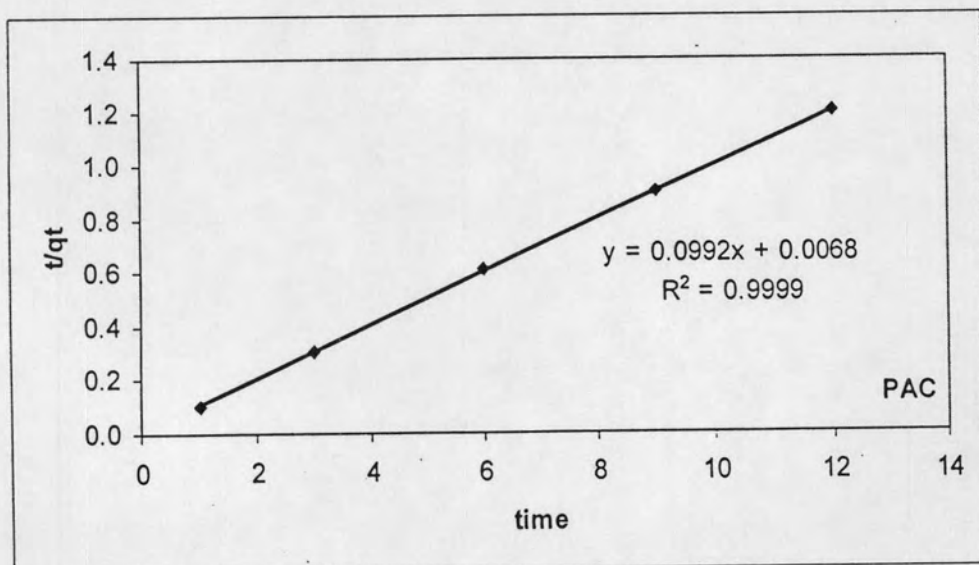
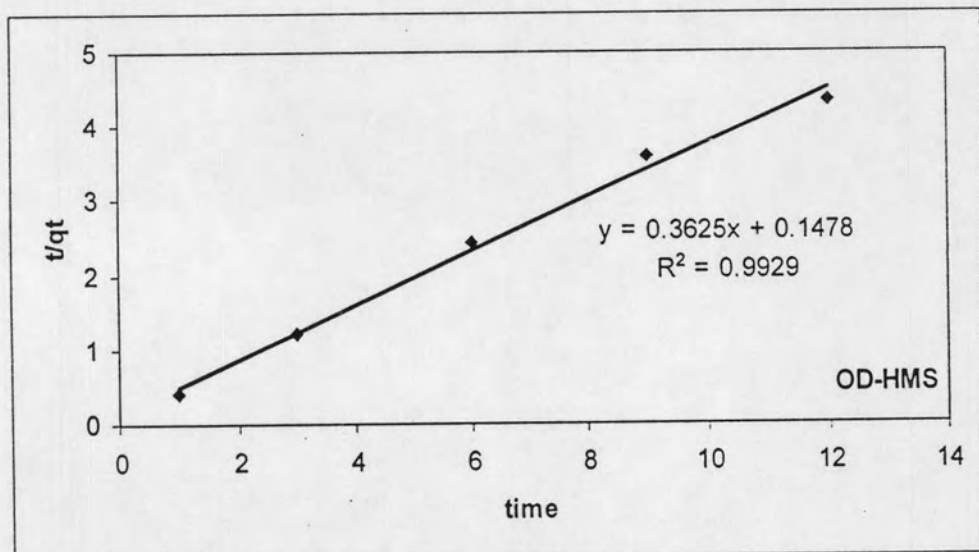
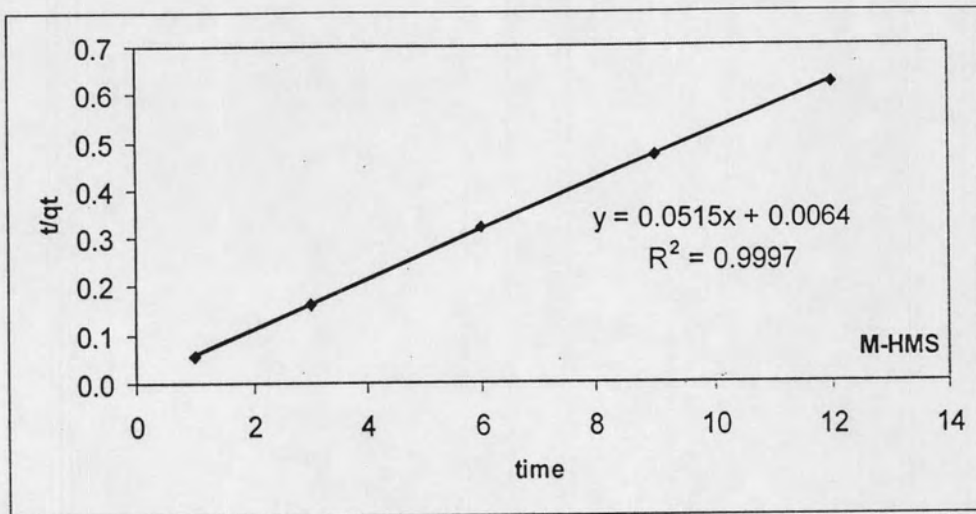
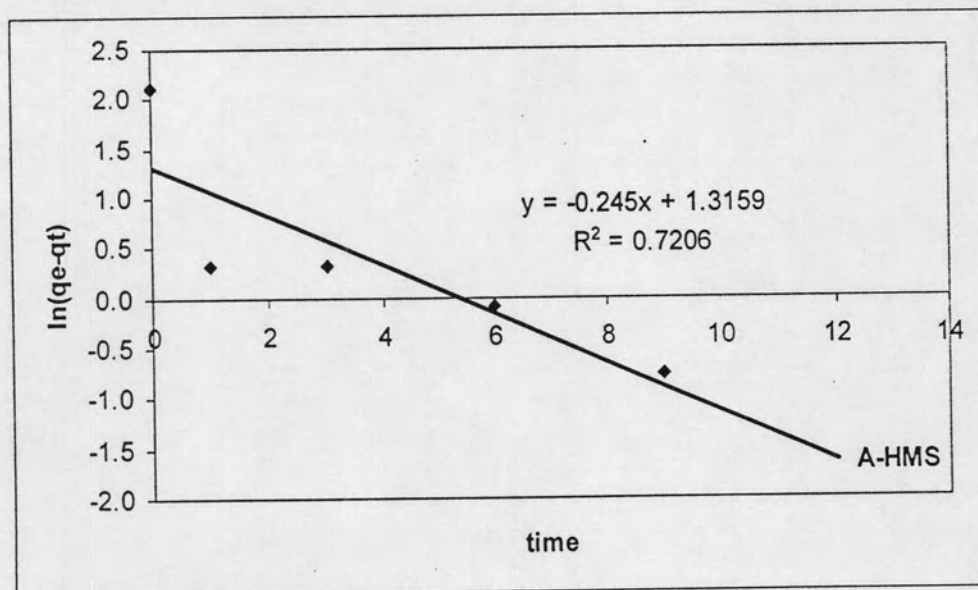
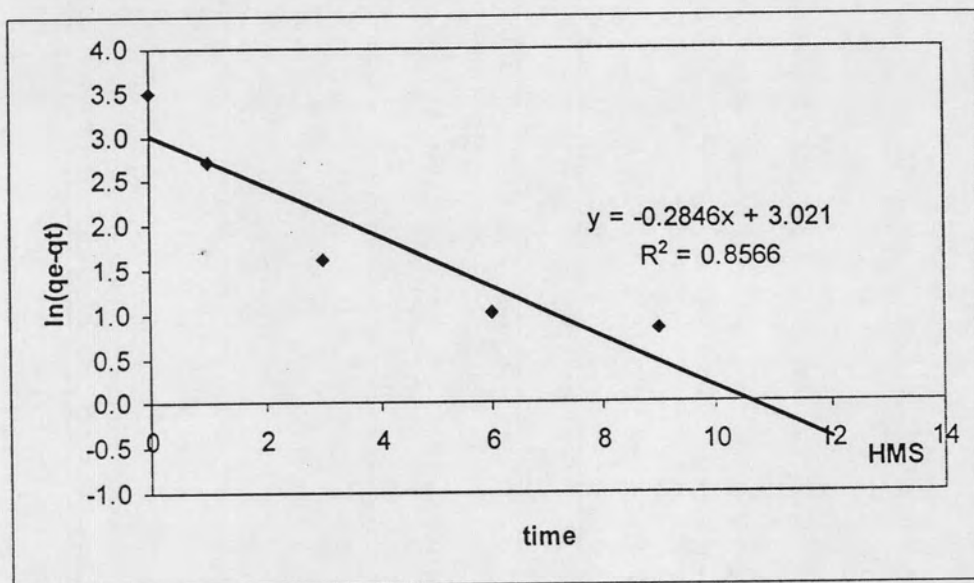


Figure F5 The pseudo first order for methylene blue adsorption kinetic.



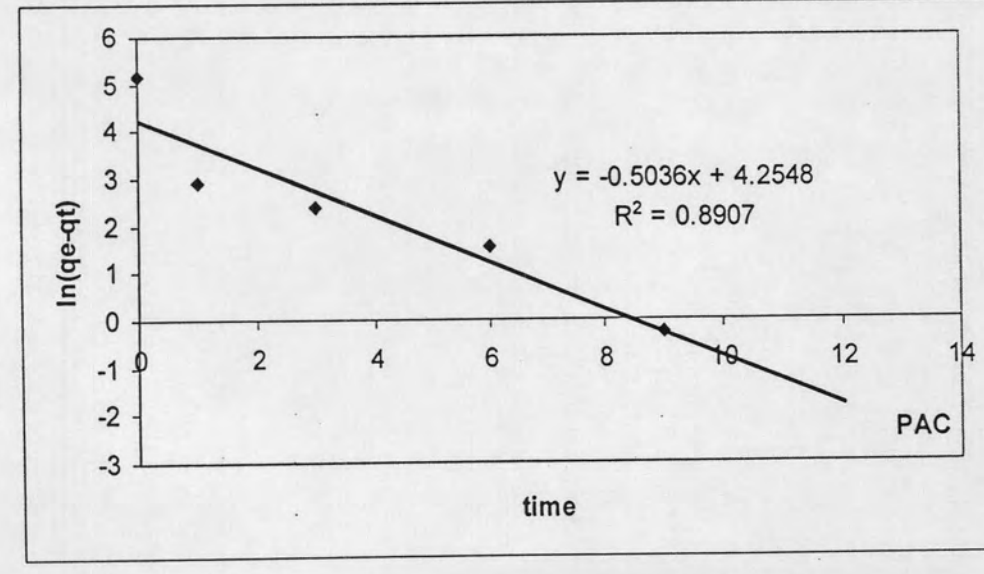
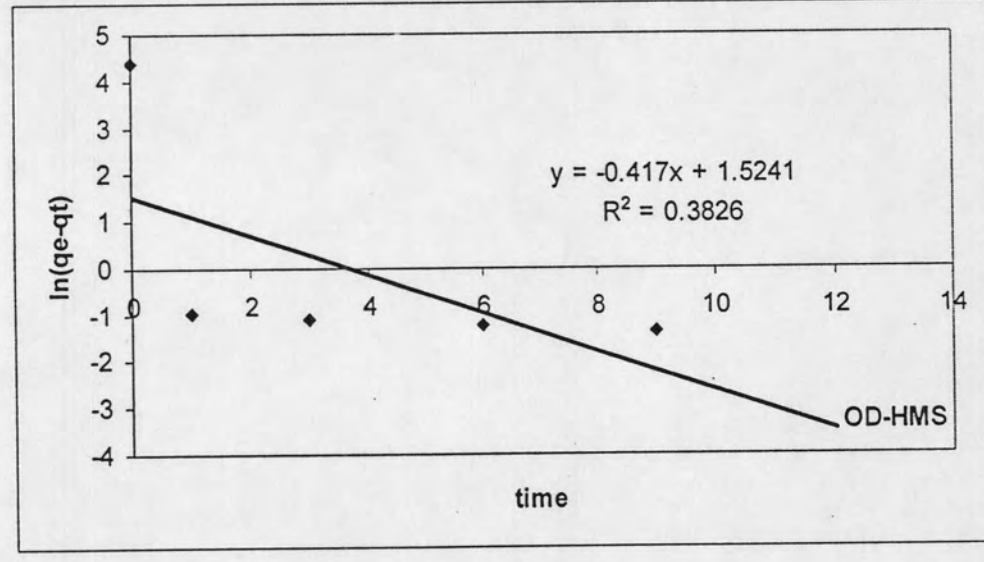
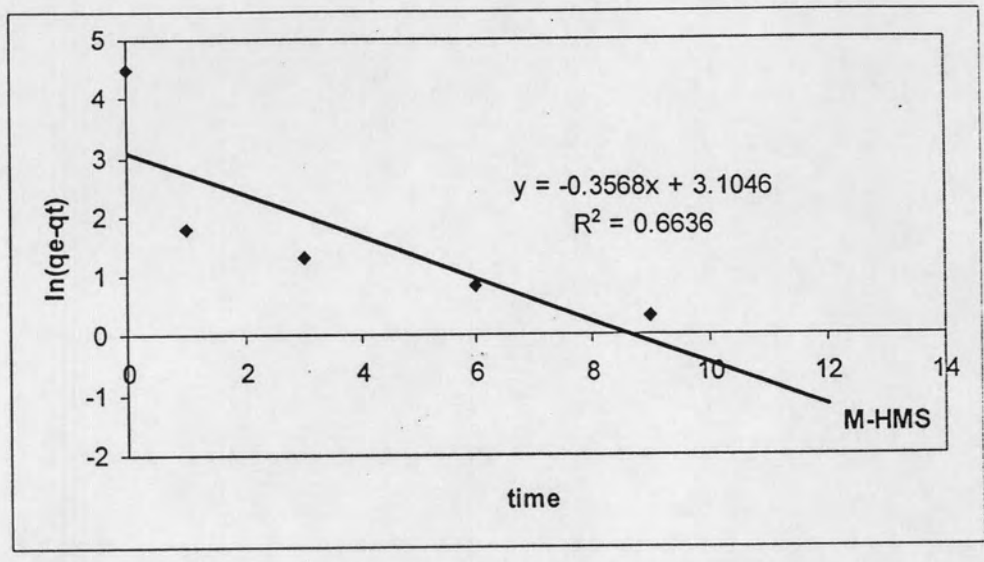
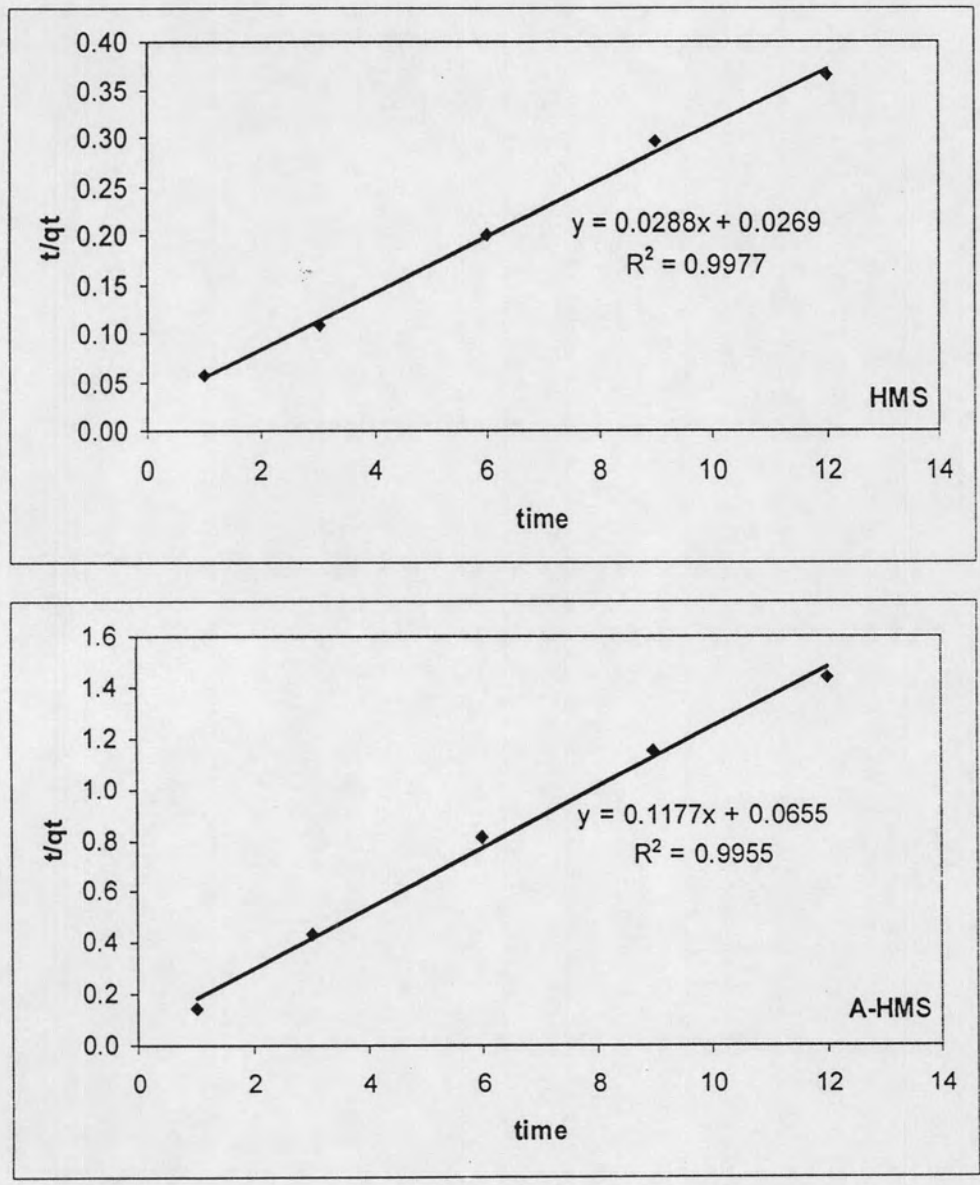


Figure F6 The pseudo second order for methylene blue adsorption kinetic.



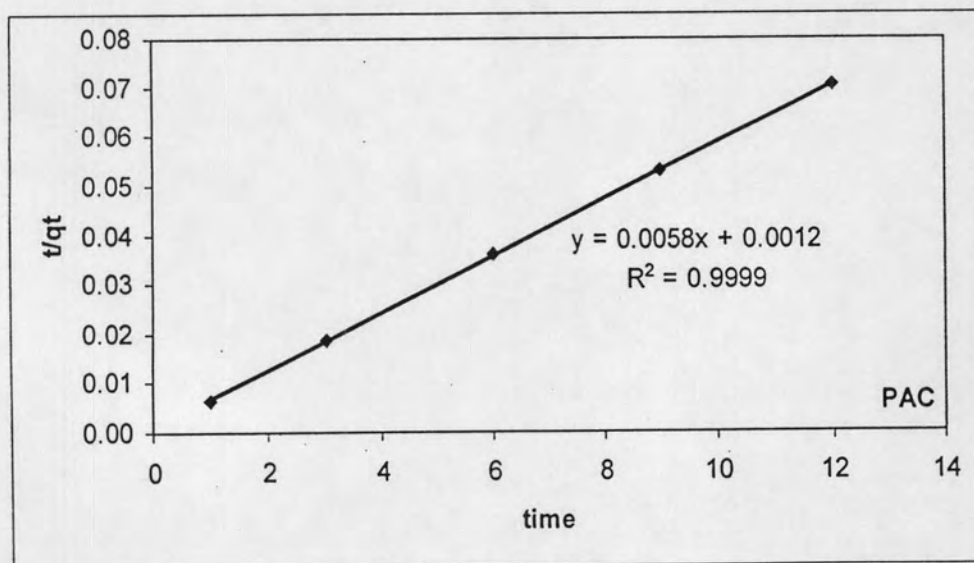
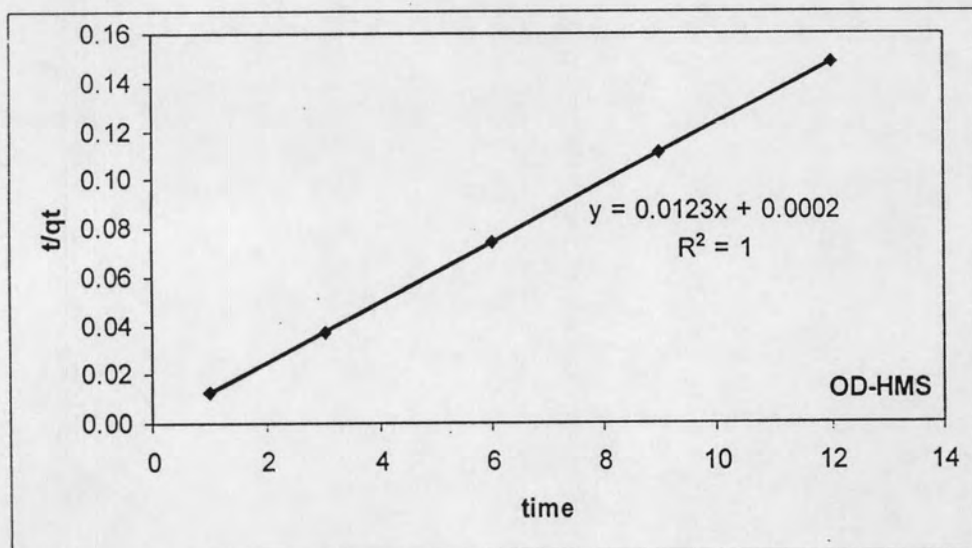
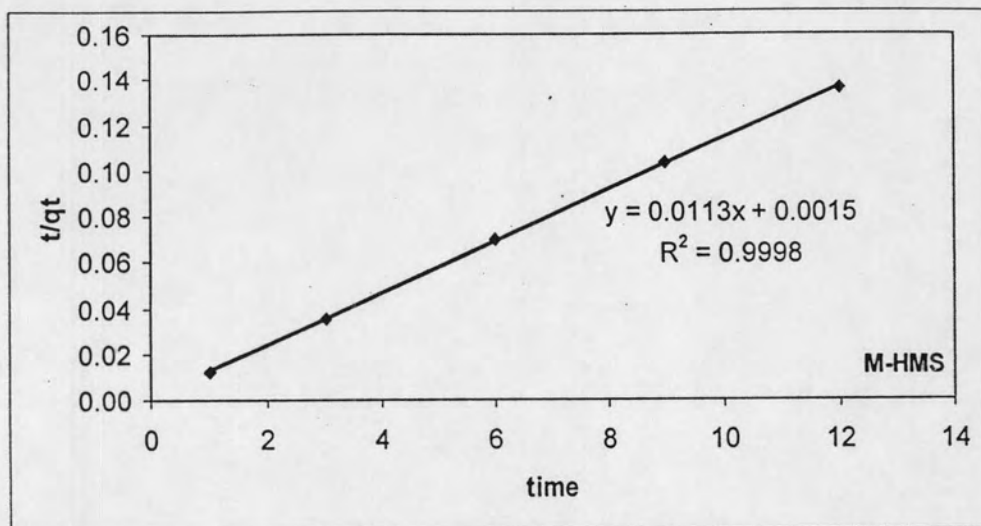
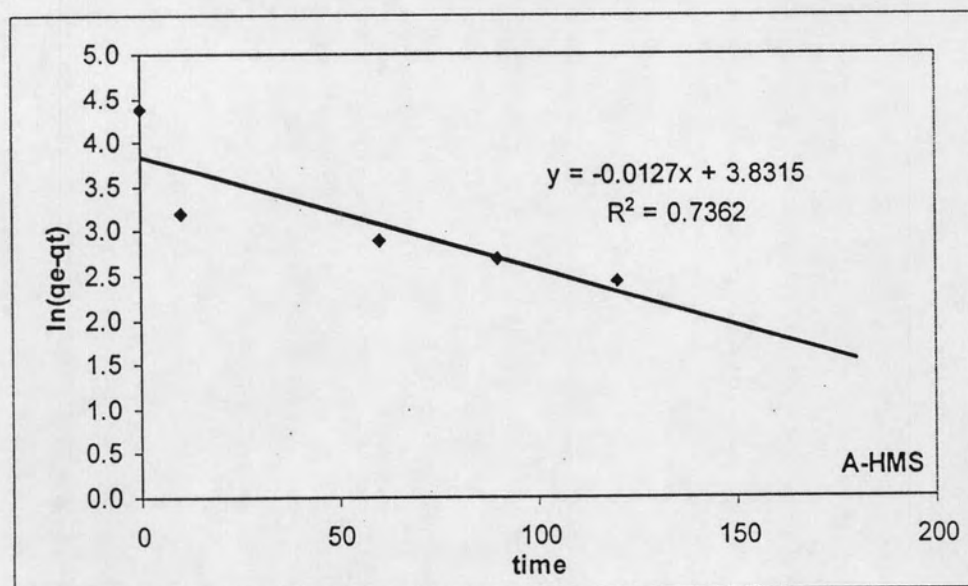
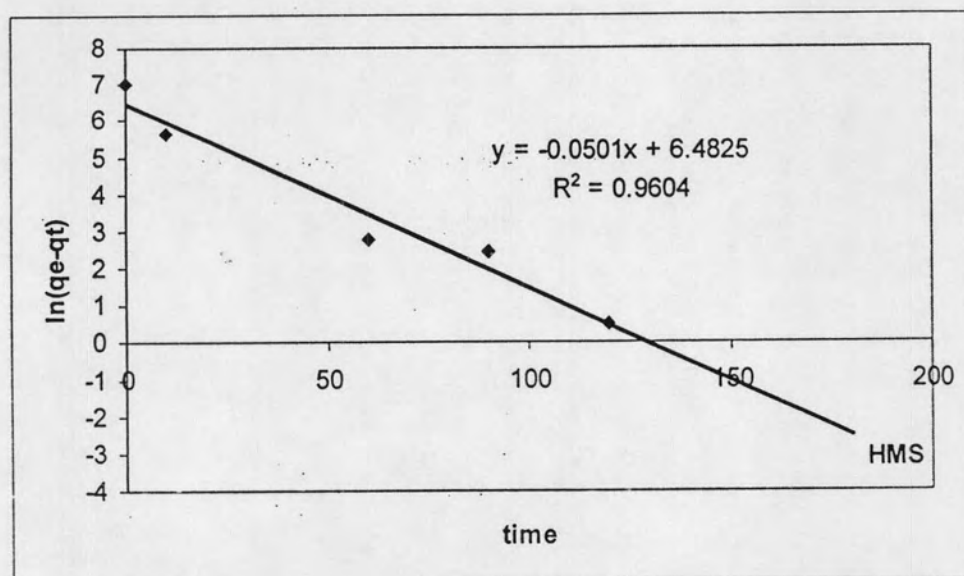




Figure F7. The pseudo first order for TX-100 adsorption kinetic.



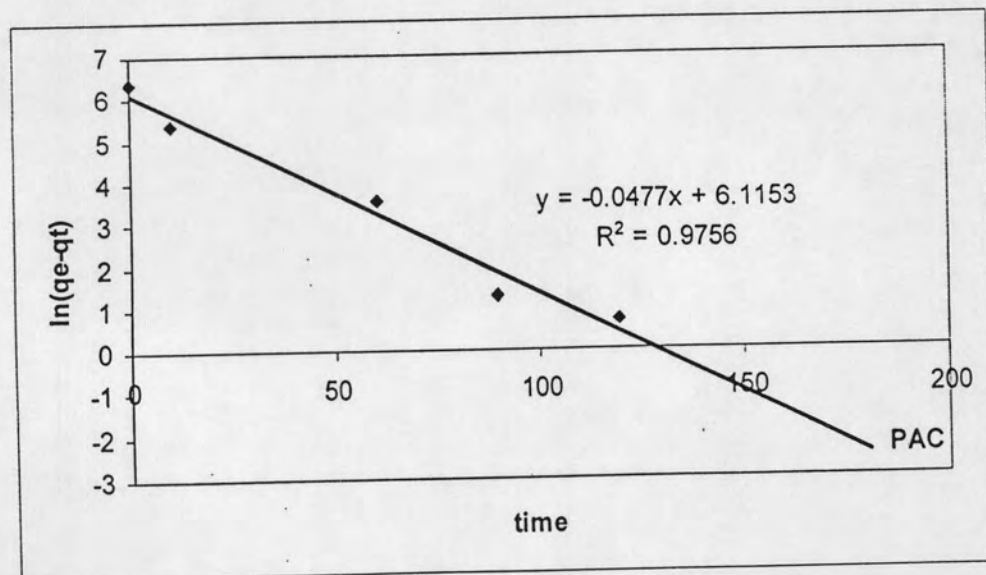
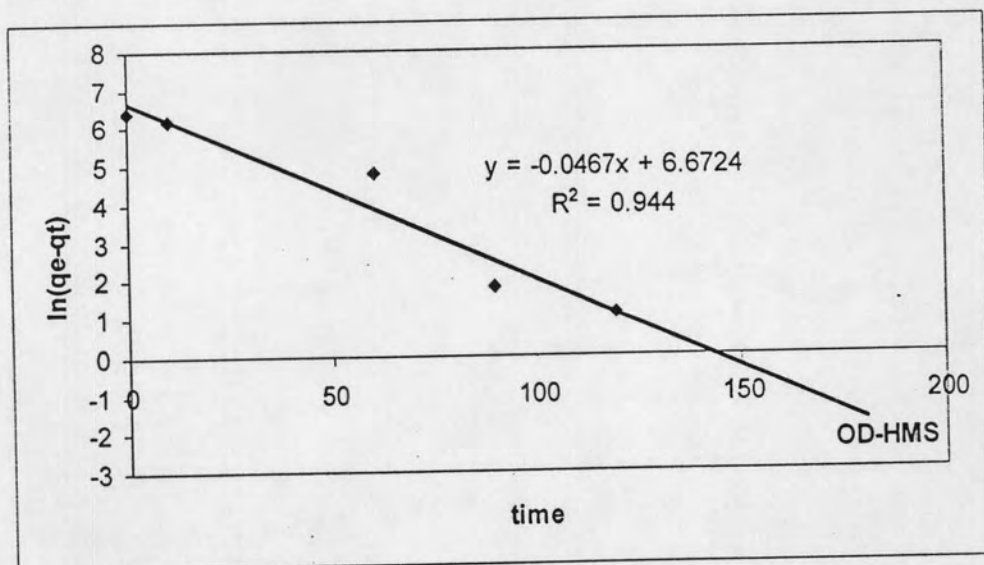
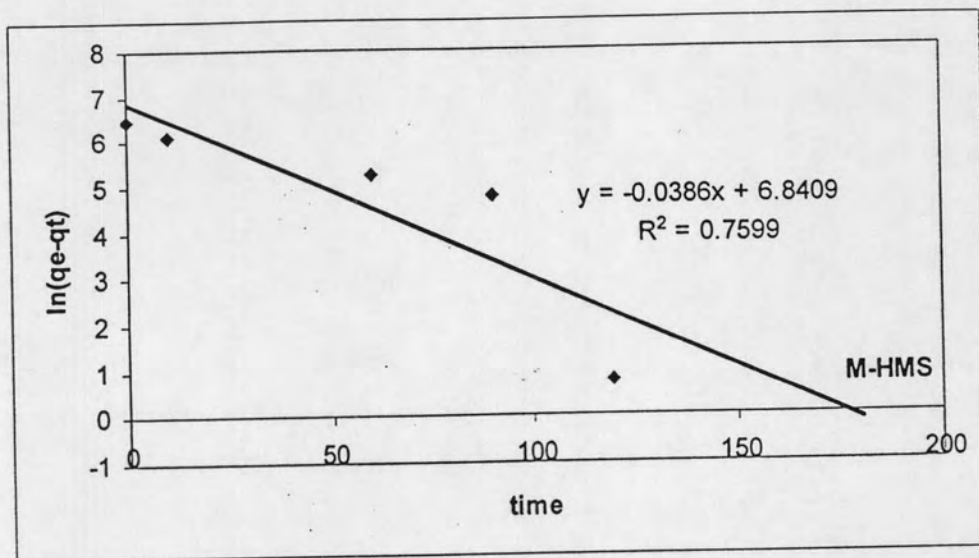
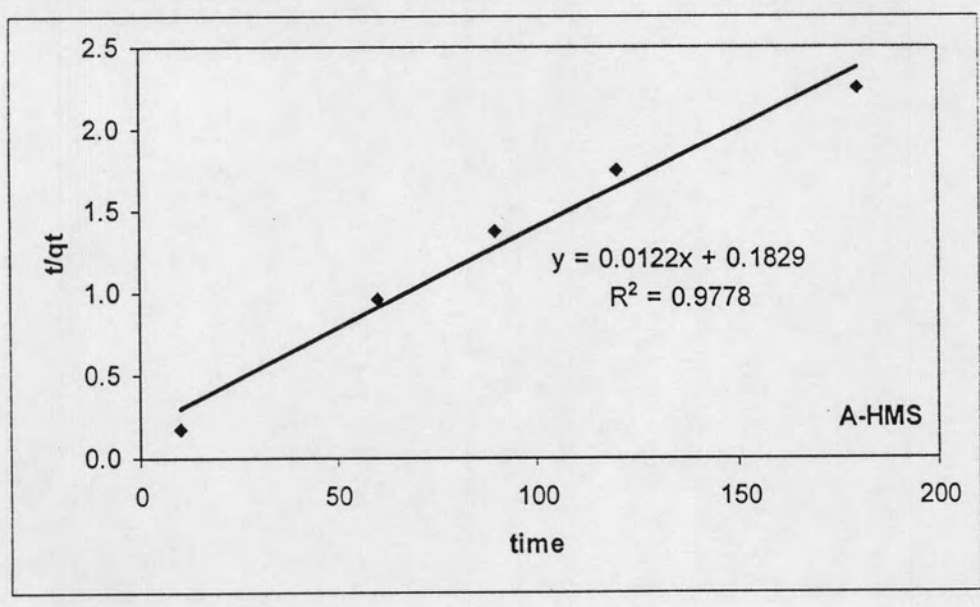
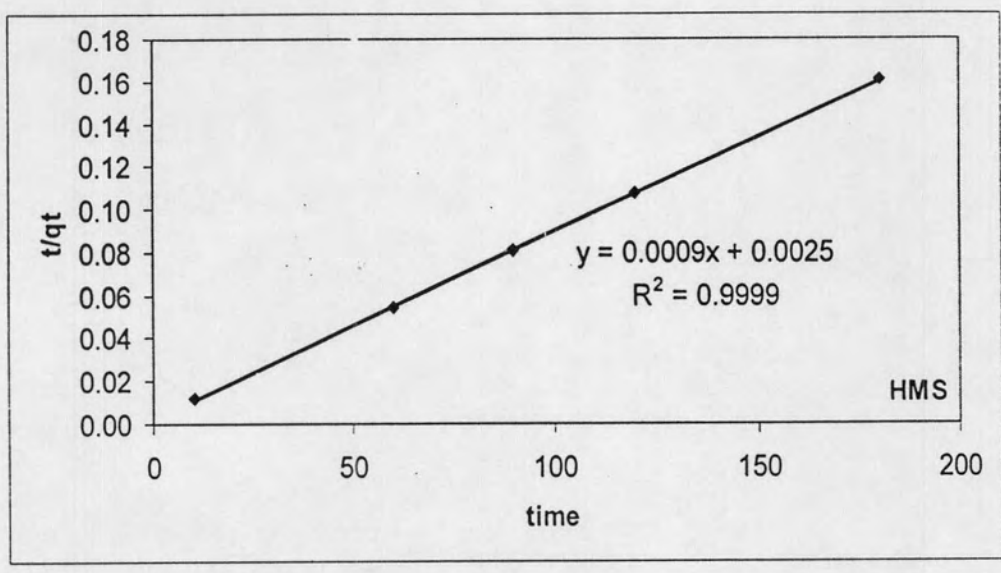
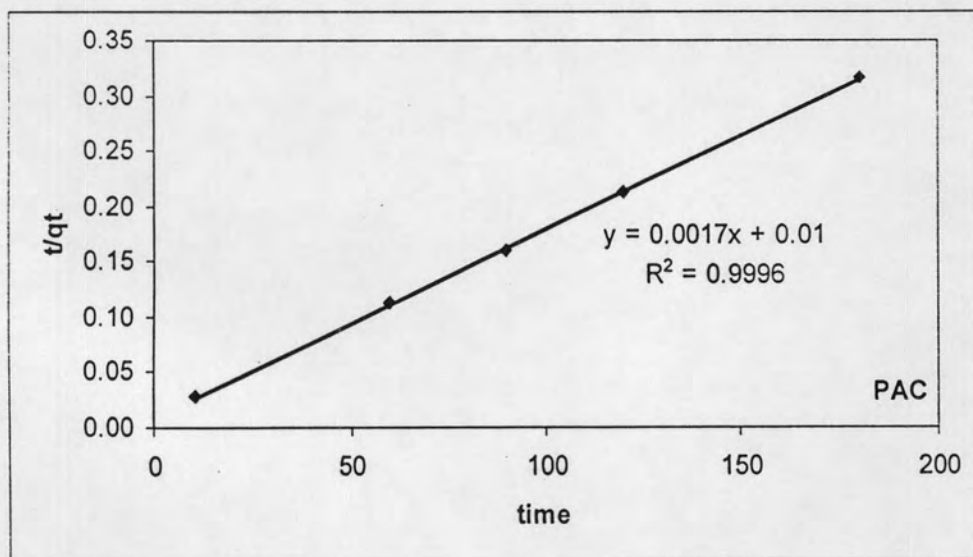
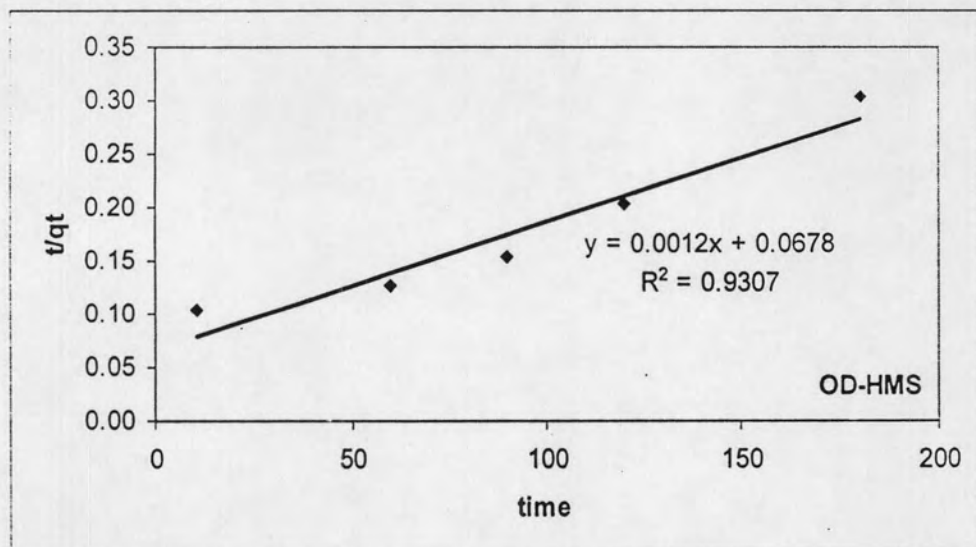
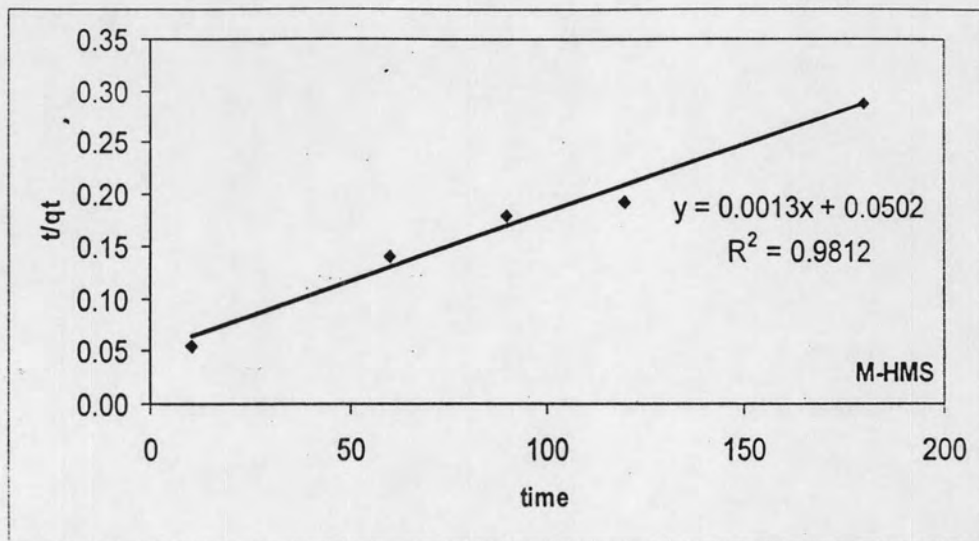


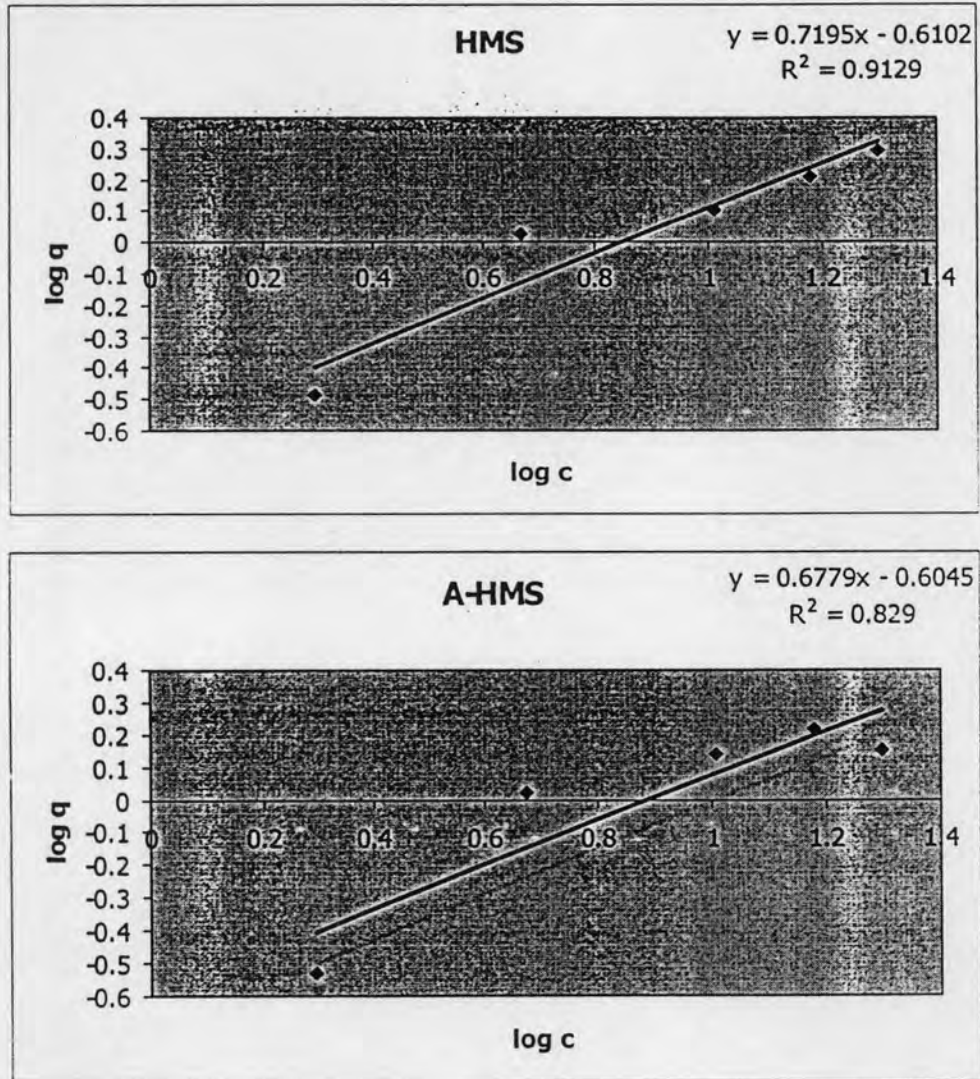
Figure F8 The pseudo second order for TX-100 adsorption kinetic.





## APPENDIX G

Figure G1 Freundlich model for Cd(II) adsorption isotherm at pH 3 on all adsorbents



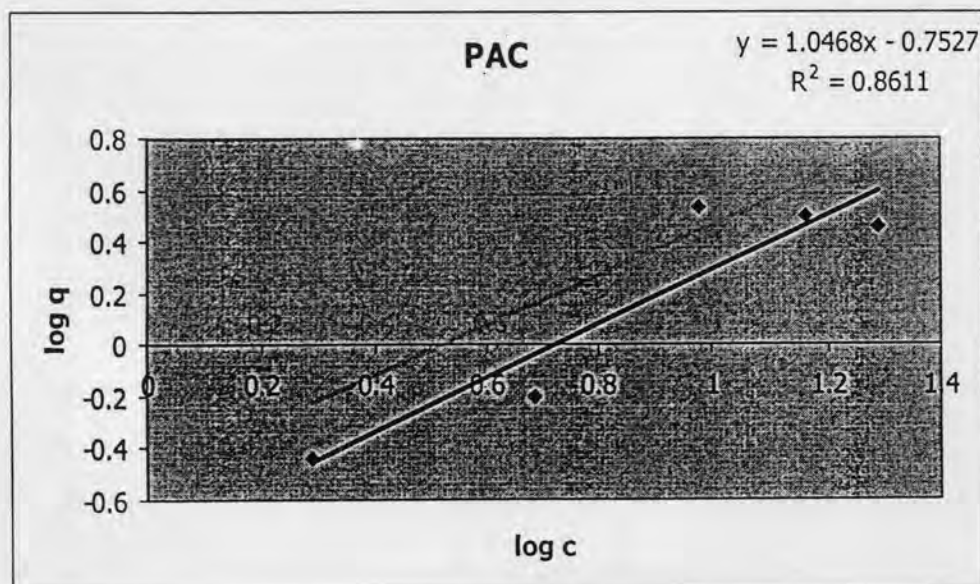
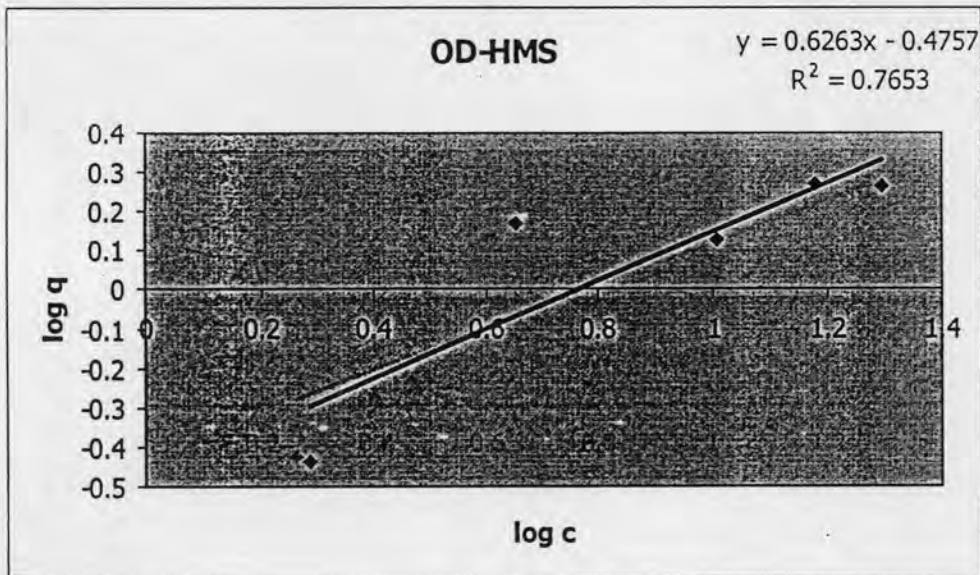
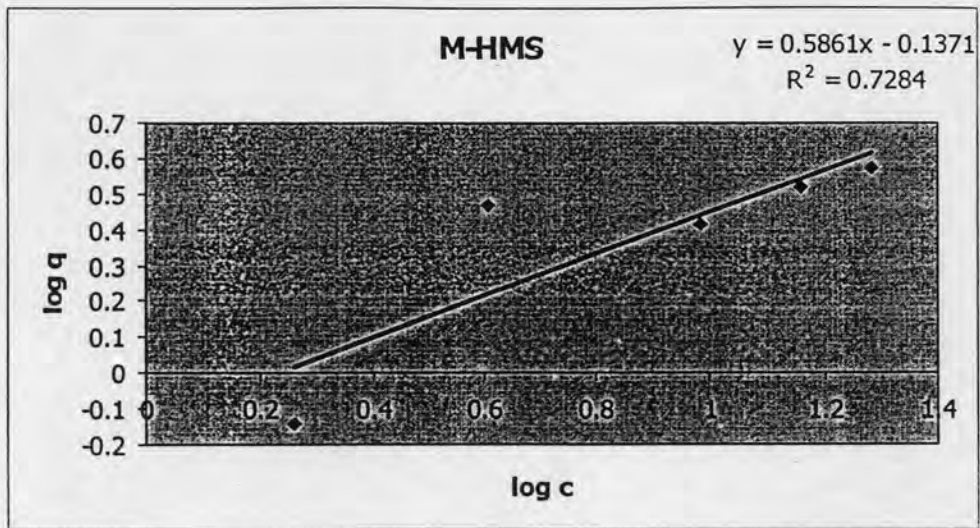
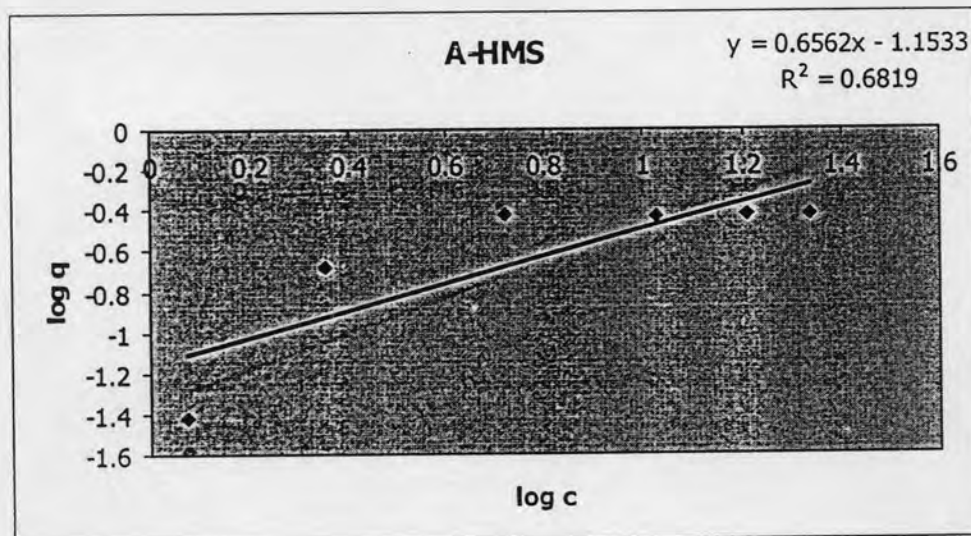
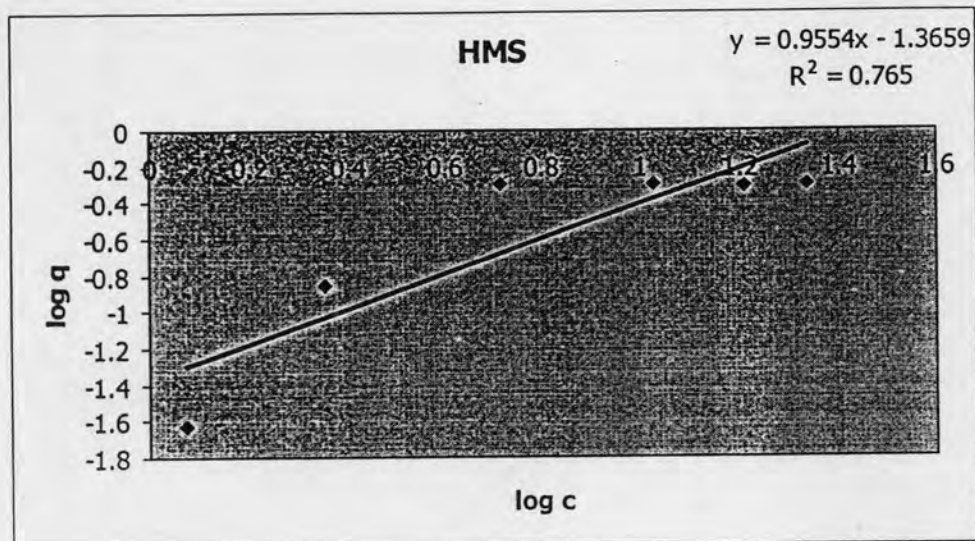


Figure G2 Freundlich model for Cd(II) adsorption isotherm at pH 5 on all adsorbents



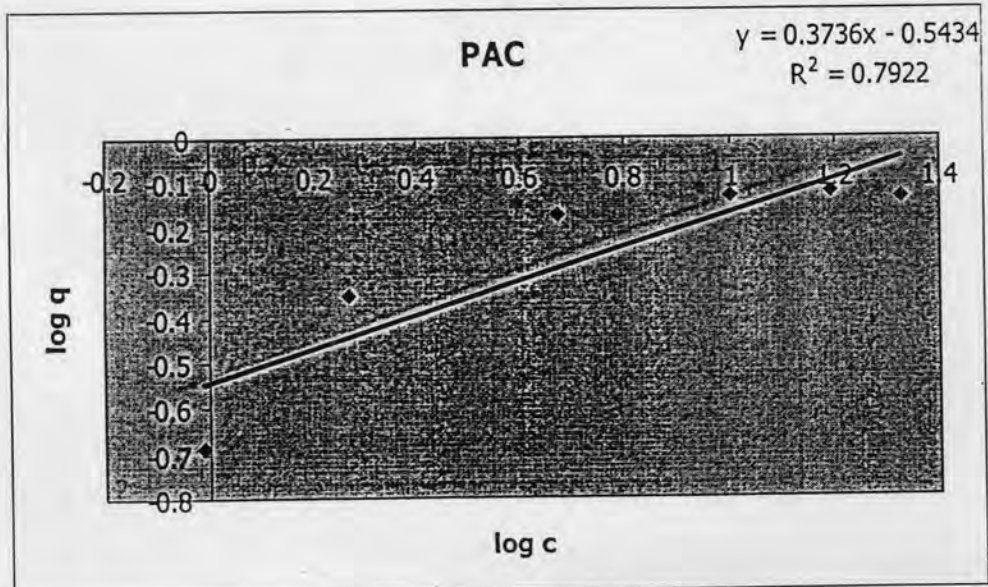
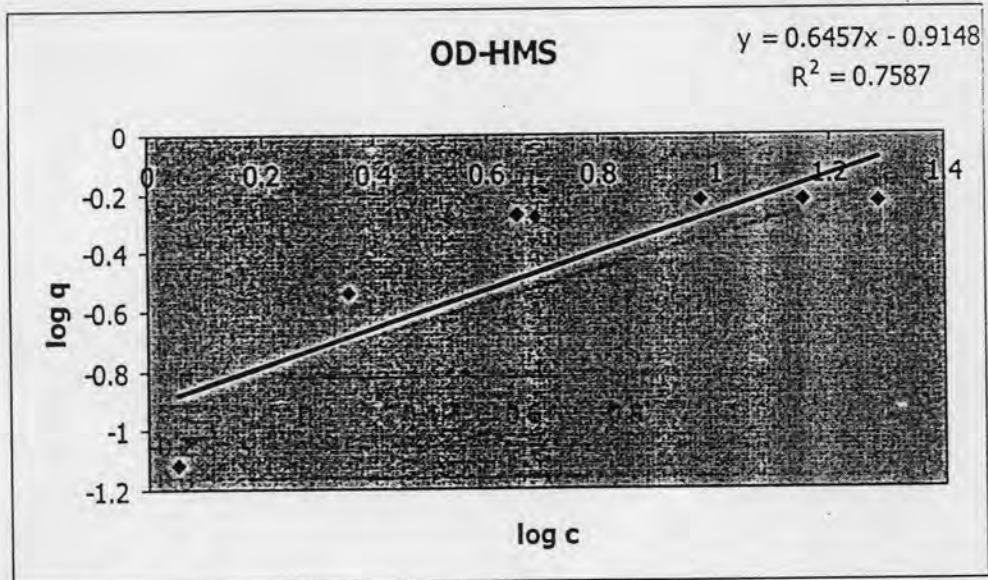
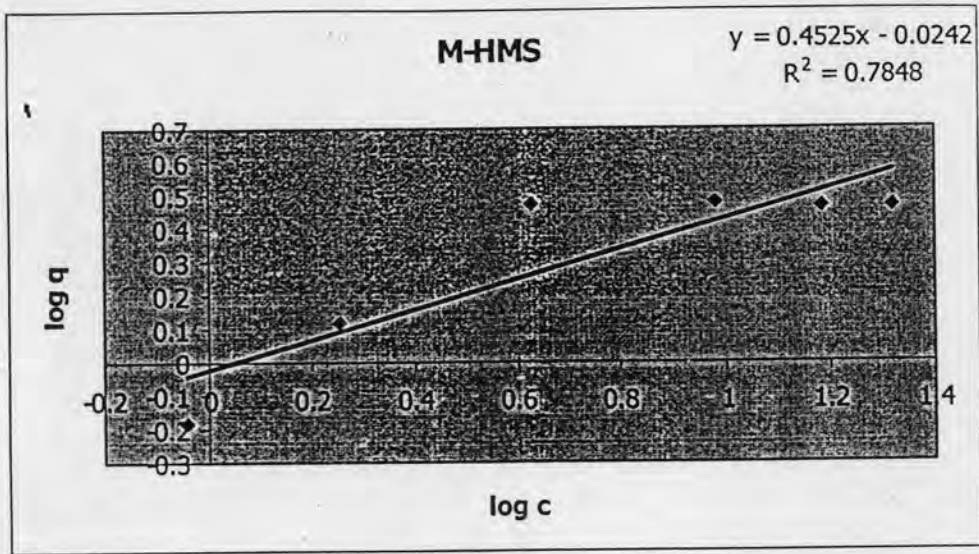
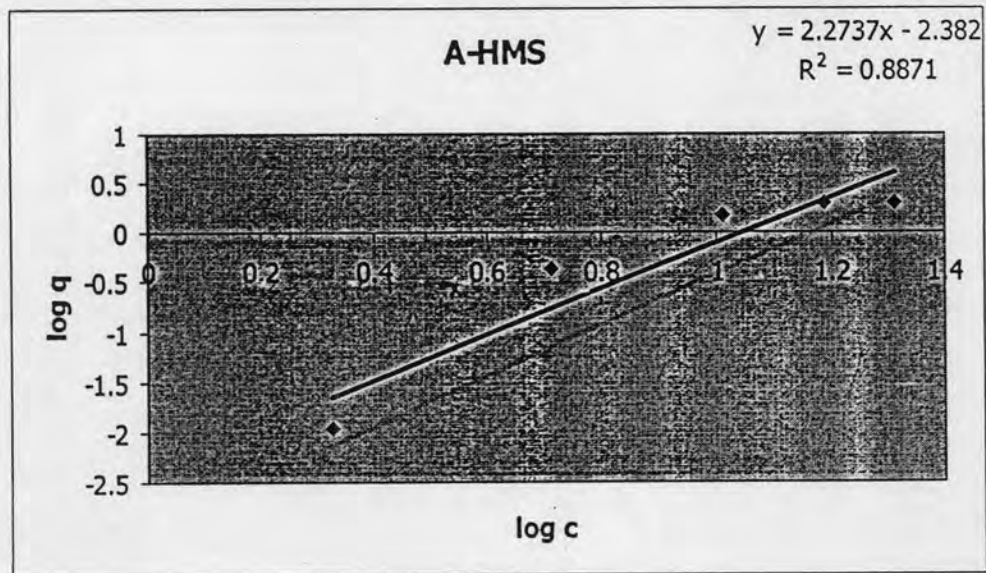
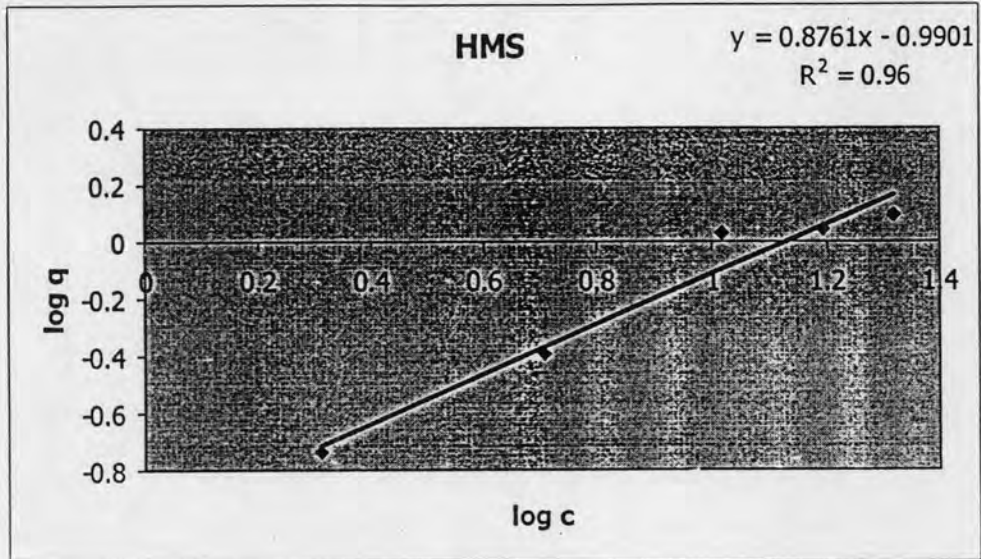




Figure G3 Freundlich model for Cu(II) adsorption isotherm at pH 3 on all adsorbents



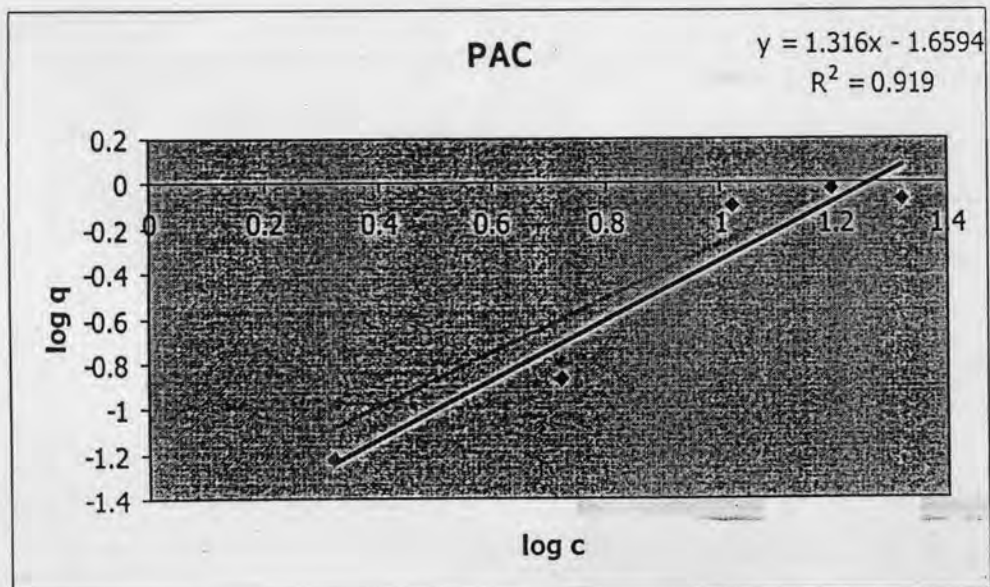
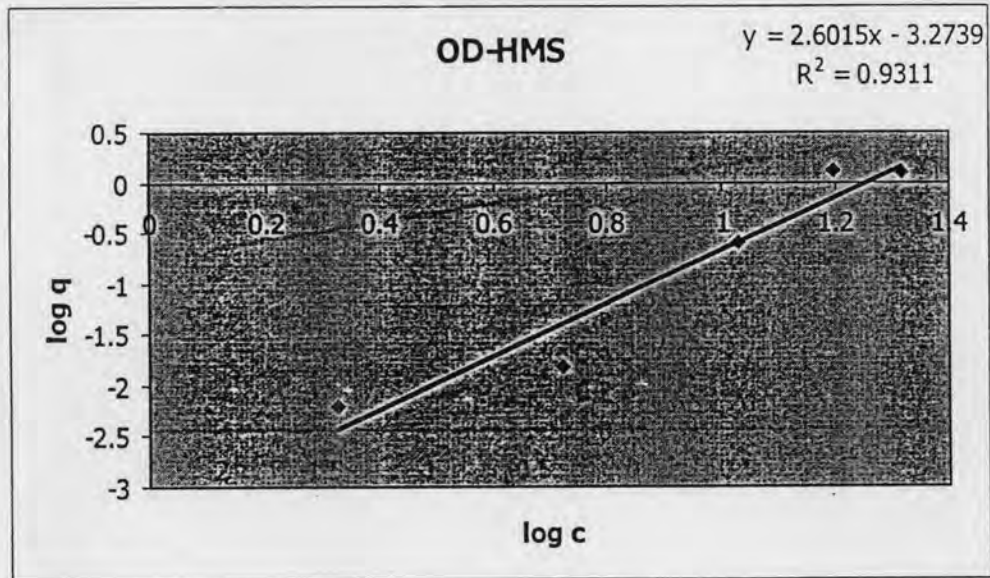
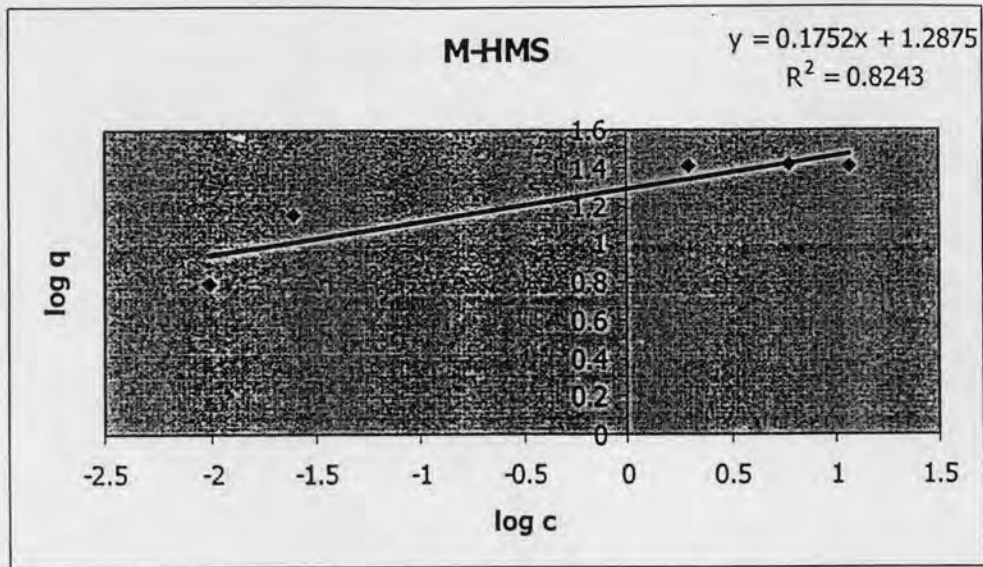
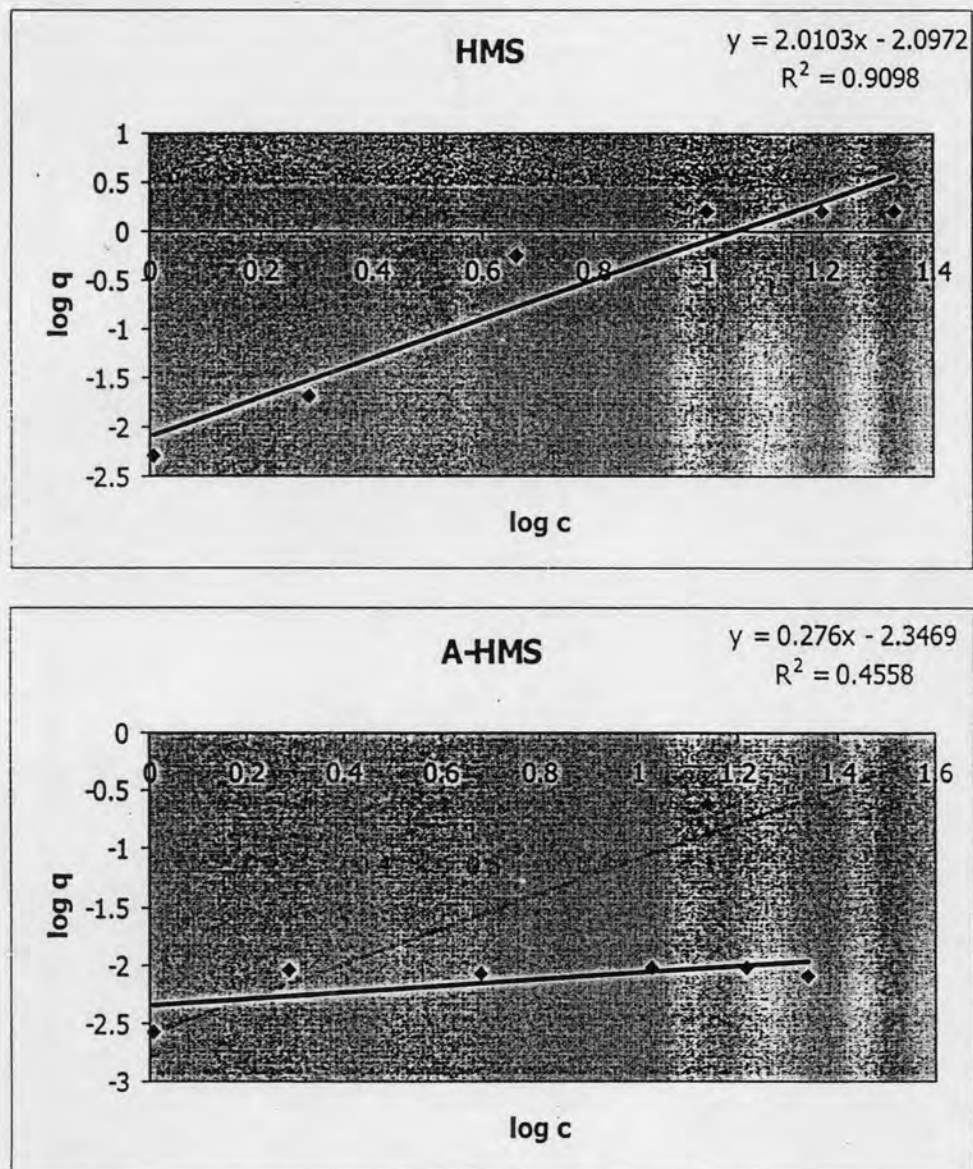
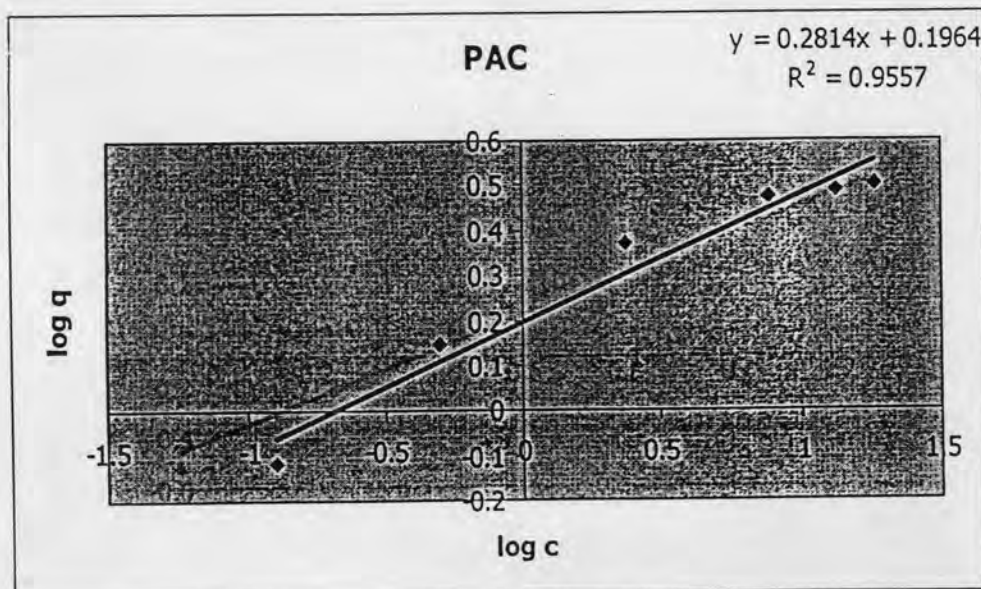
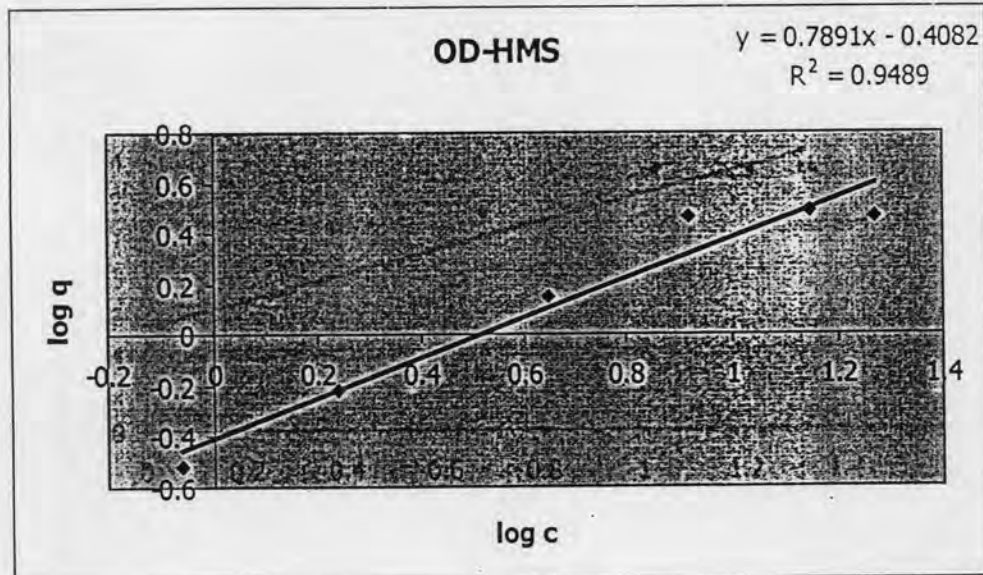
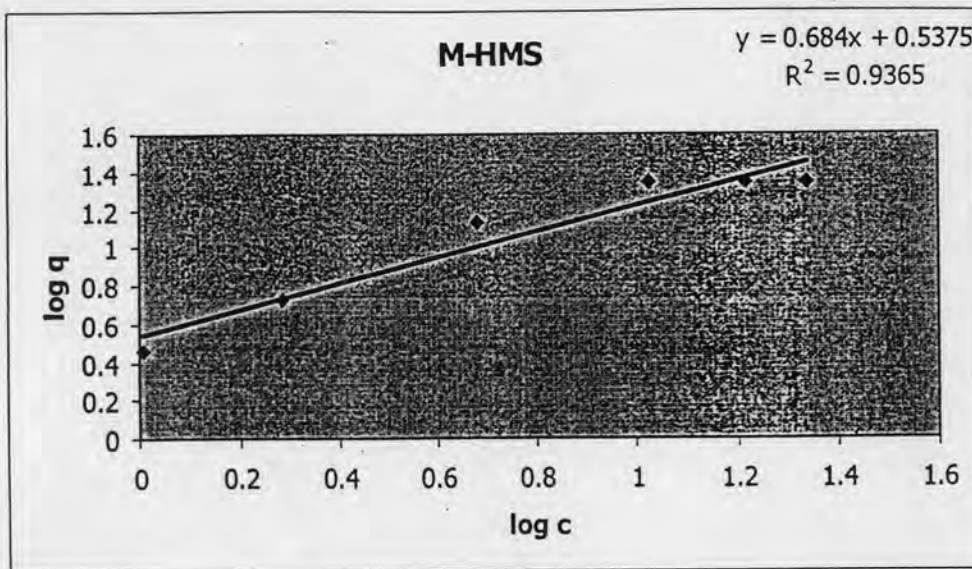
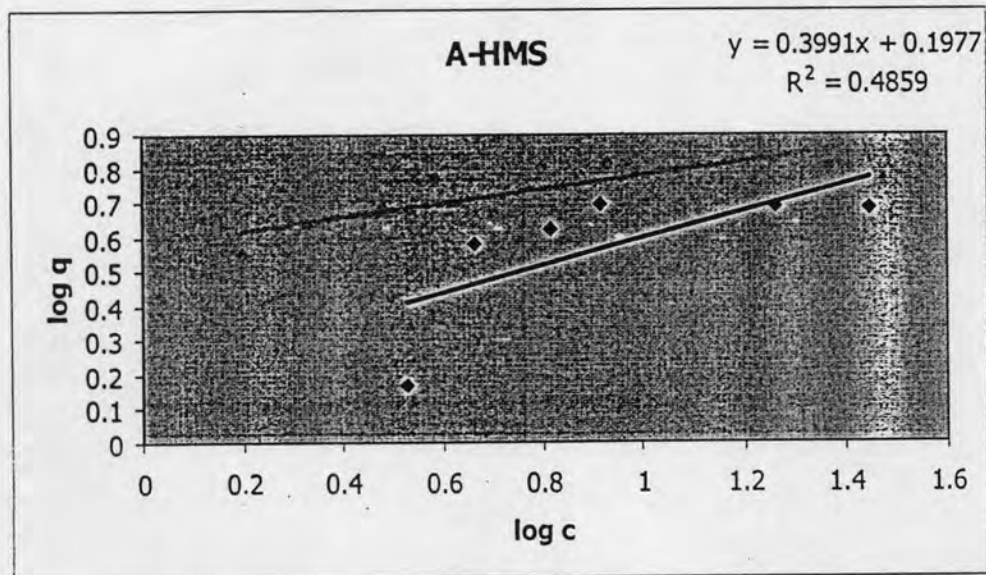
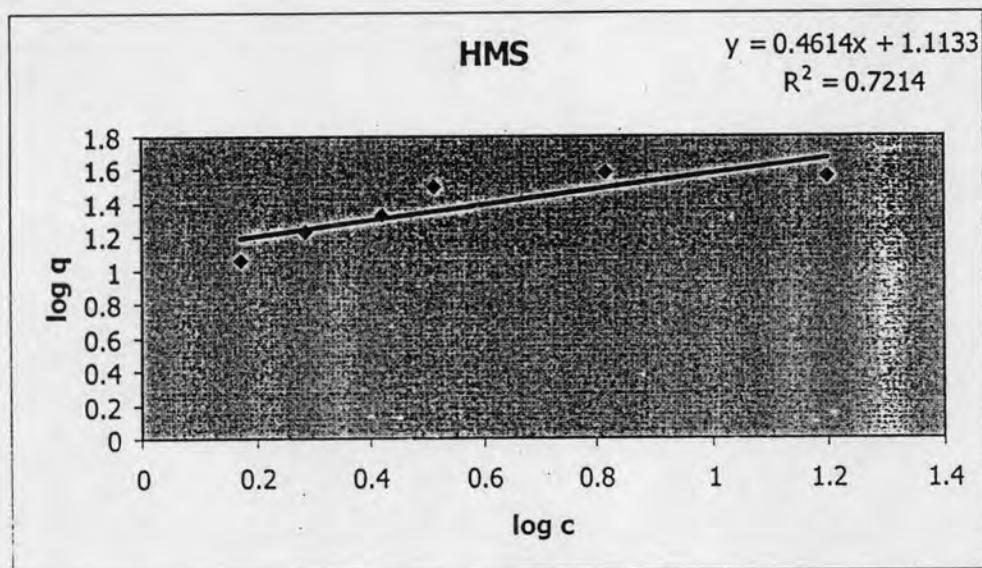


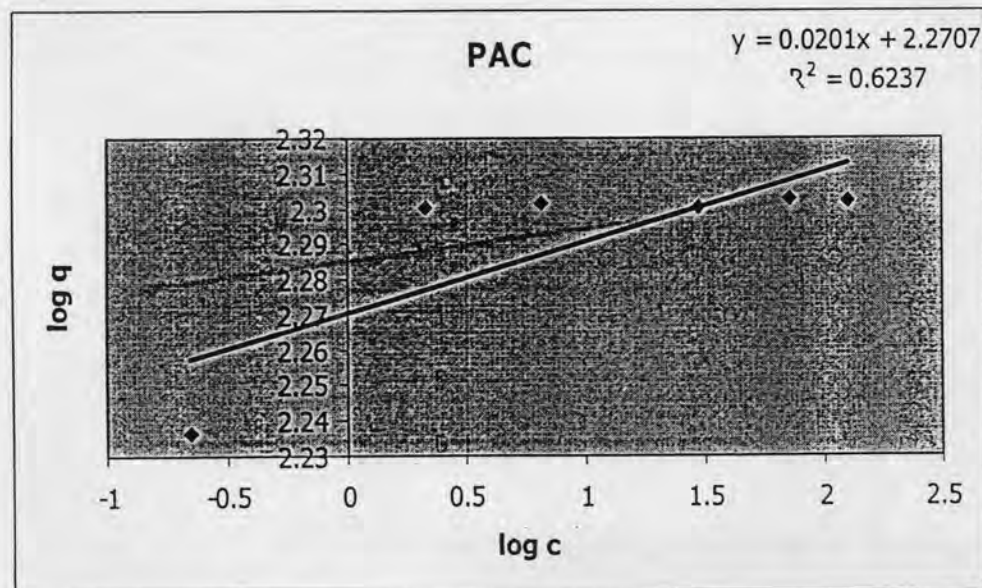
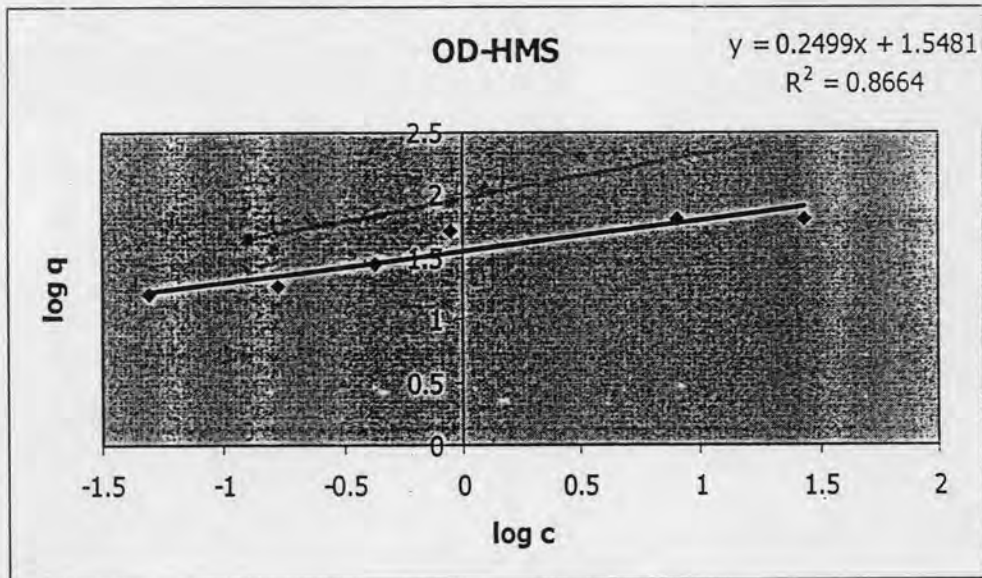
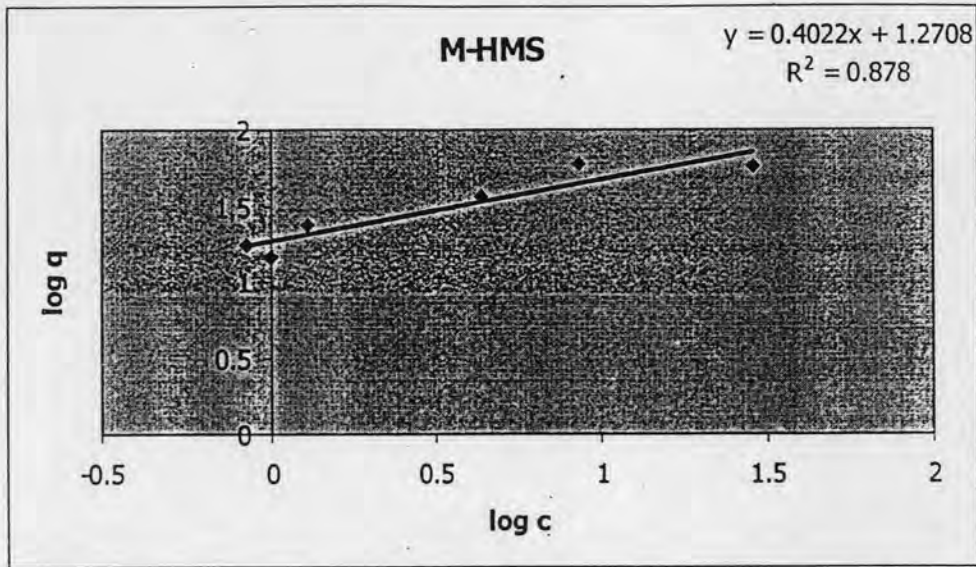
Figure G4 Freundlich model for Cu(II) adsorption isotherm at pH 5 on all adsorbents



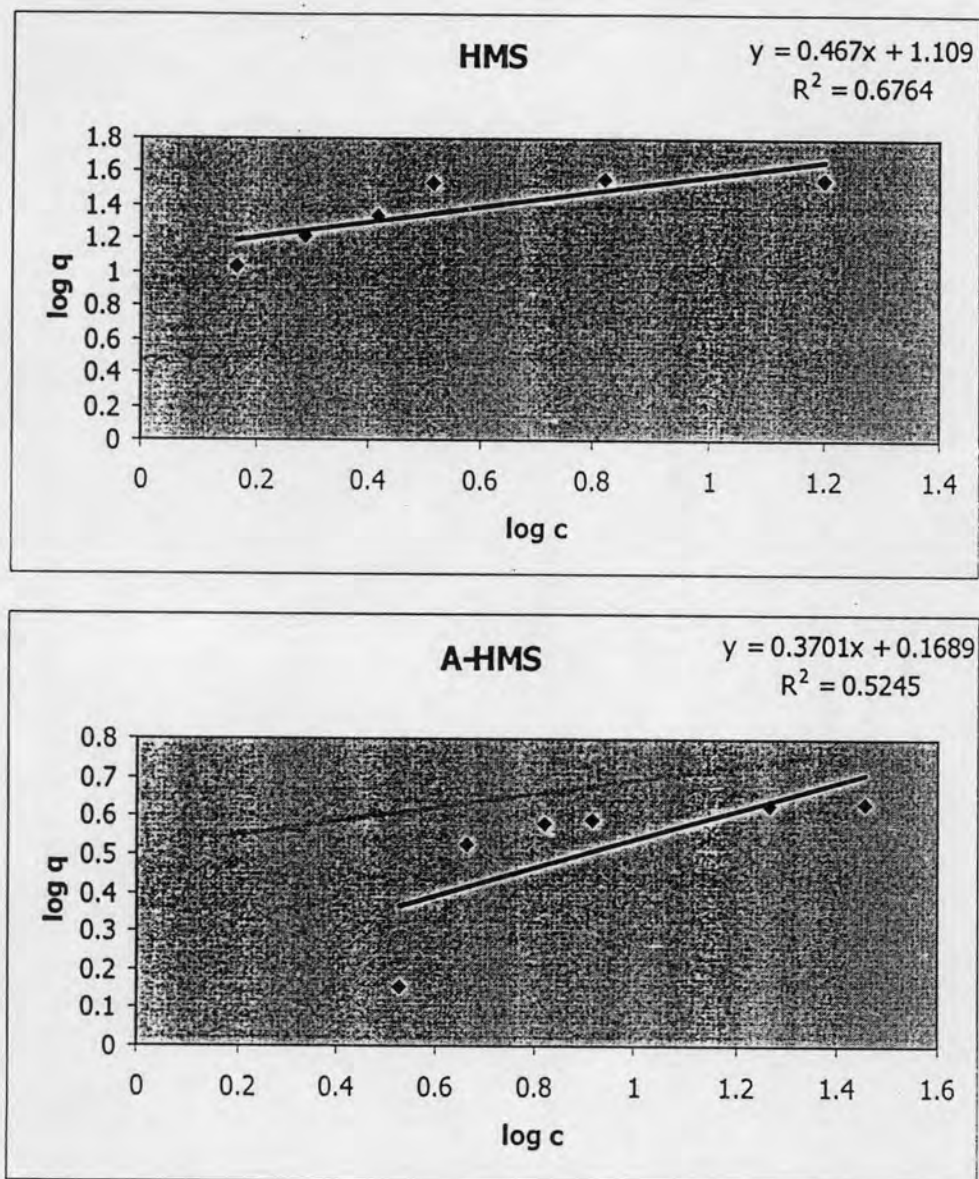


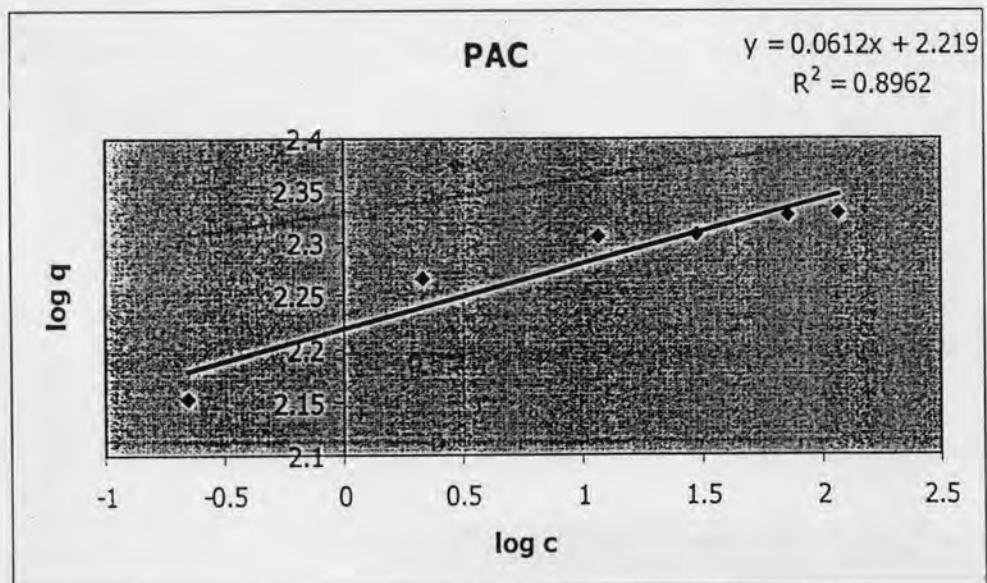
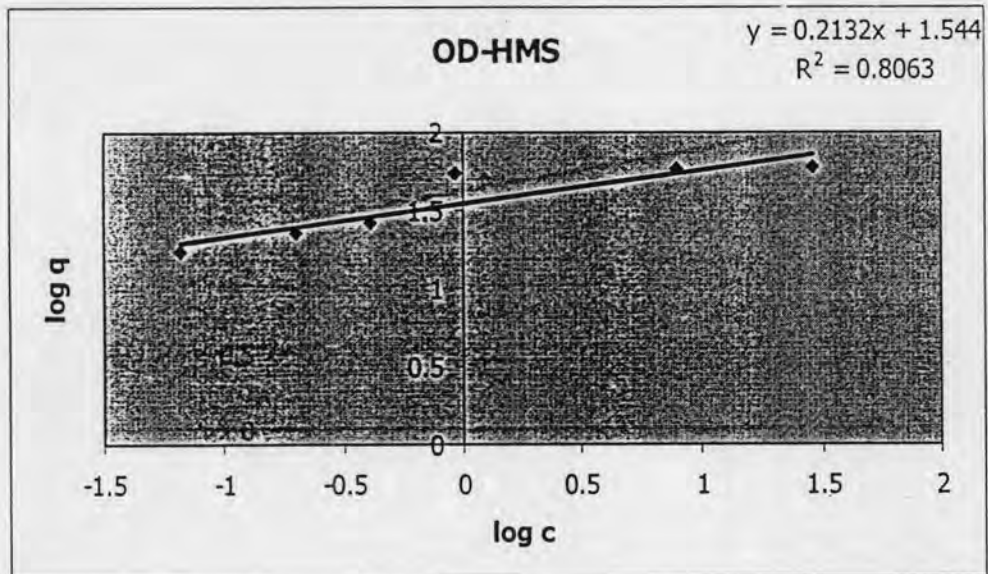
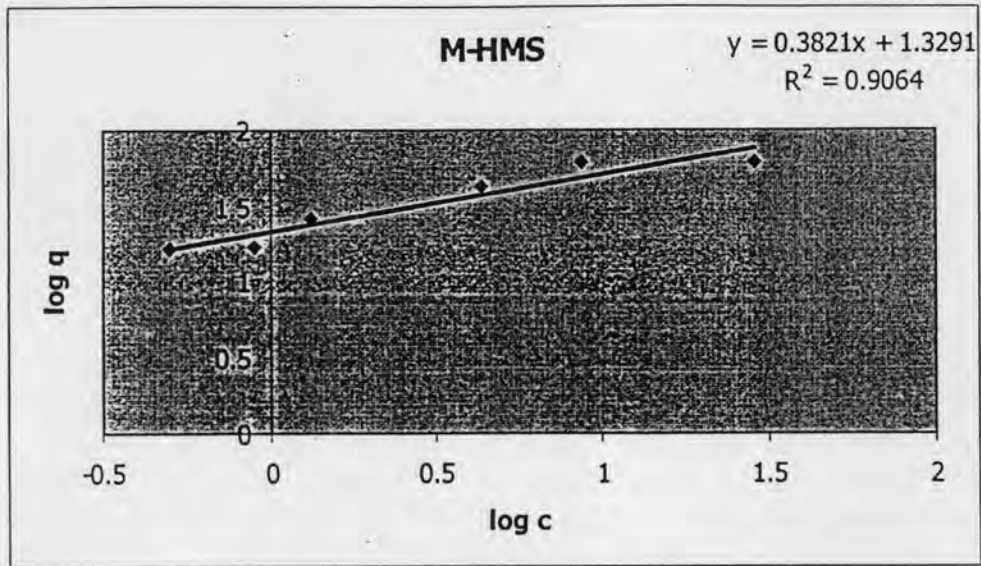
**Figure G5** Freundlich model for methylene blue adsorption isotherm at pH 5 on all adsorbents





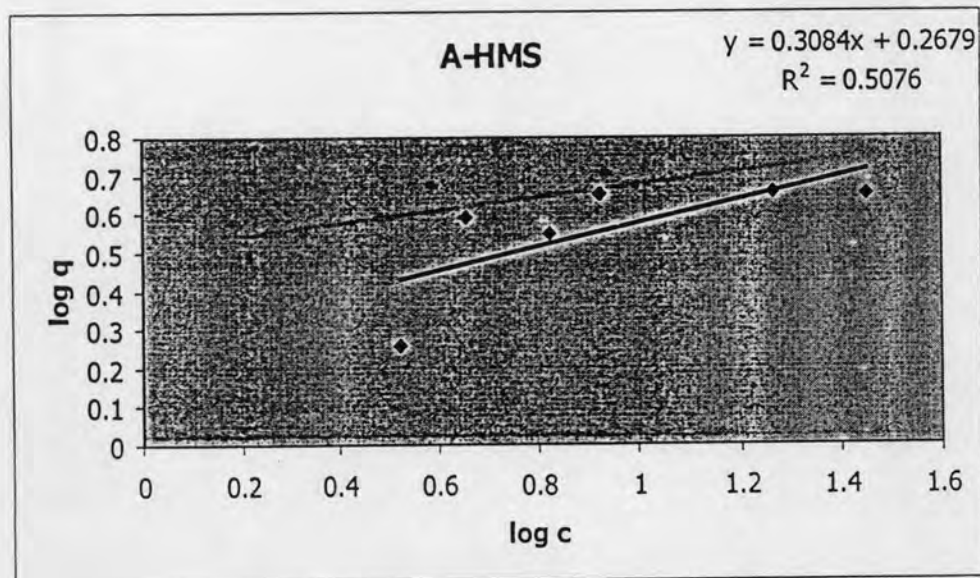
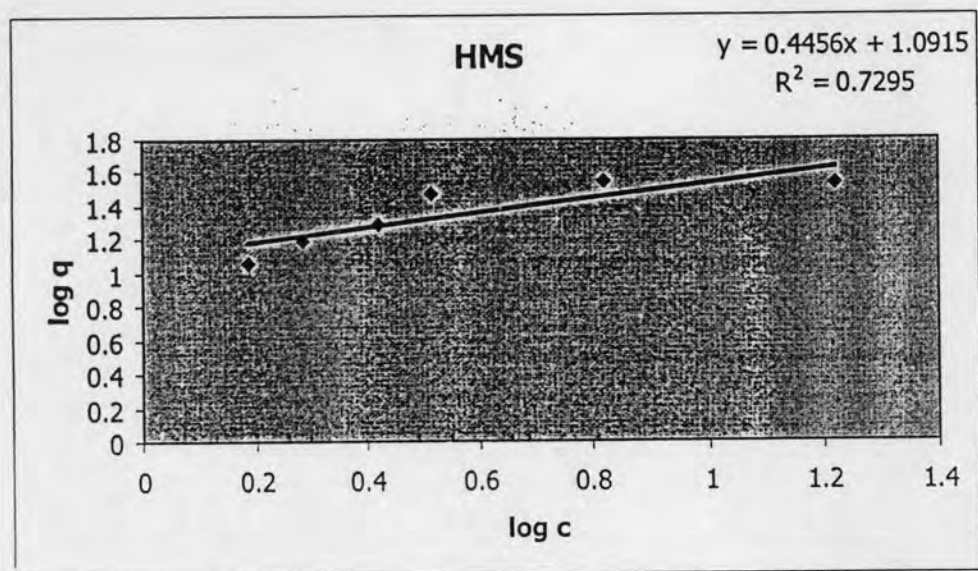
**Figure G6** Freundlich model for methylene blue adsorption isotherm at pH 7 on all adsorbents

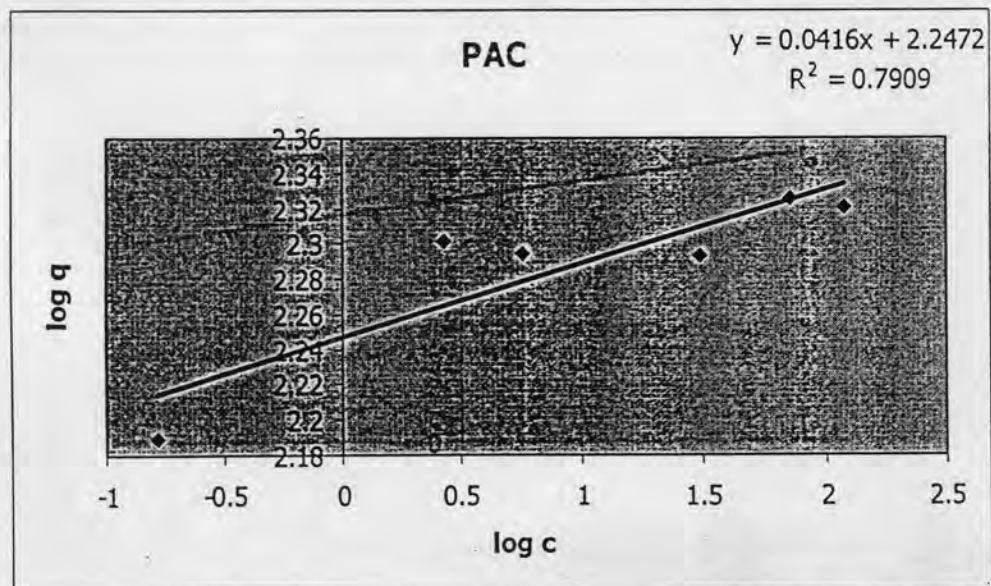
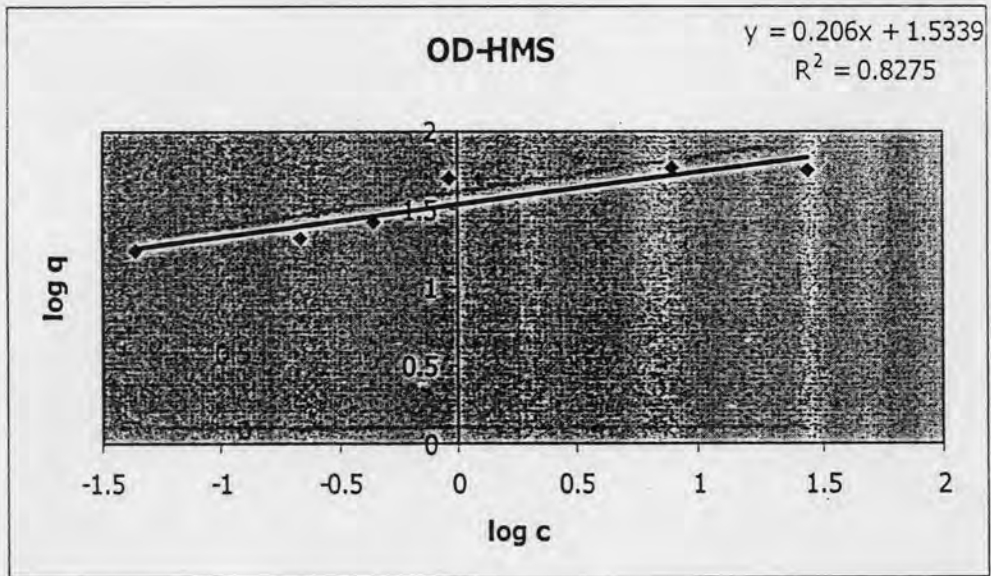
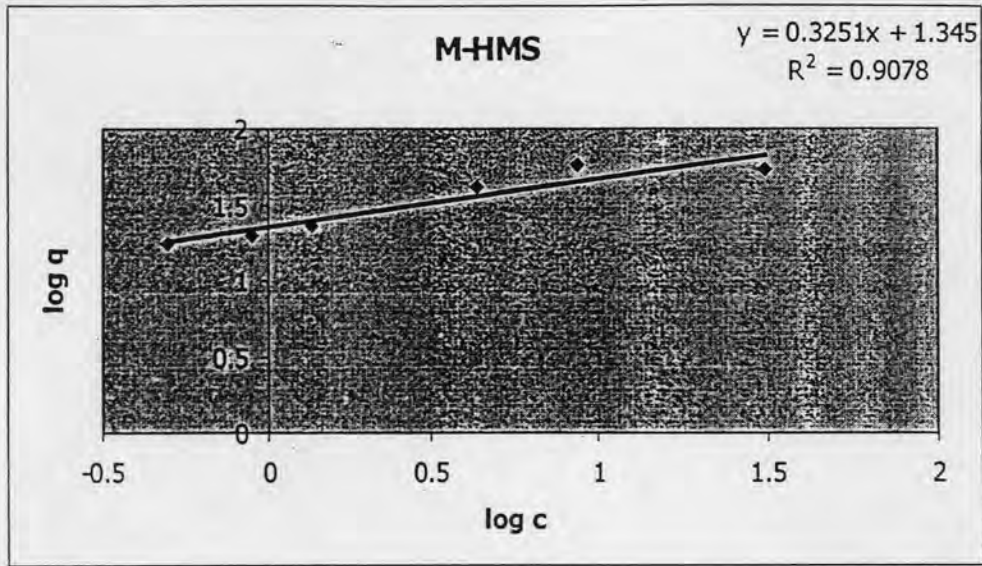




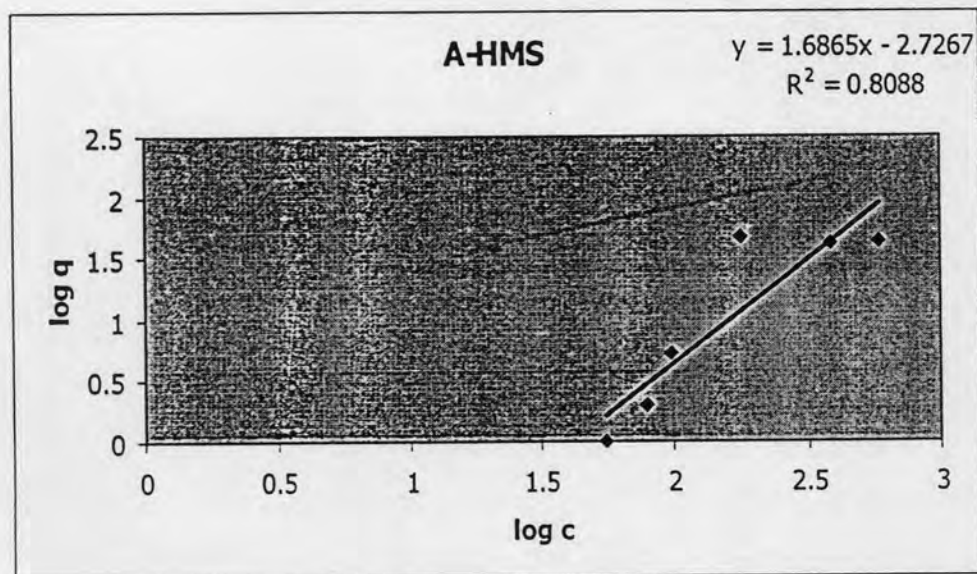
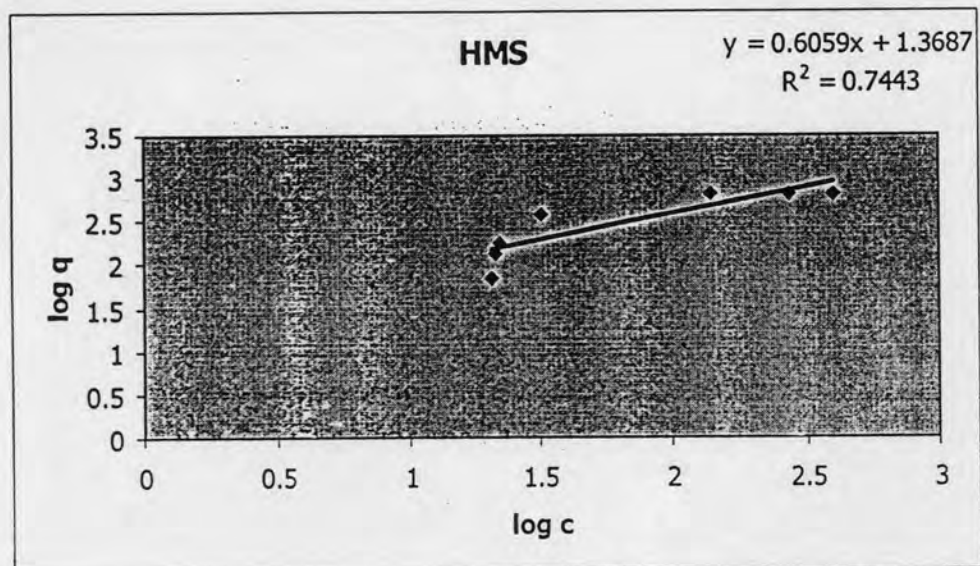


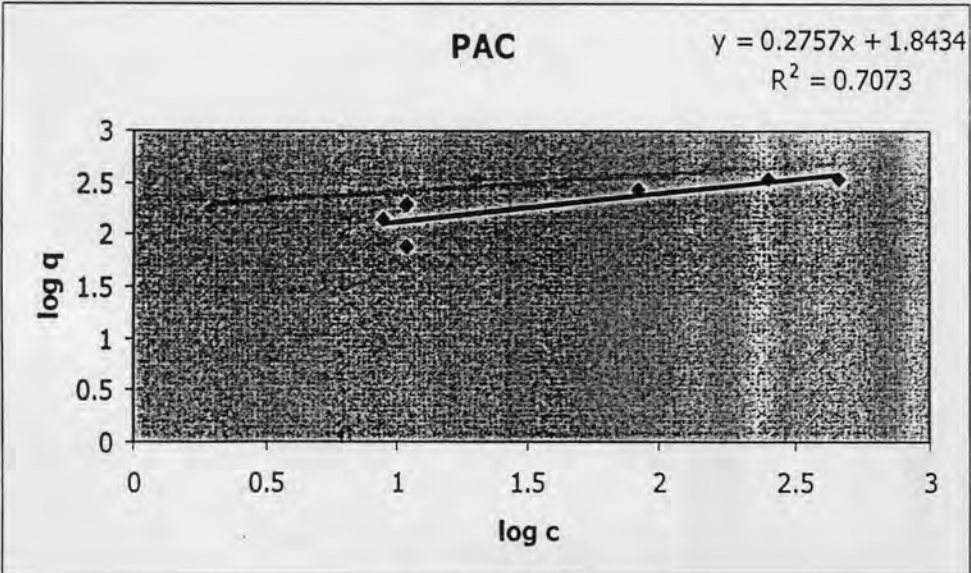
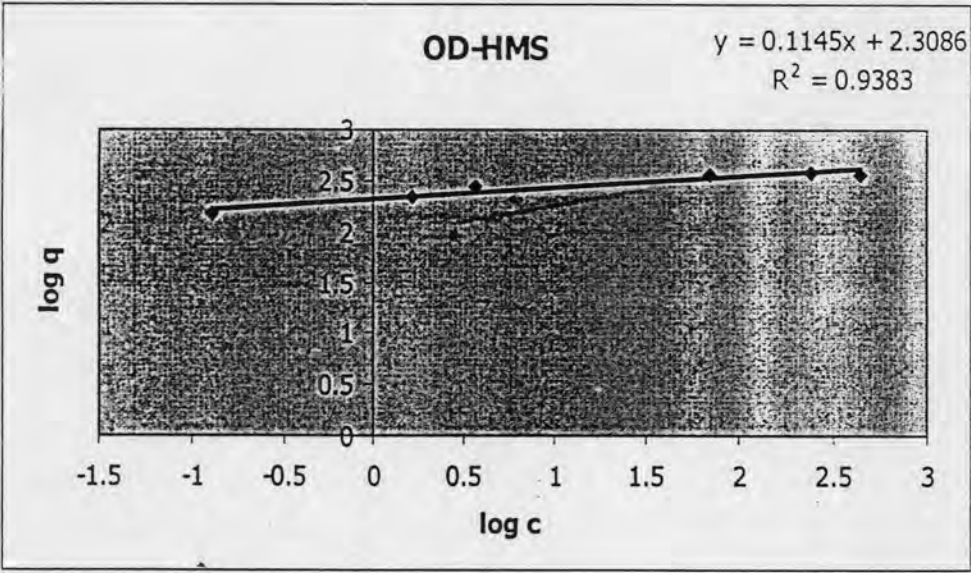
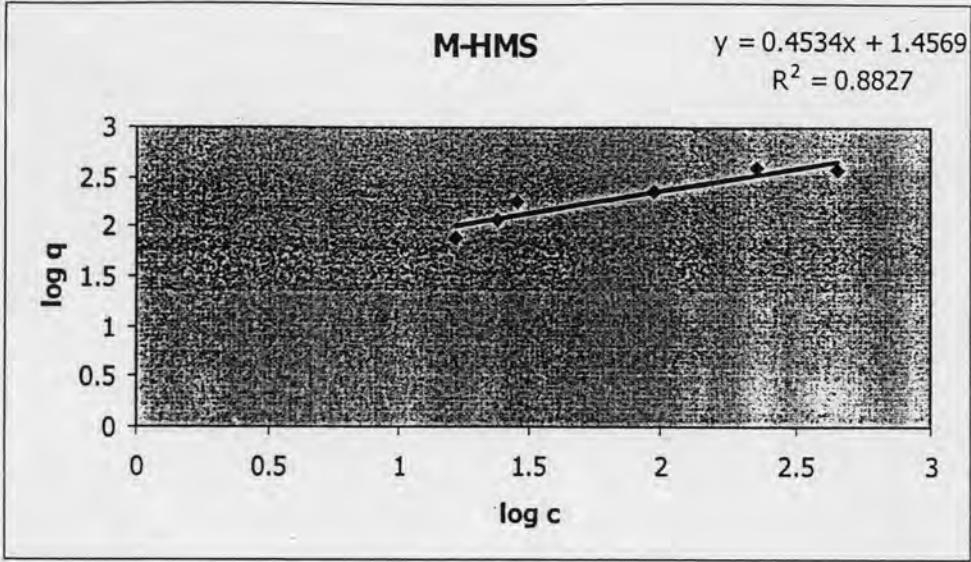
**Figure G7** Freundlich model for methylene blue adsorption isotherm at pH 9 on all adsorbents



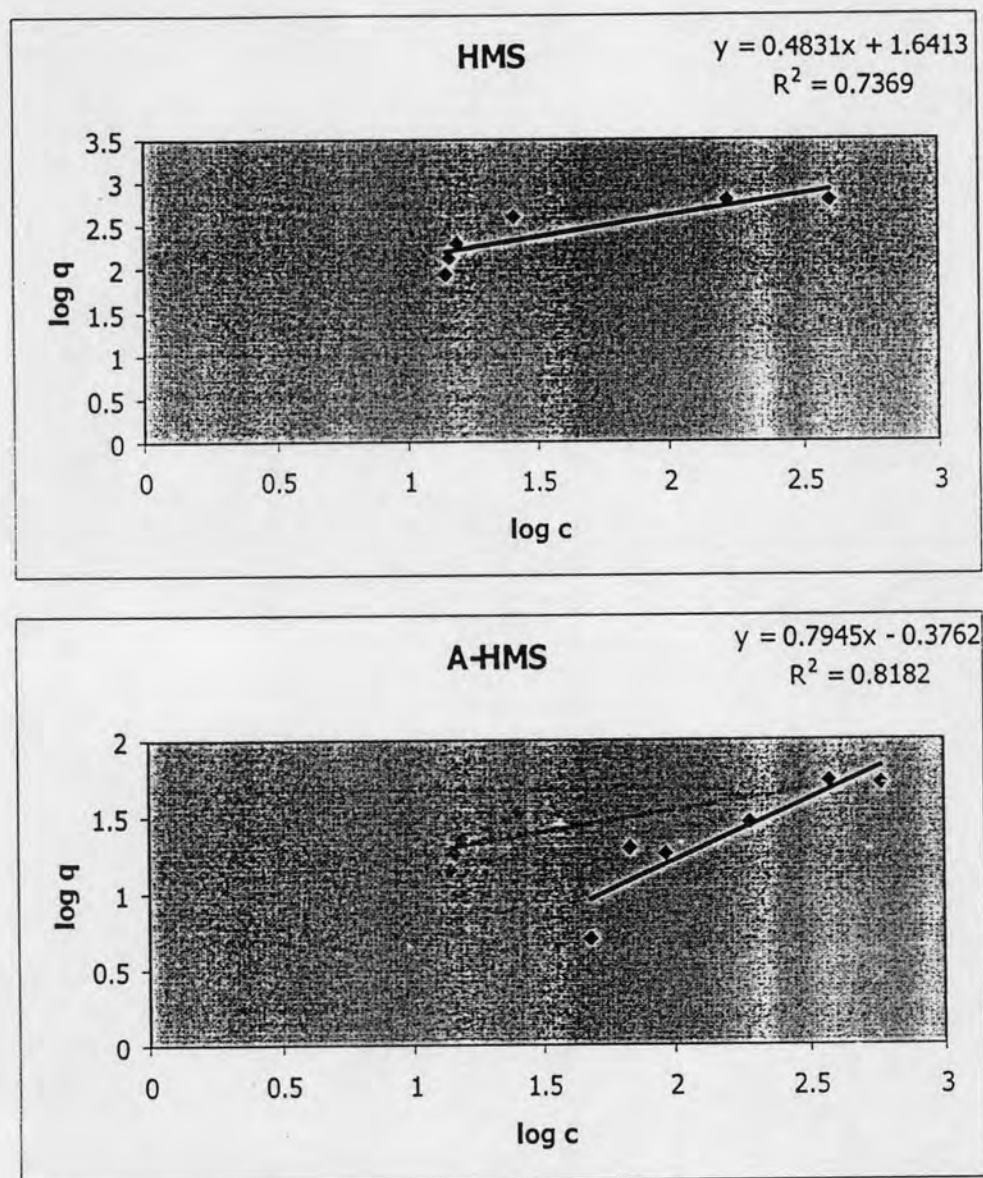


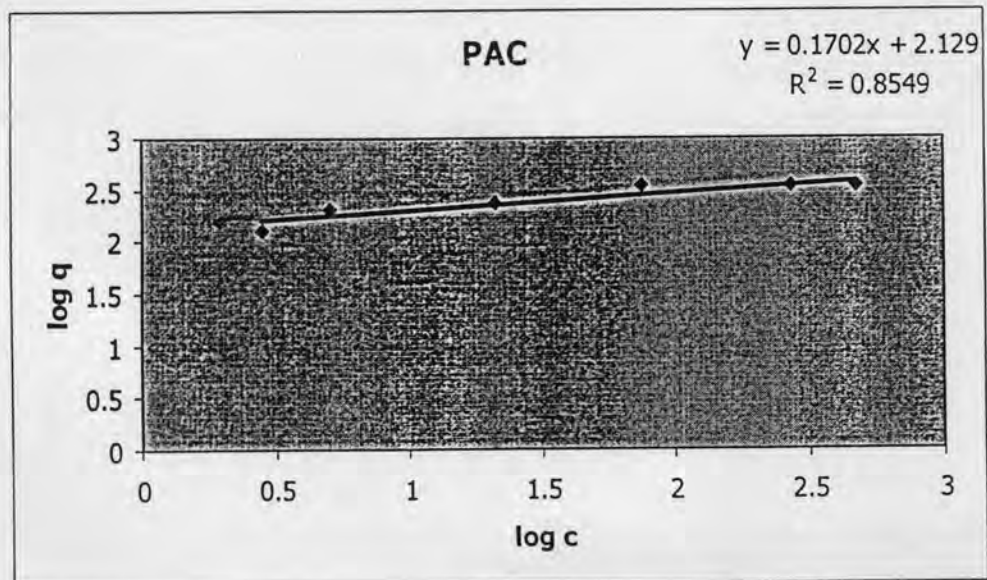
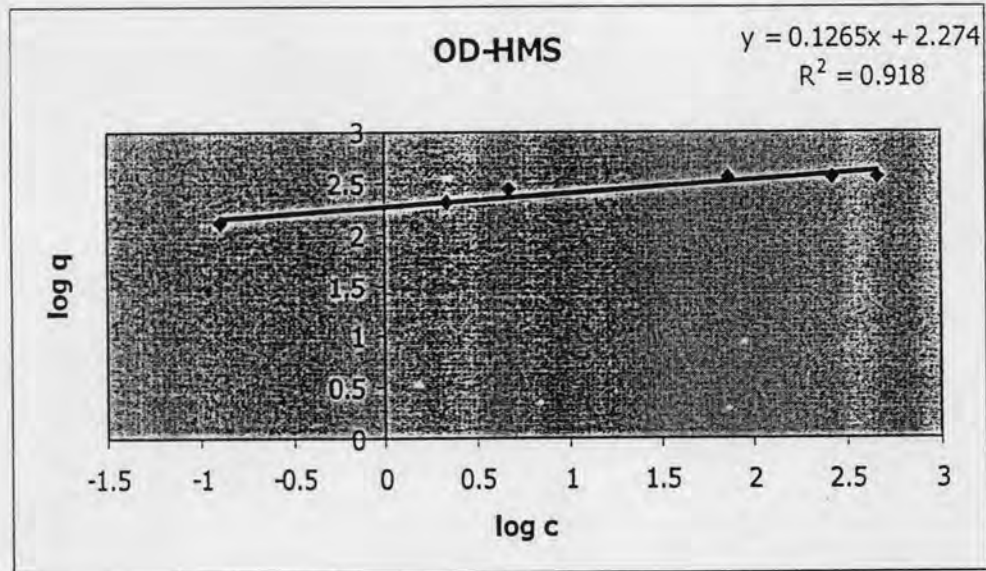
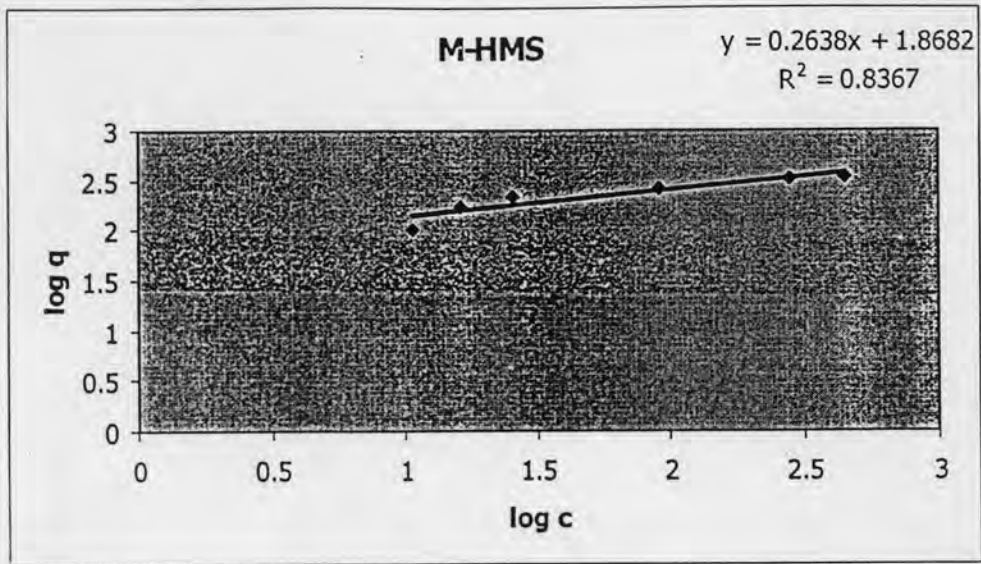
**Figure G8** Freundlich model for TX-100 adsorption isotherm at pH 5 on all adsorbents



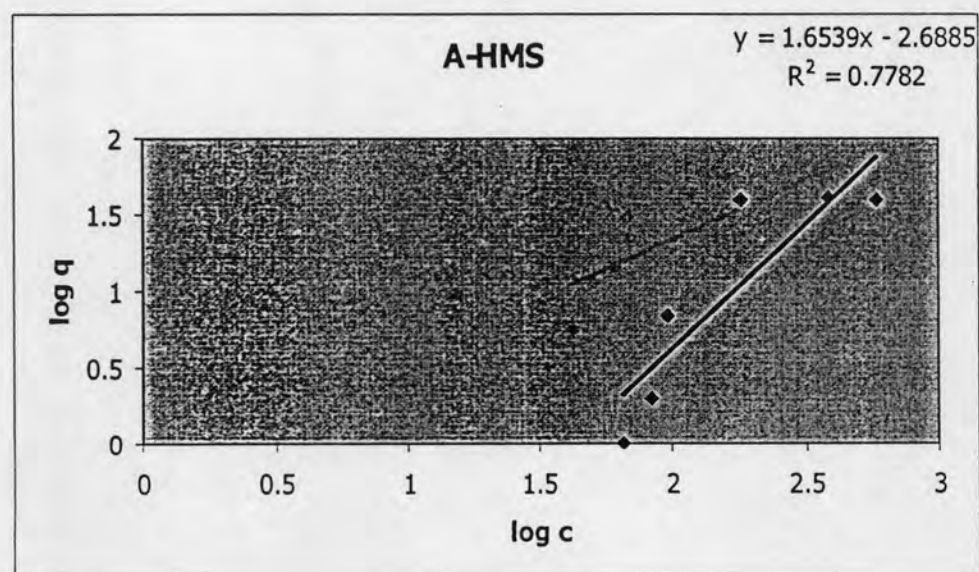
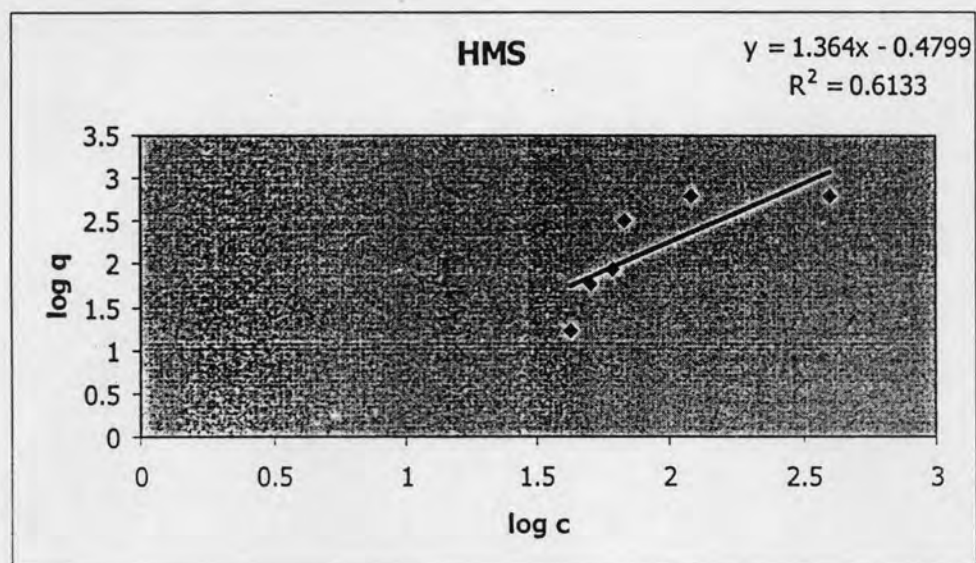


**Figure G9** Freundlich model for TX-100 adsorption isotherm at pH 7 on all adsorbents





**Figure G10** Freundlich model for TX-100 adsorption isotherm at pH 9 on all adsorbents



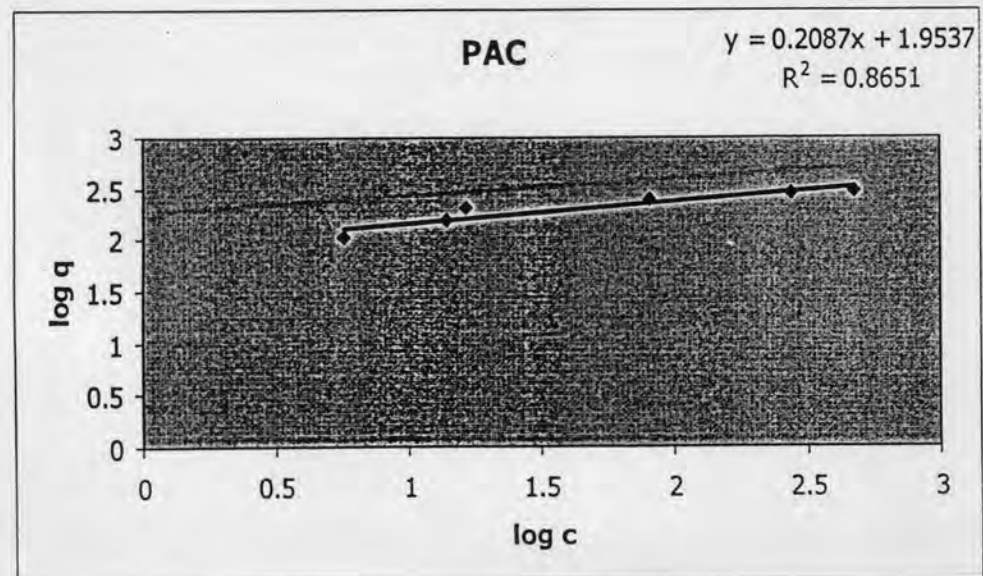
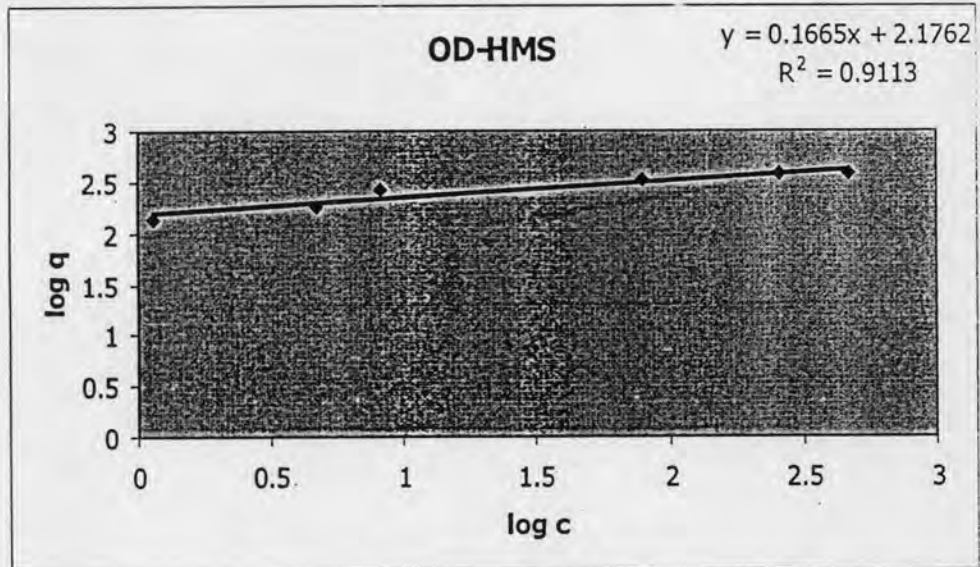
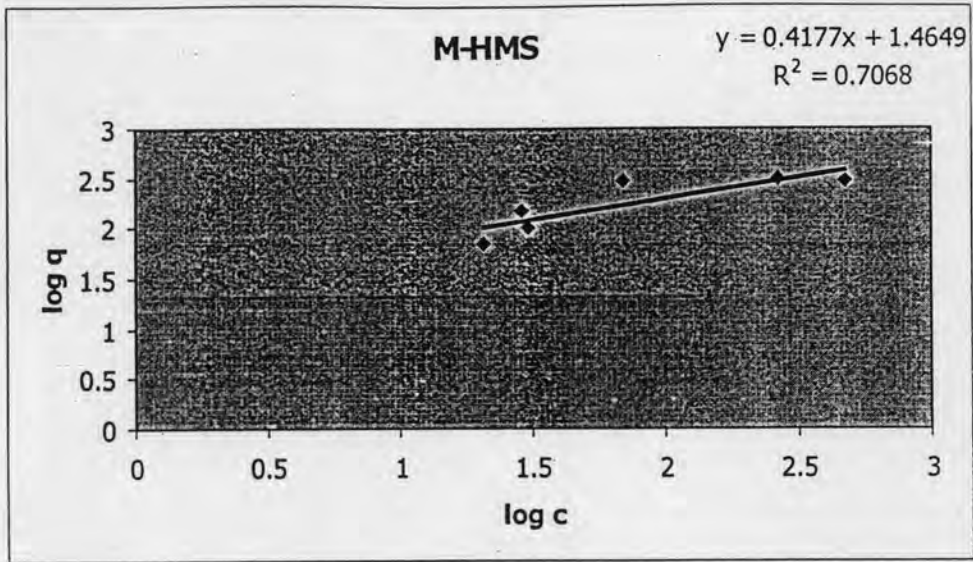
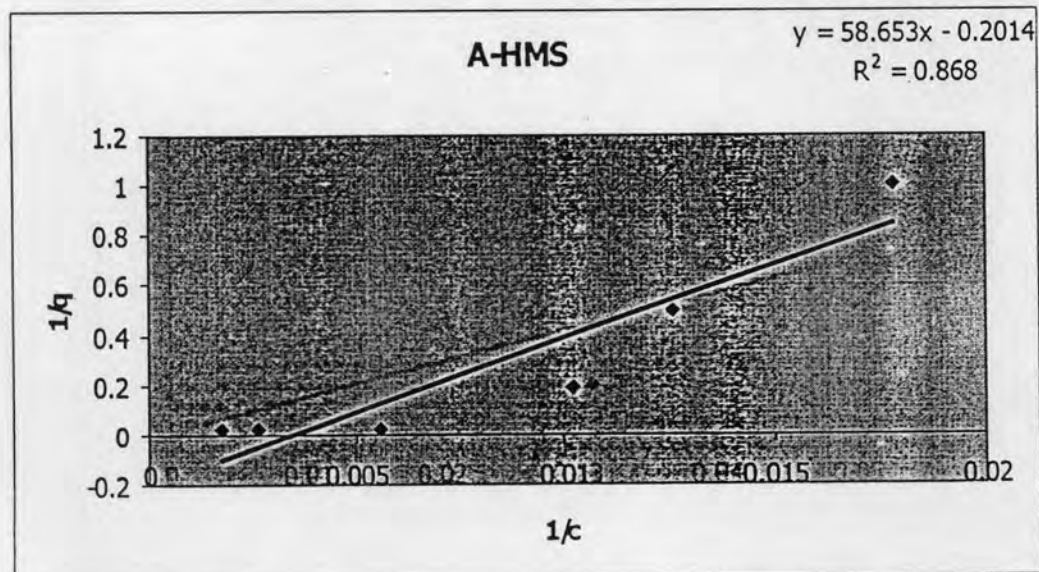
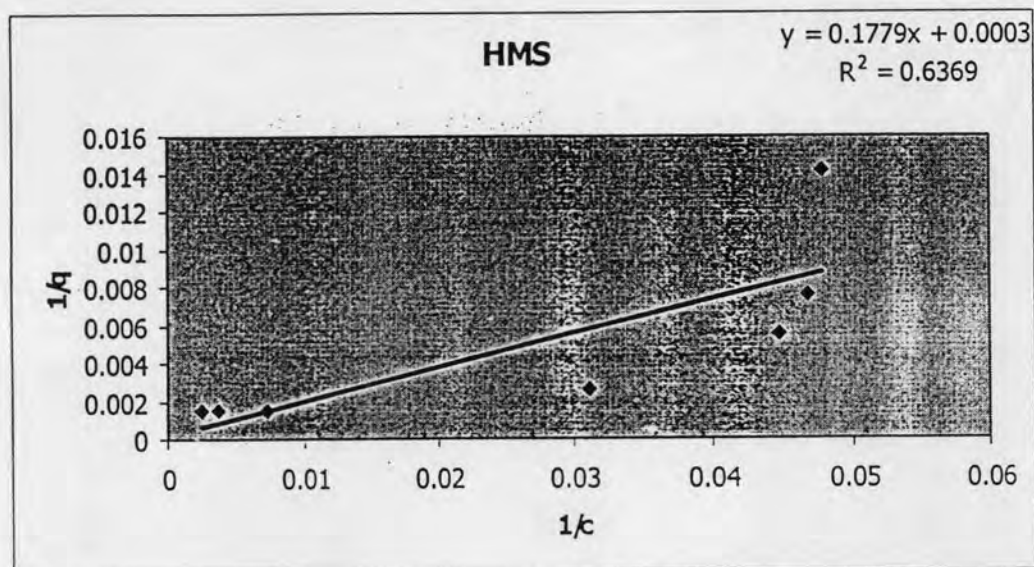




Figure G11 Langmuir model for TX-100 adsorption isotherm at pH 5 on all adsorbents



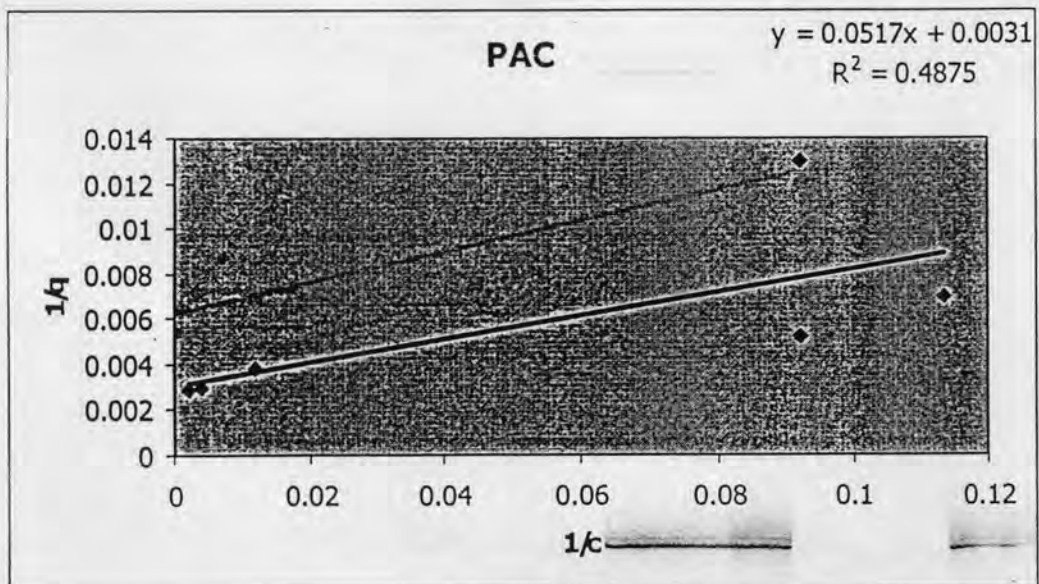
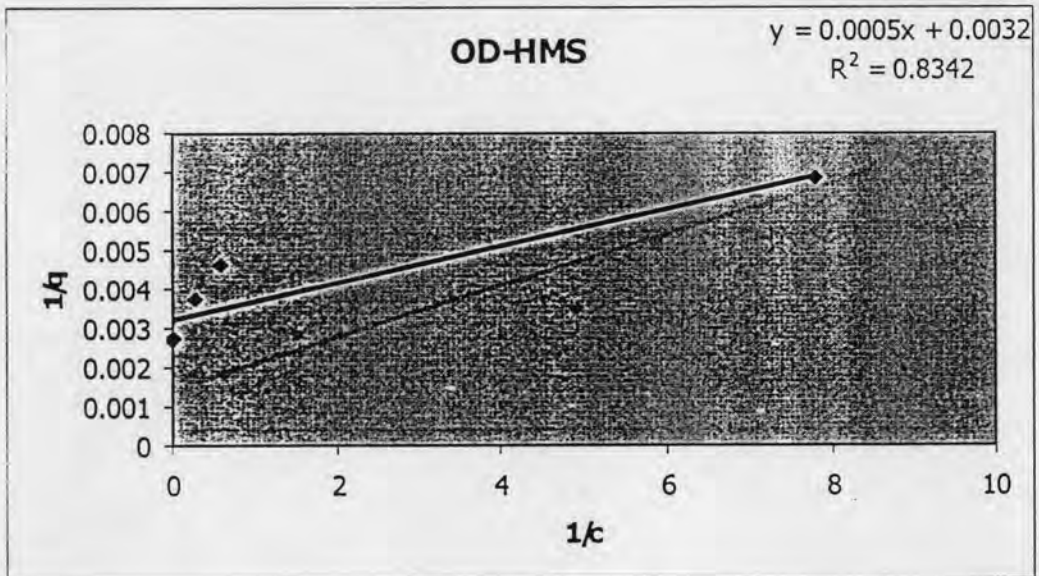
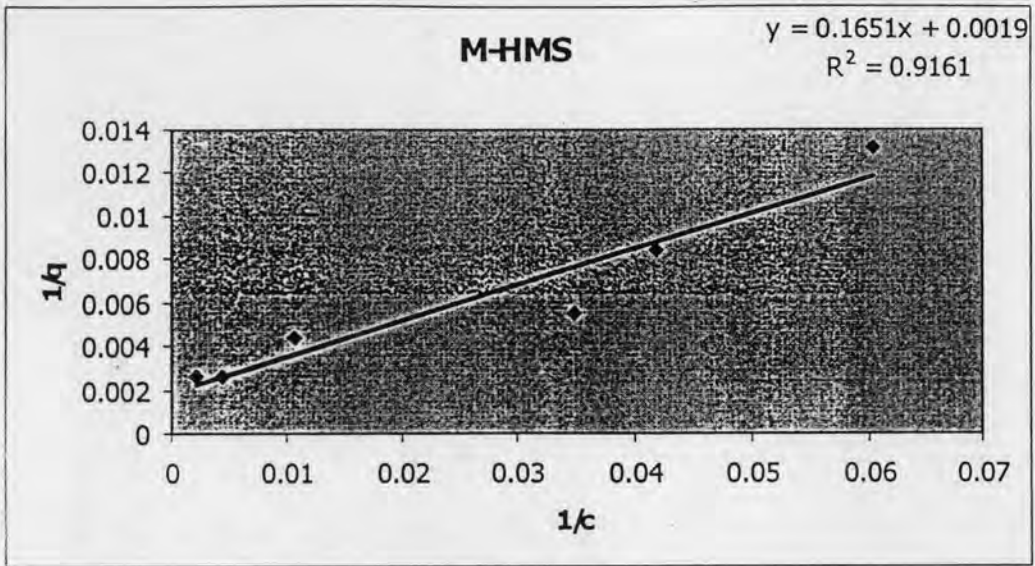
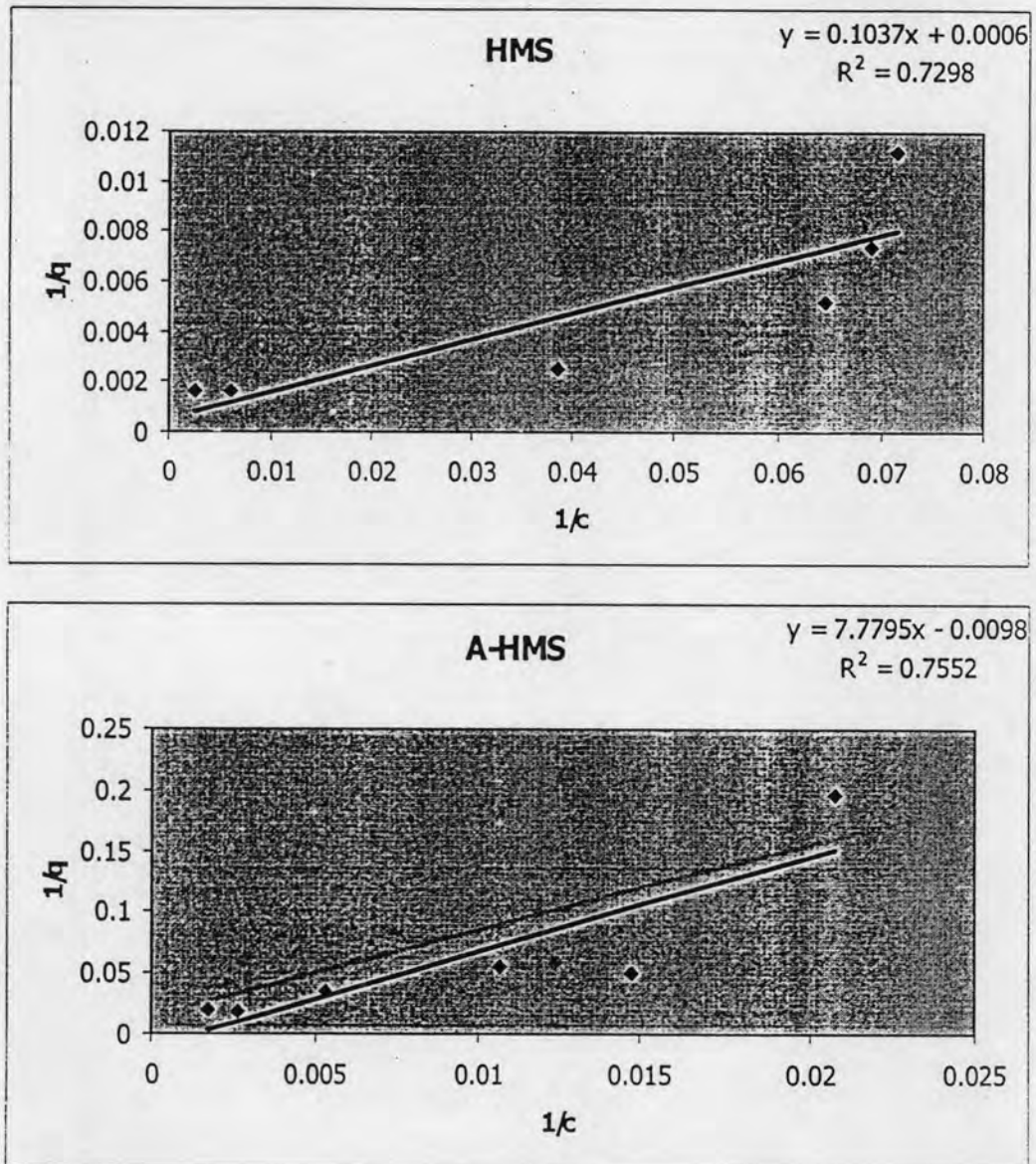


Figure G12 Langmuir model for TX-100 adsorption isotherm at pH 7 on all adsorbents



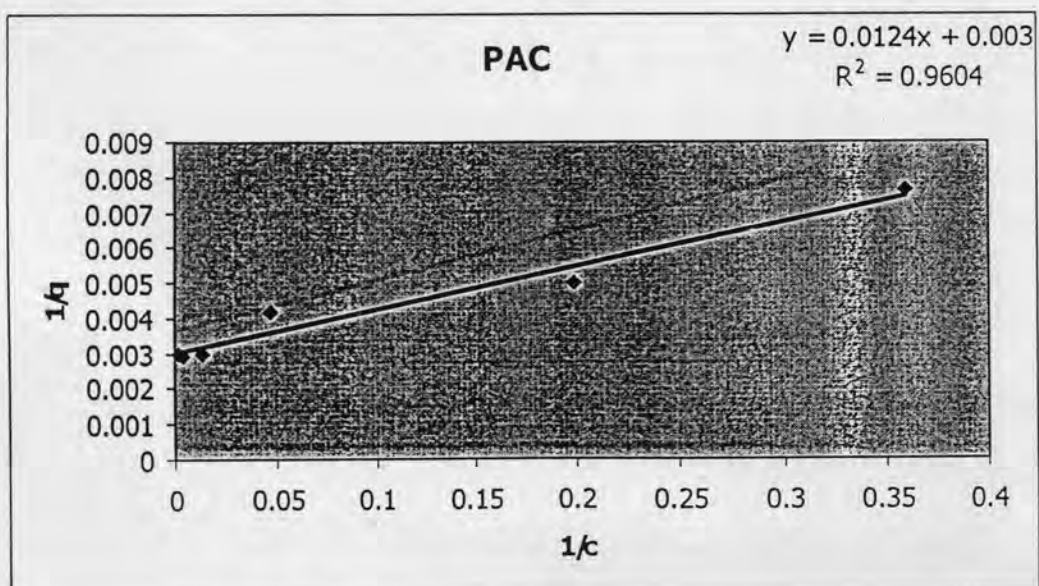
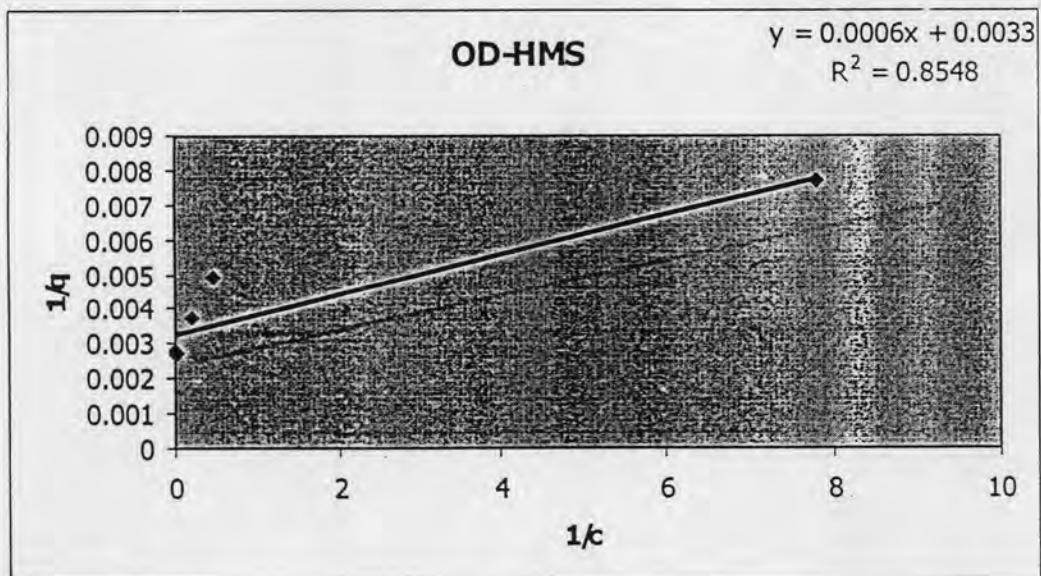
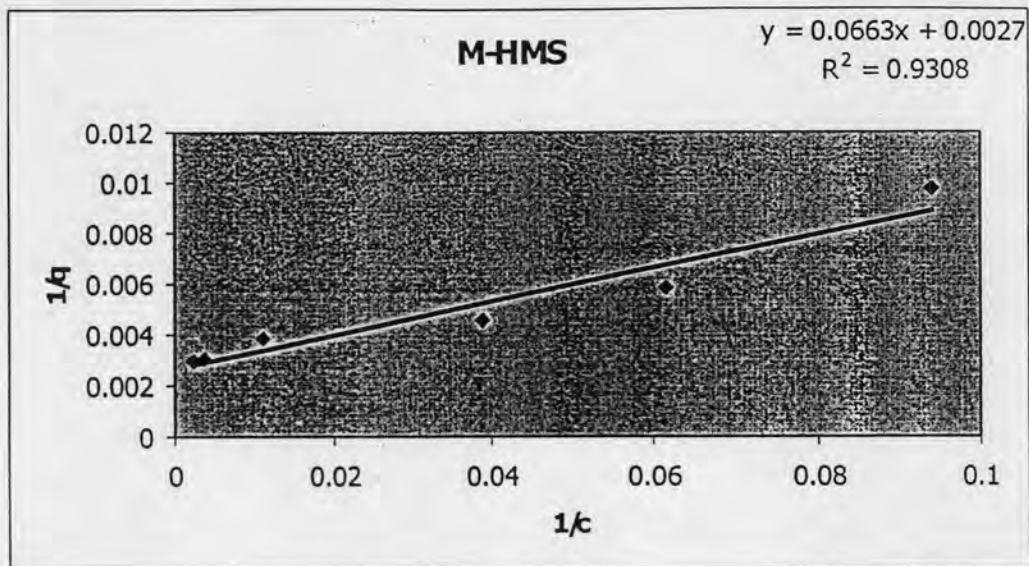
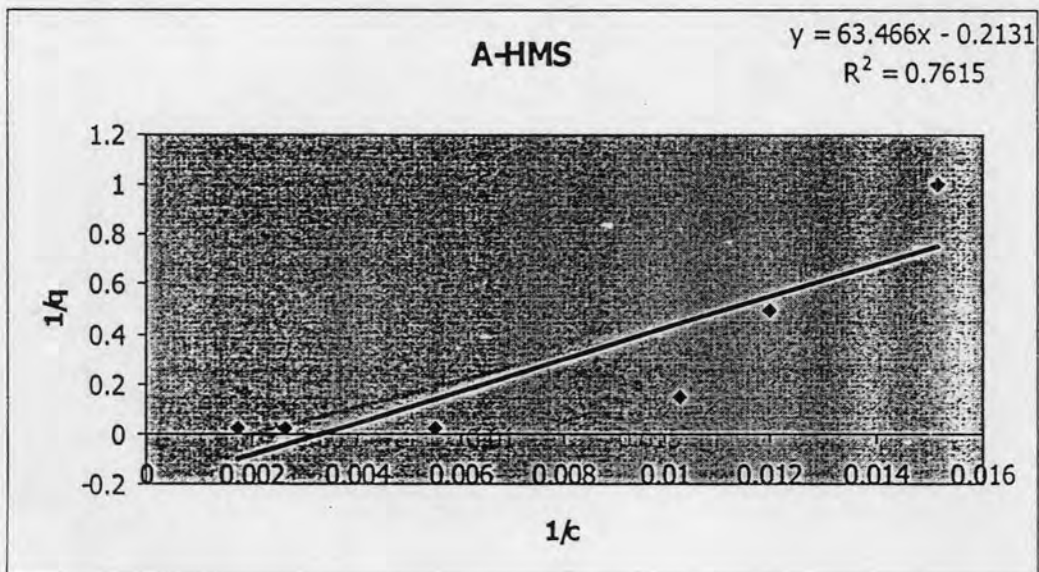
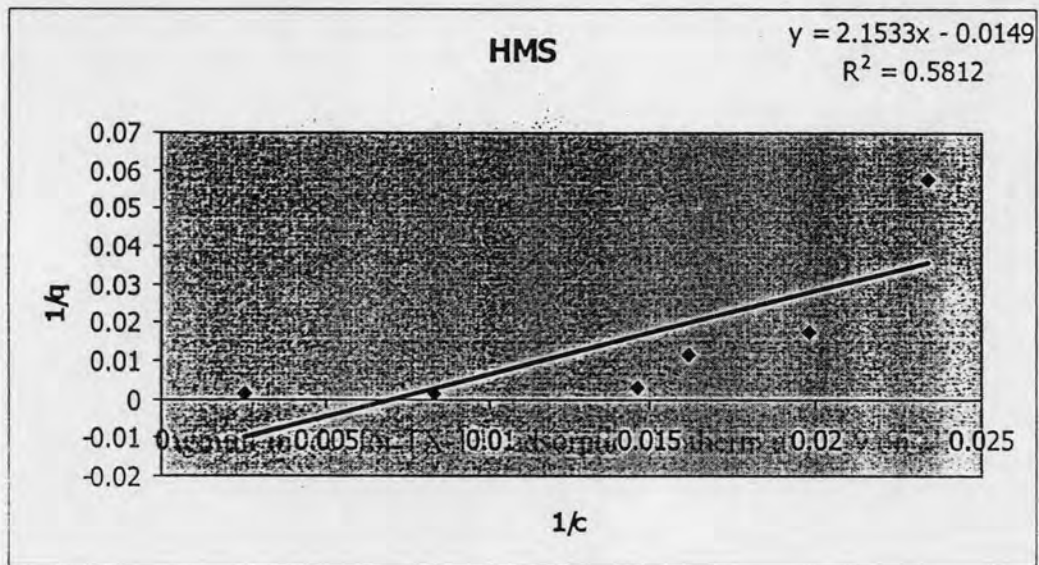


Figure G13 Langmuir model for TX-100 adsorption isotherm at pH 9 on all adsorbents



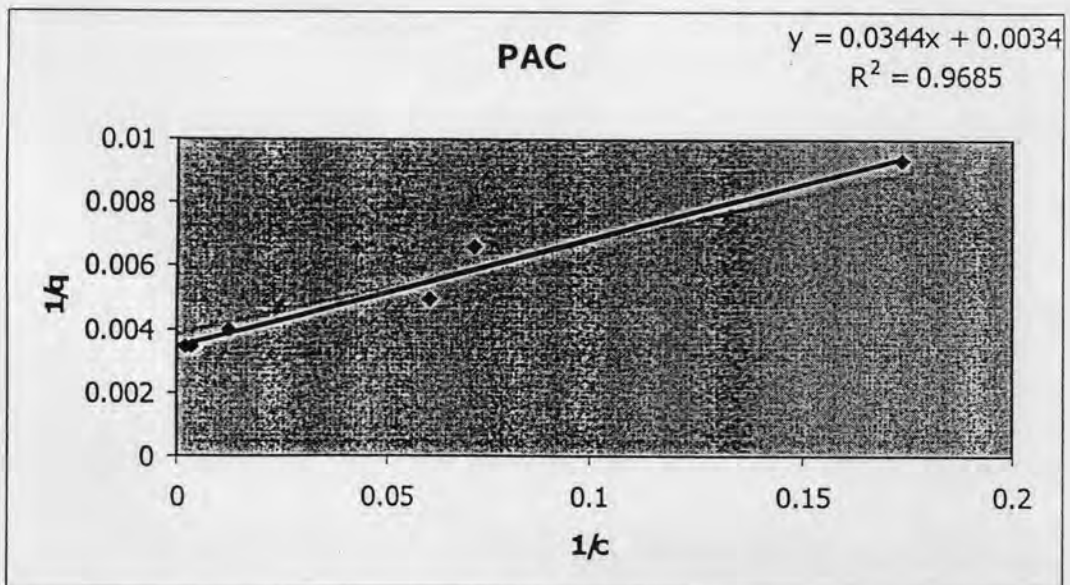
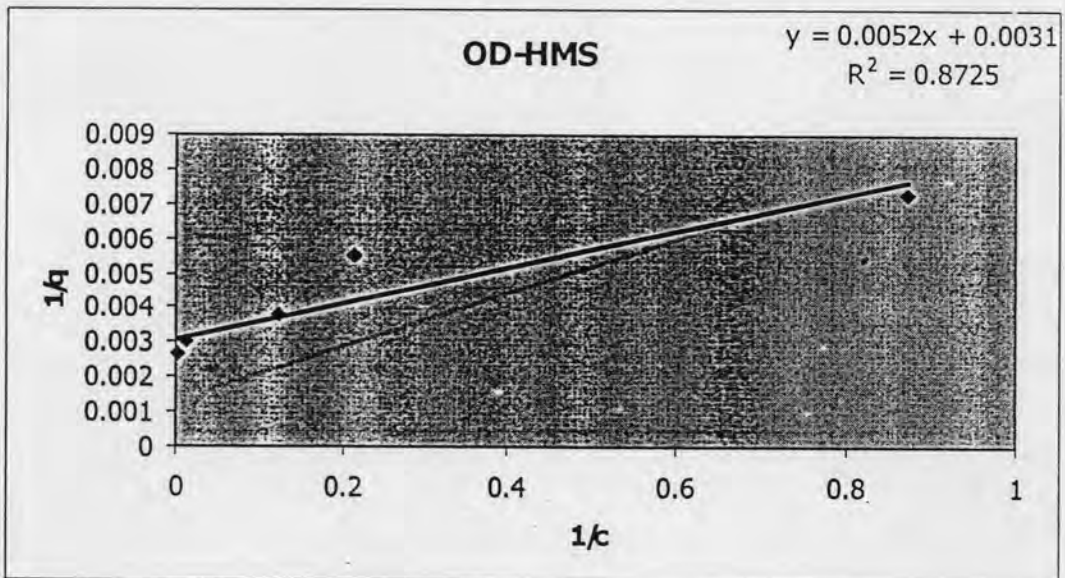
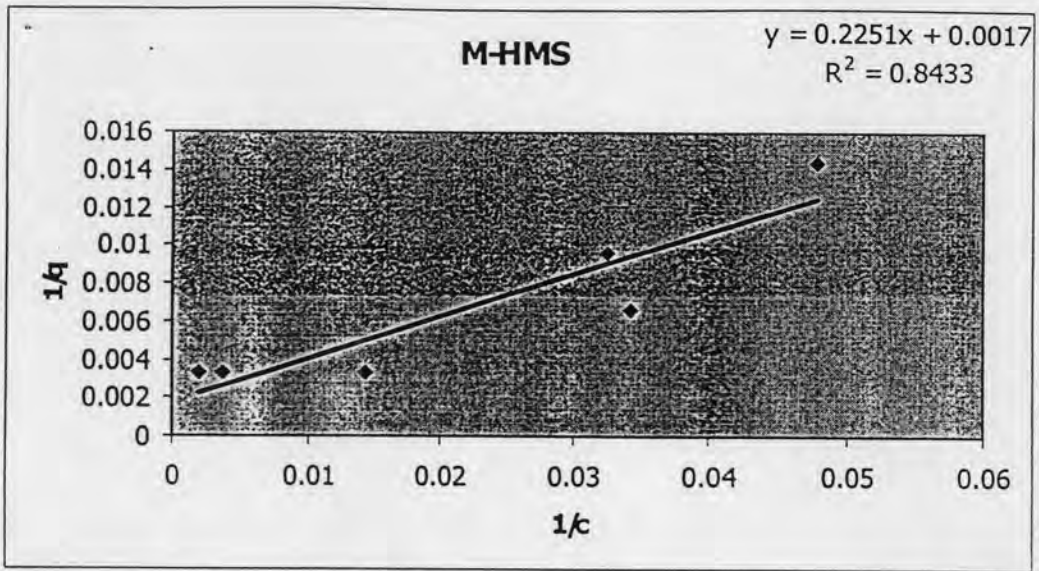
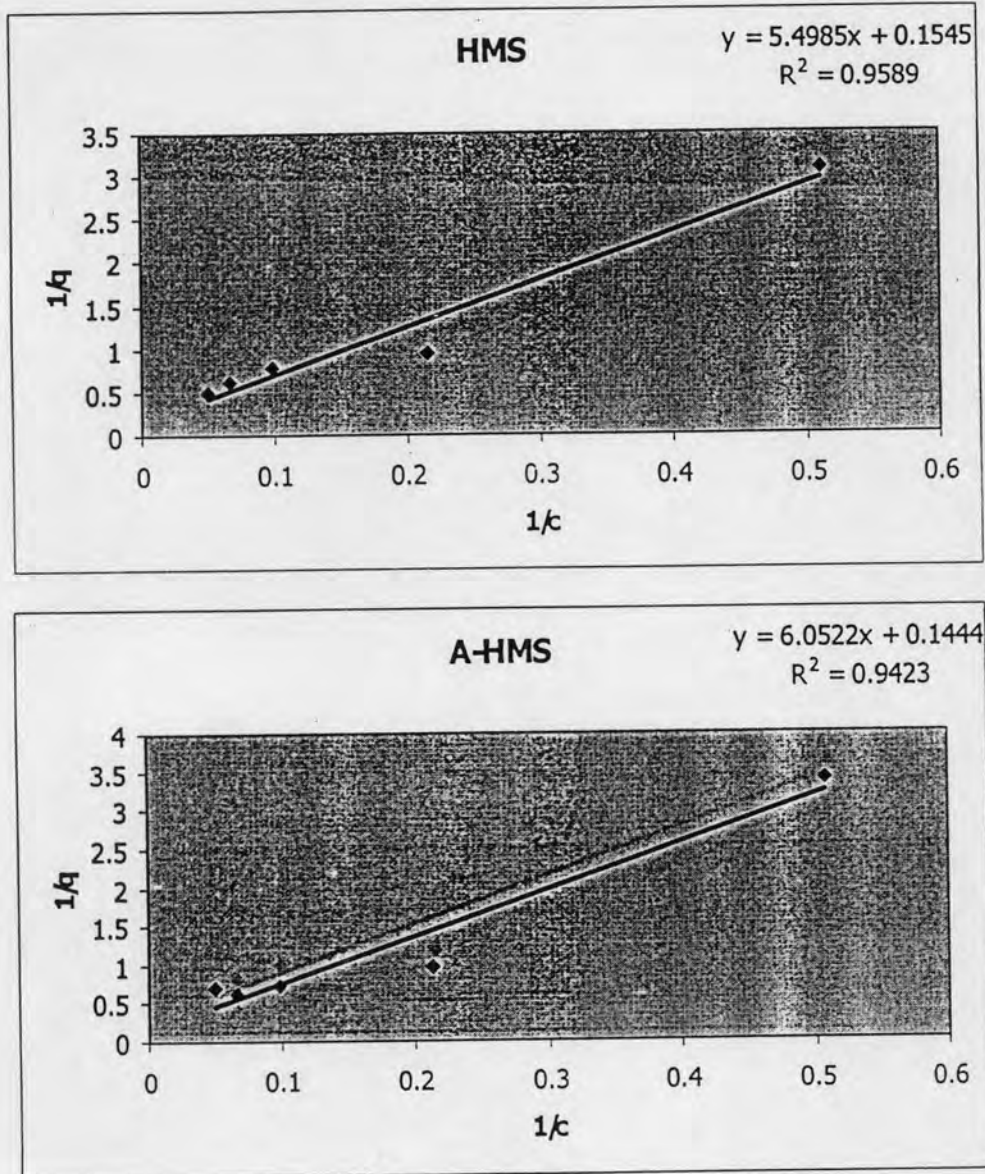


Figure G14 Langmuir model for Cd(II) adsorption isotherm at pH 3 on all adsorbents



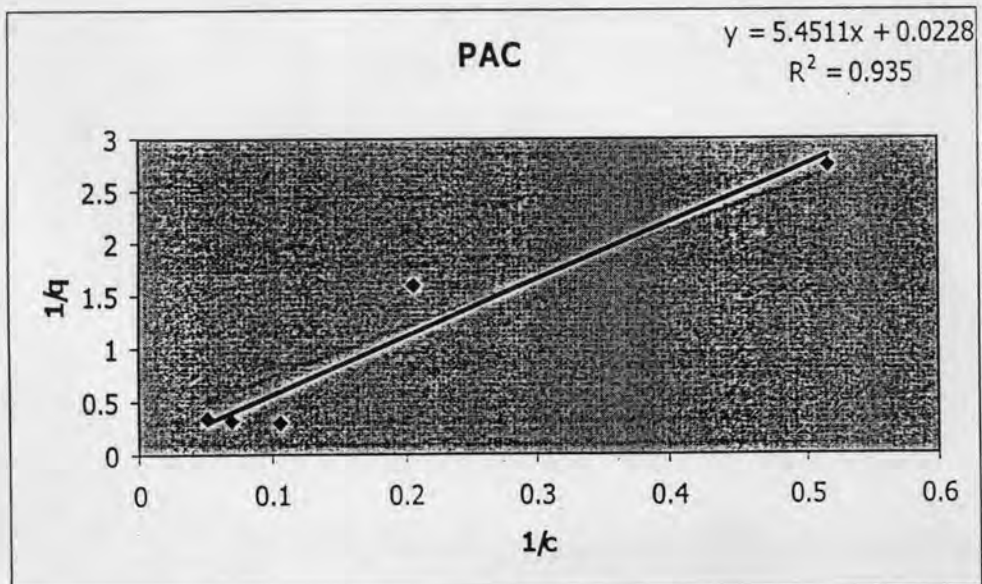
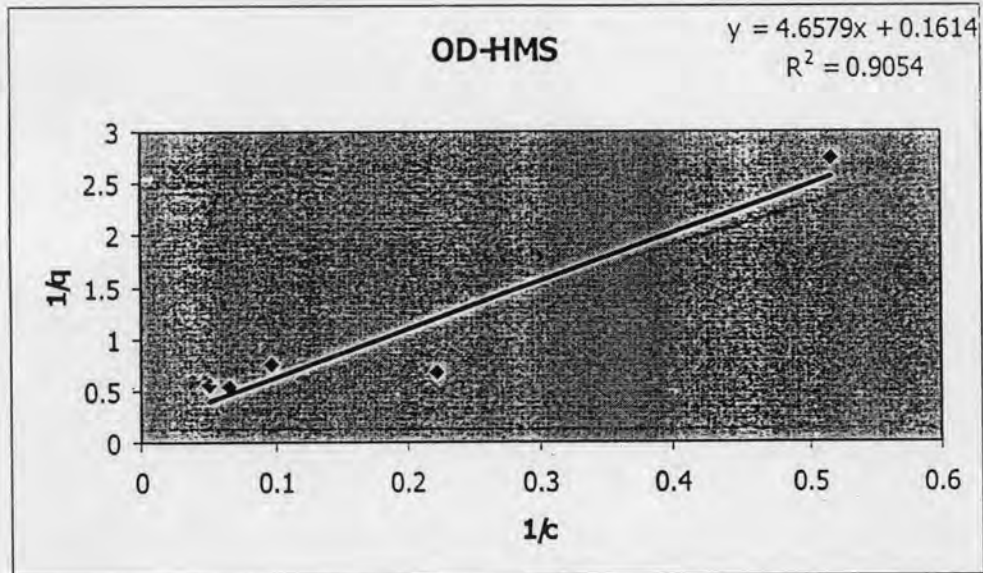
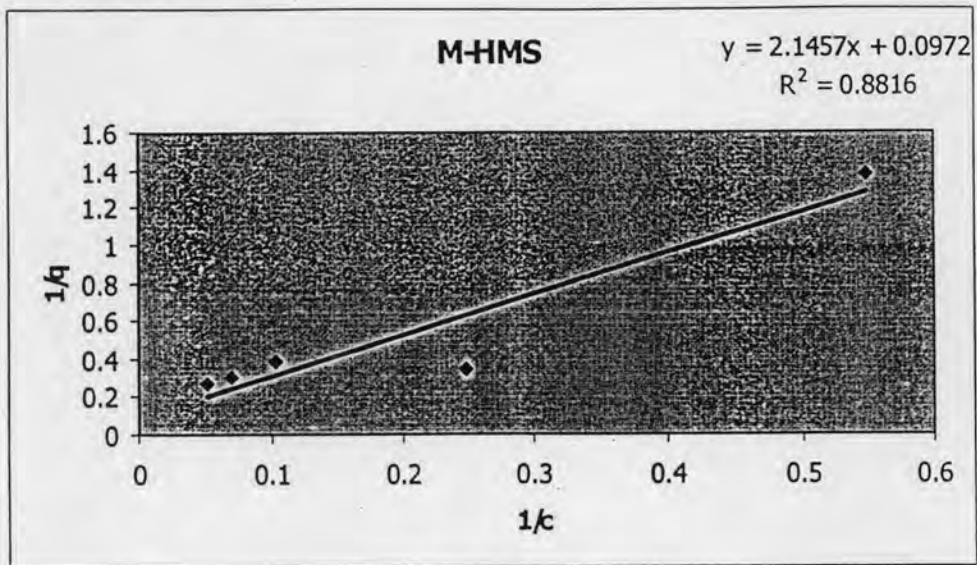
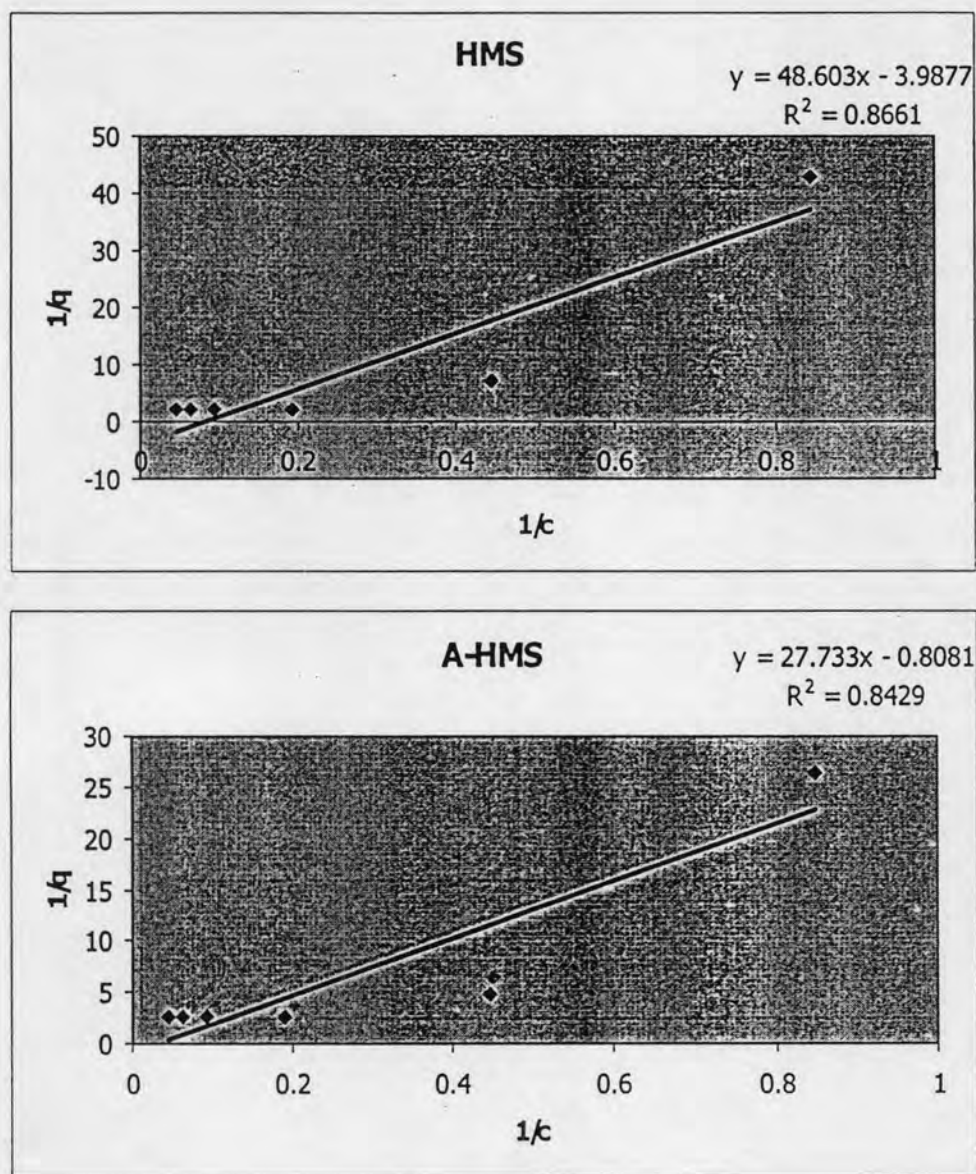




Figure G15 Langmuir model for Cd(II) adsorption isotherm at pH 5 on all adsorbents



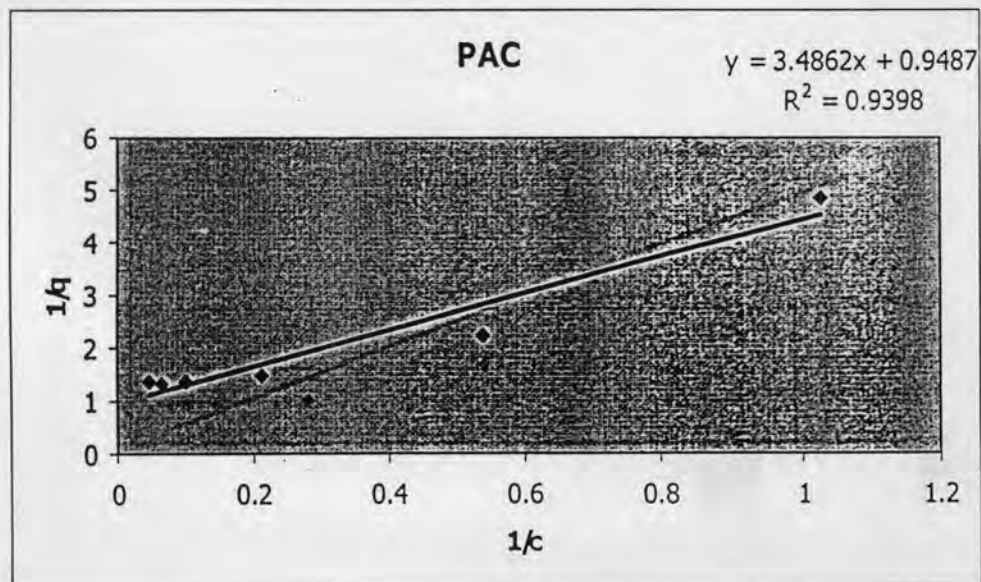
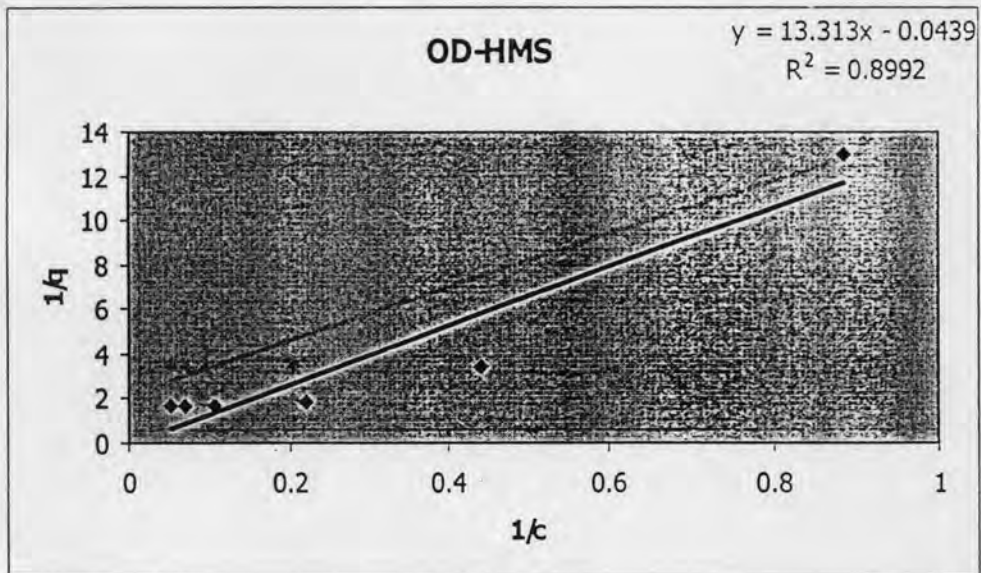
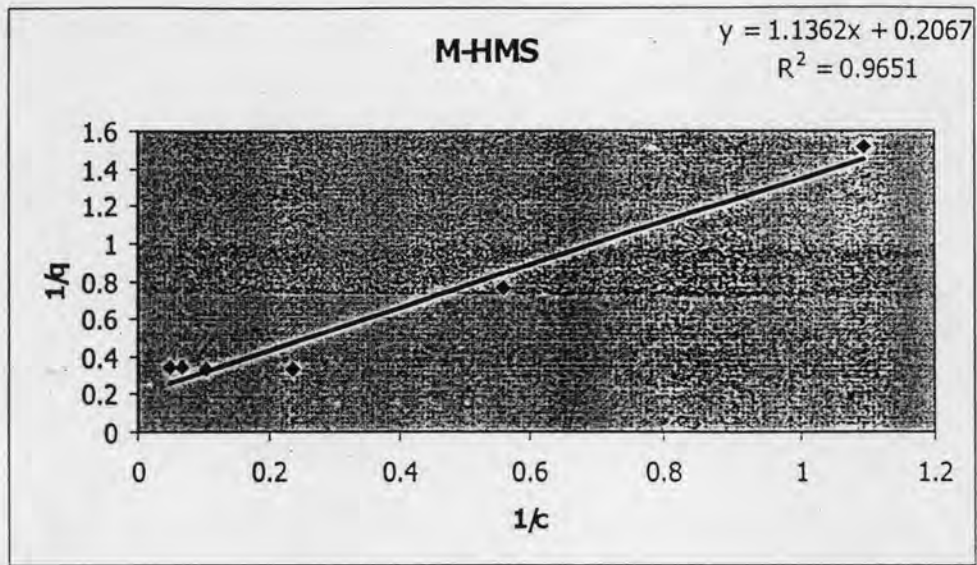
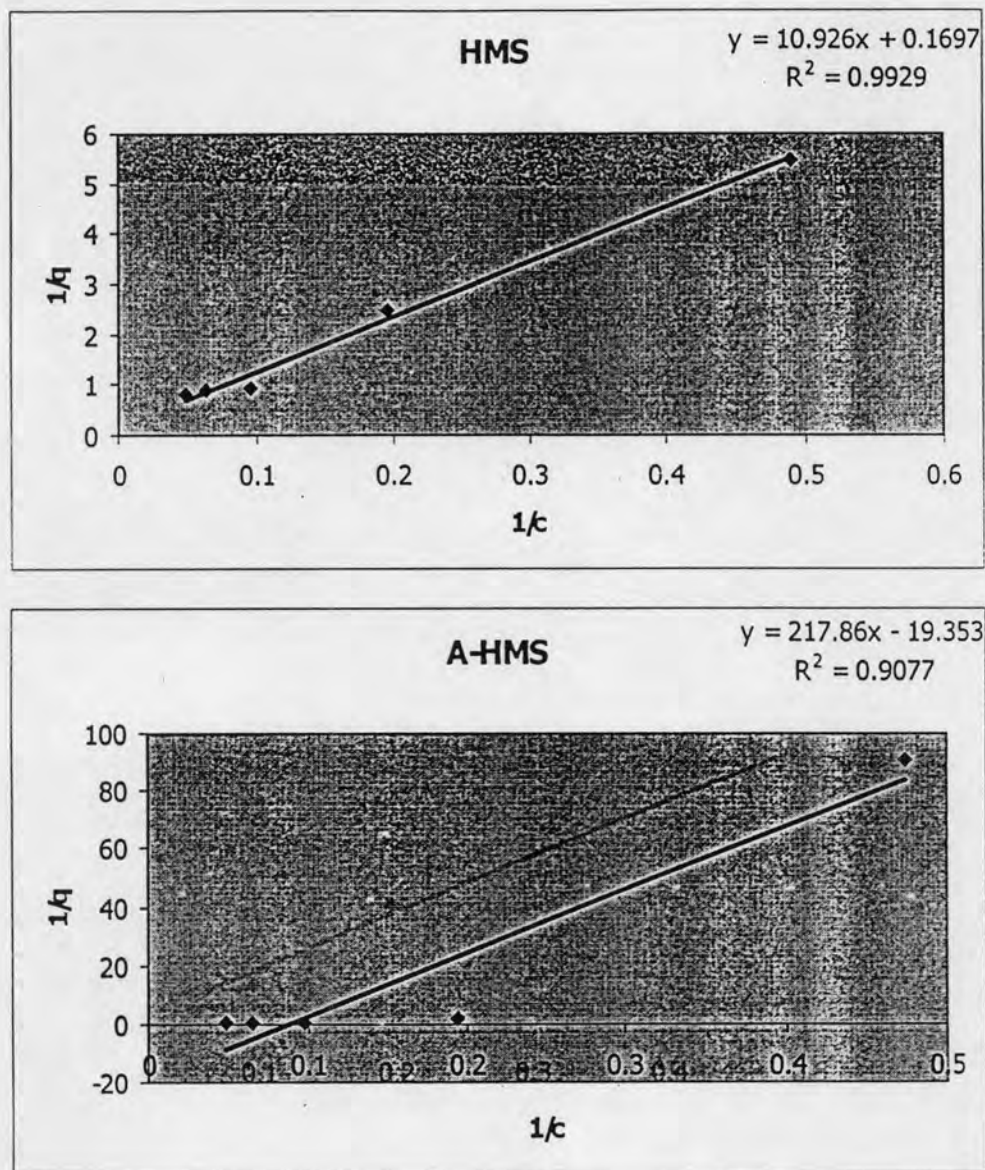


Figure G16 Langmuir model for Cu(II) adsorption isotherm at pH 3 on all adsorbents



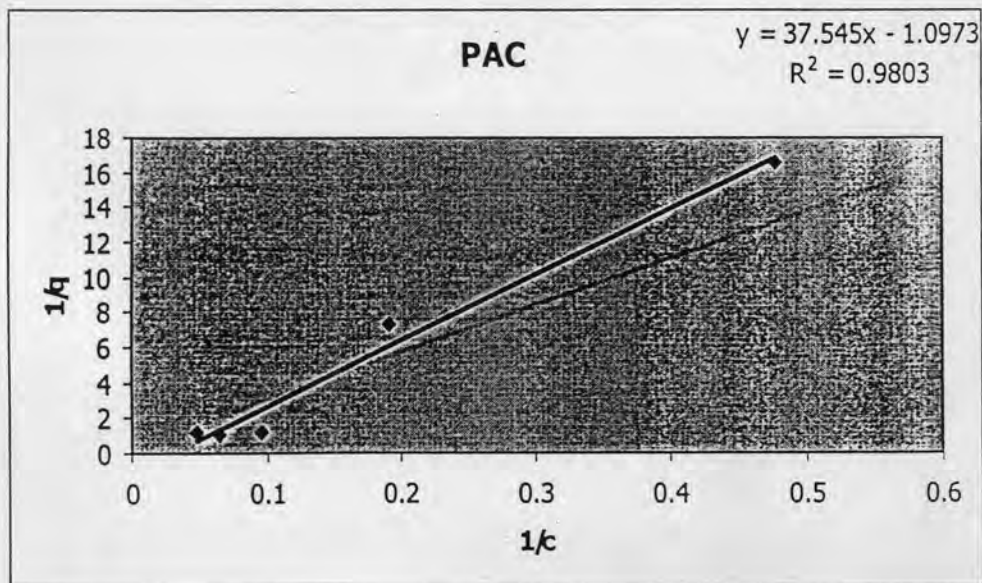
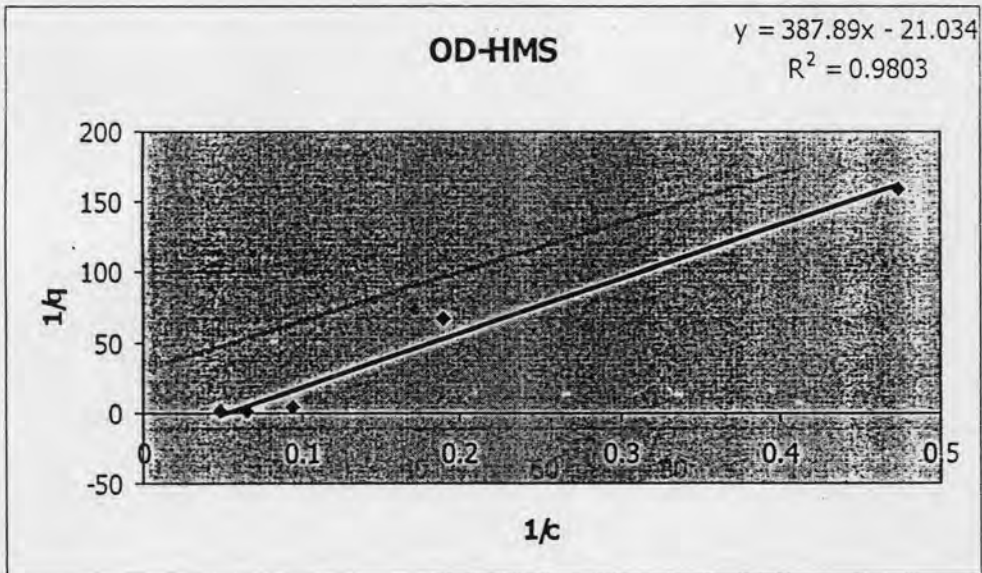
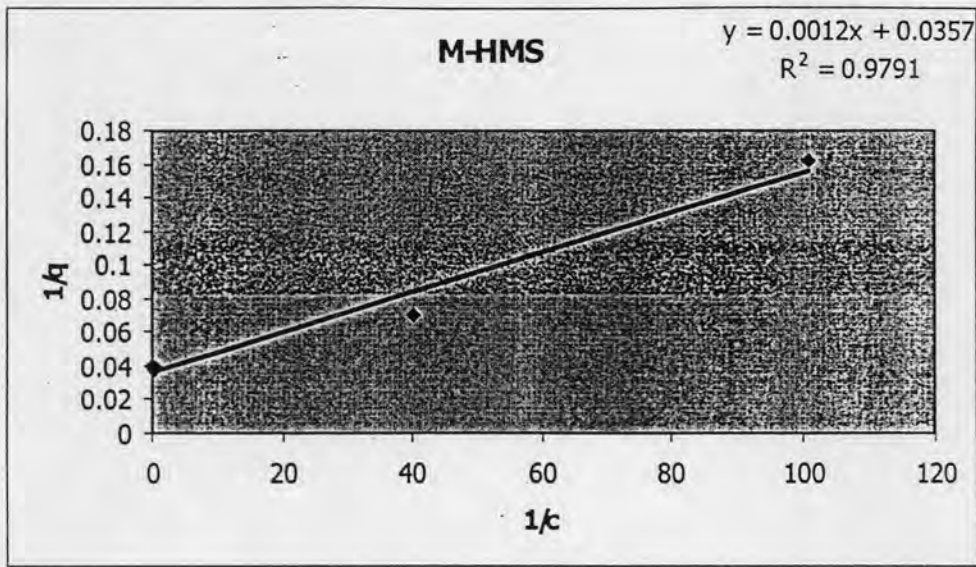
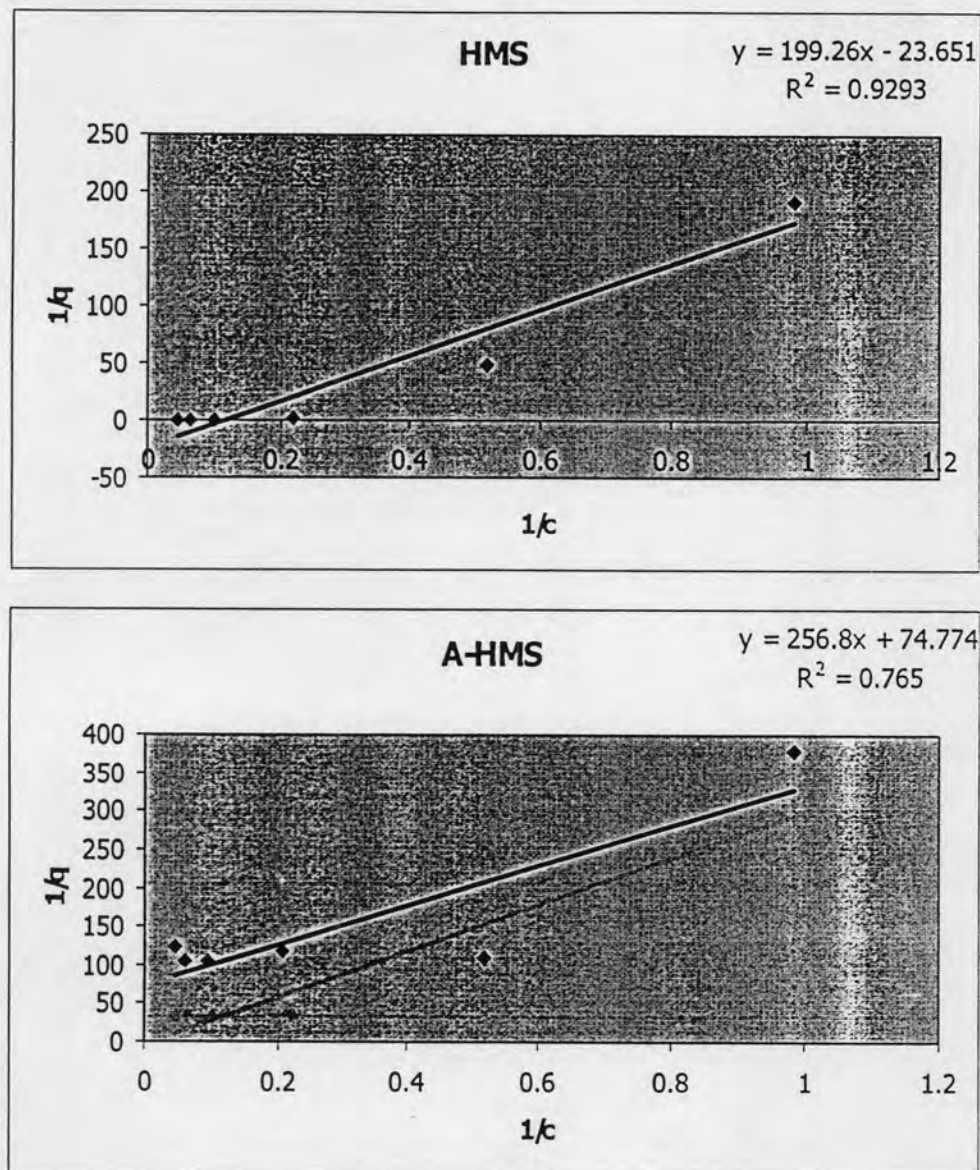


Figure G17 Langmuir model for Cu(II) adsorption isotherm at pH 5 on all adsorbents



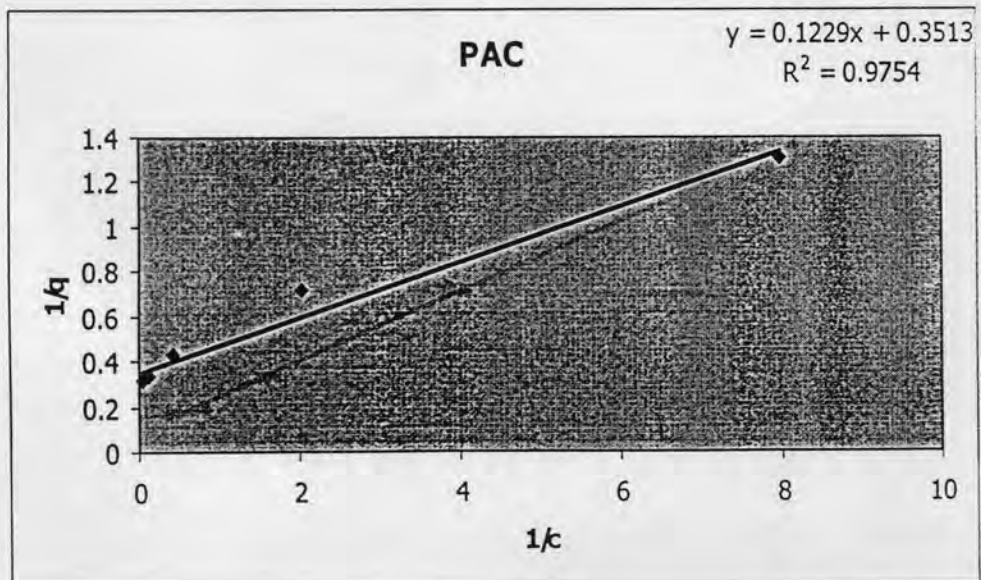
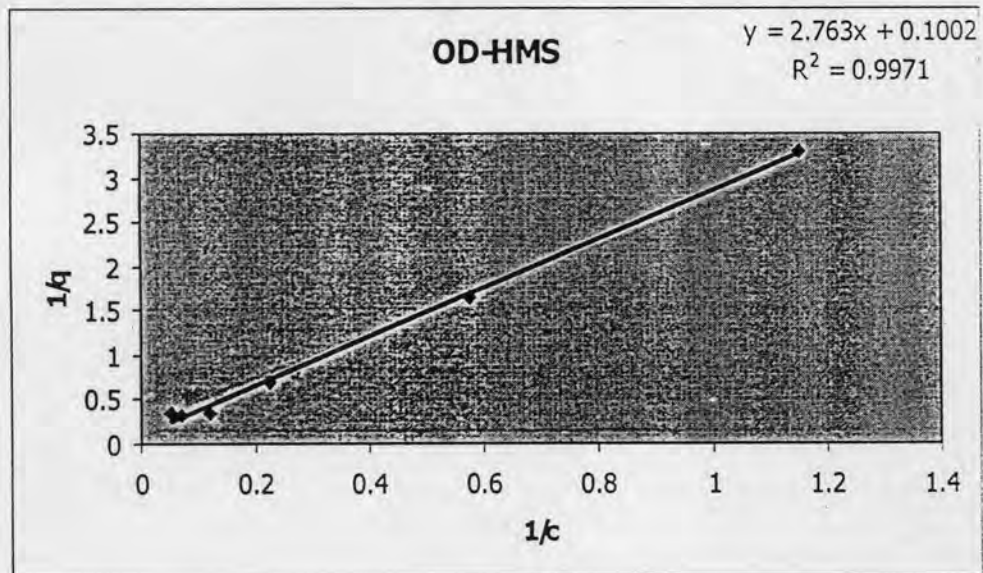
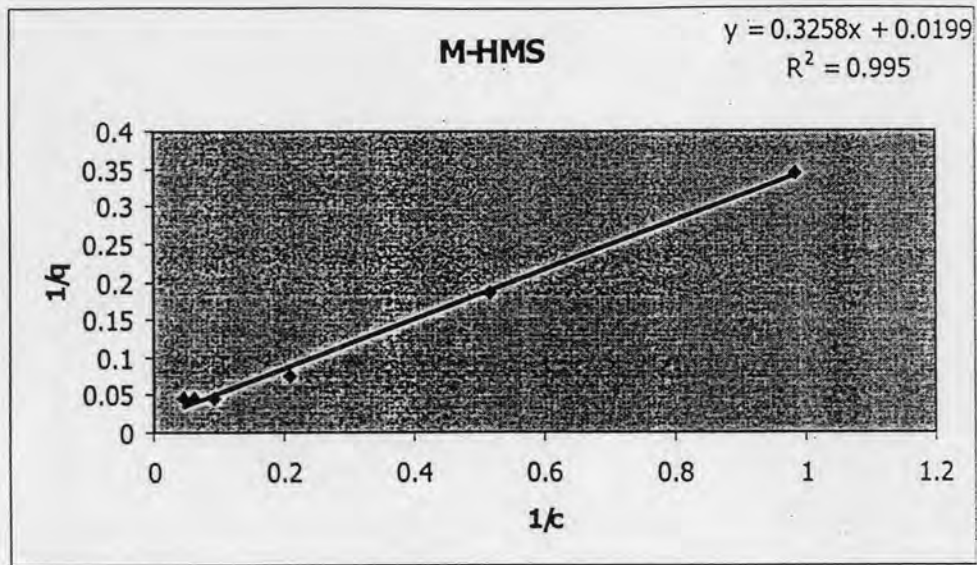
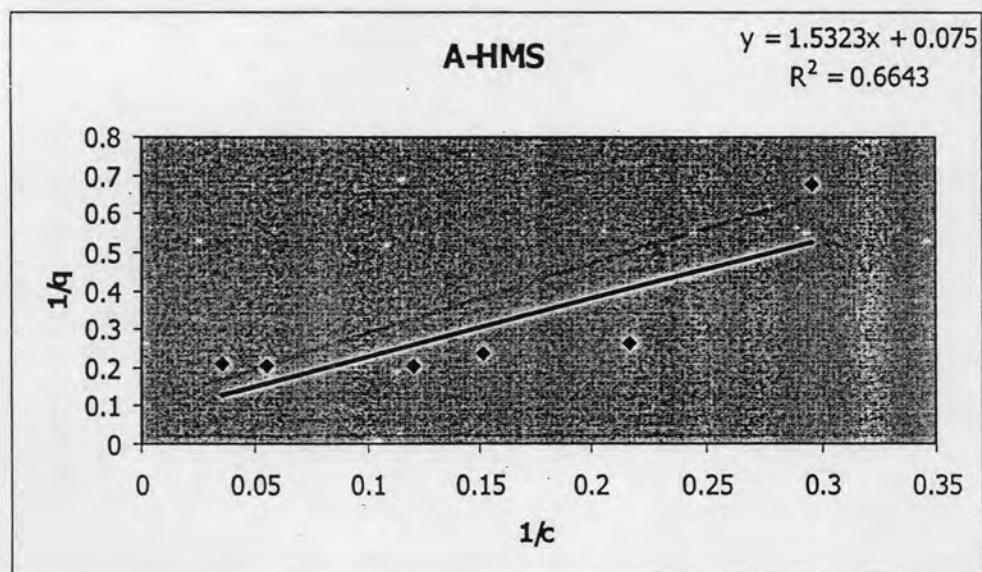
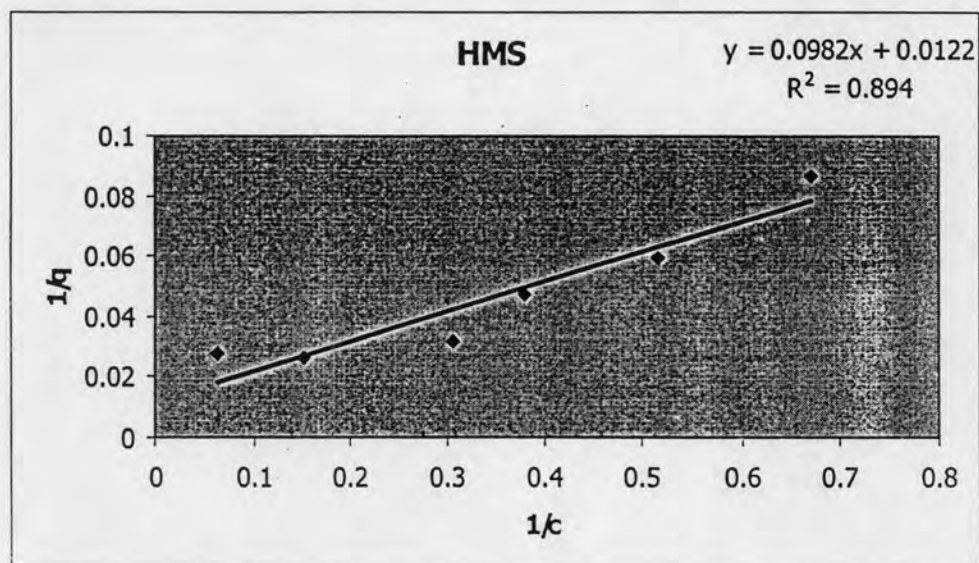
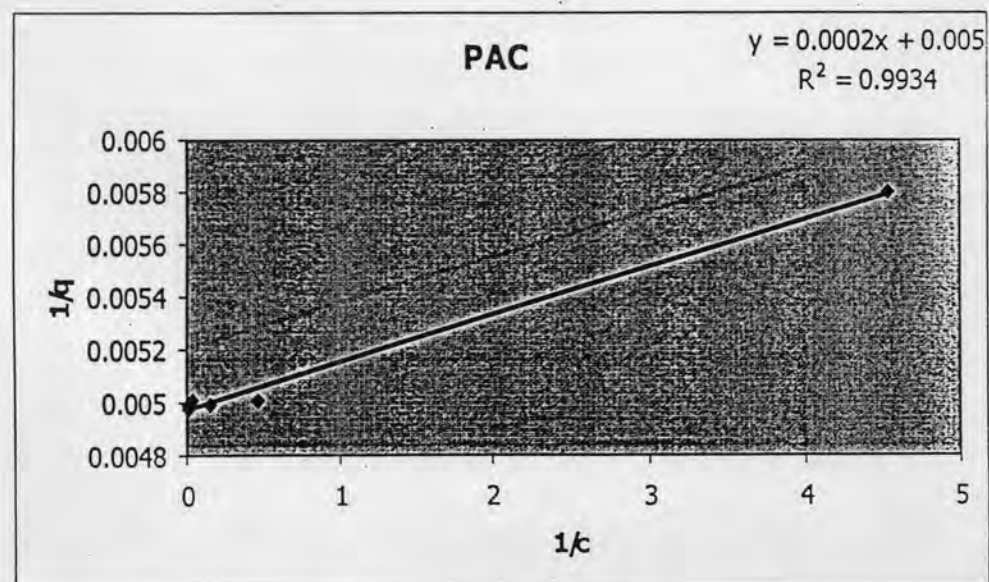
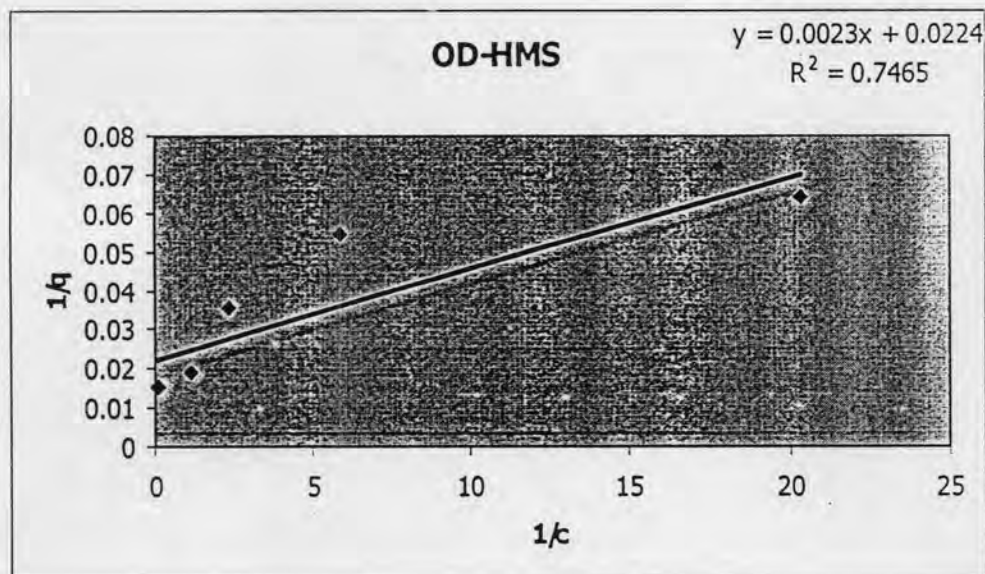
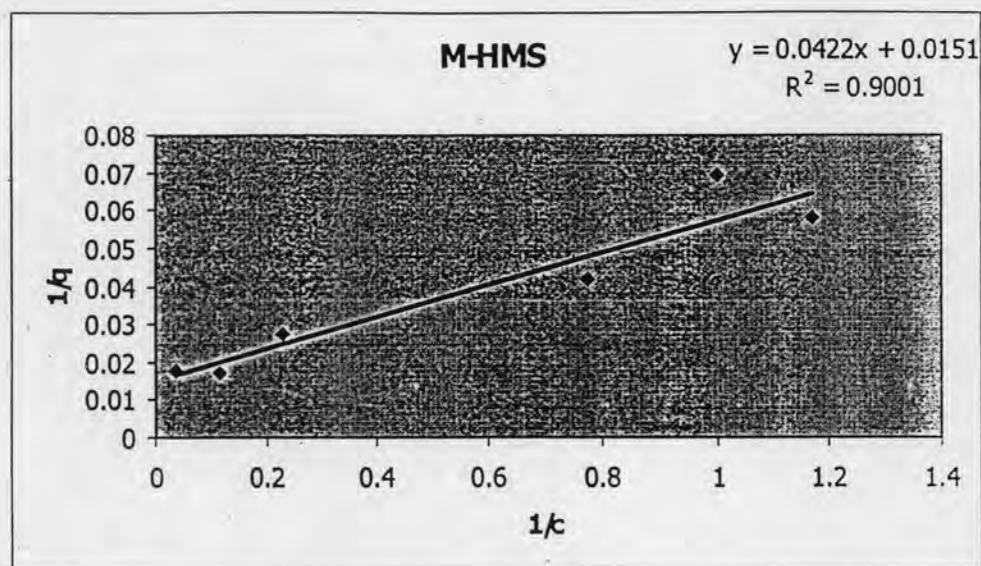


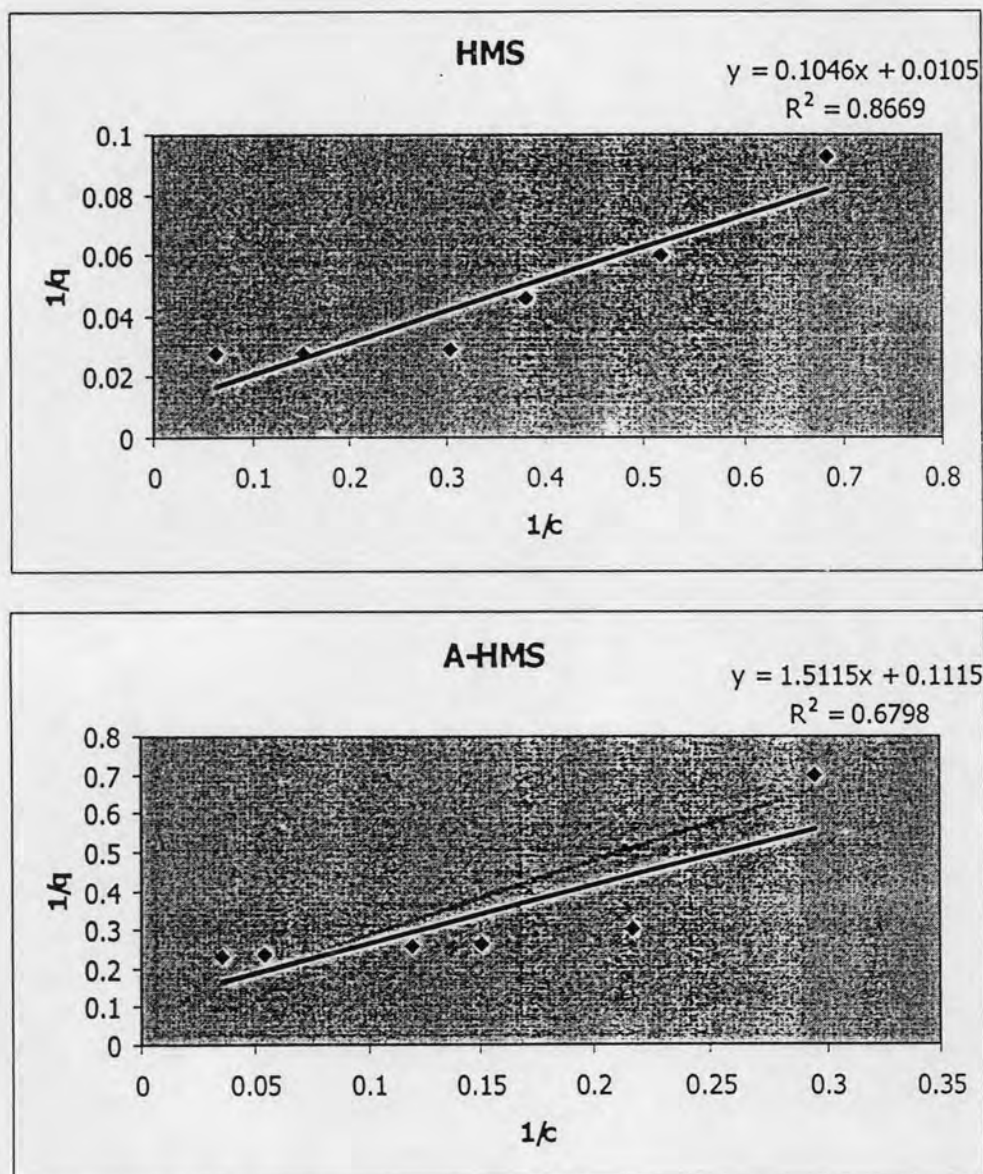
Figure G18 Langmuir model for methylene blue adsorption isotherm at pH 5 on all adsorbents







**Figure G19** Langmuir model for methylene blue adsorption isotherm at pH 7 on all adsorbents



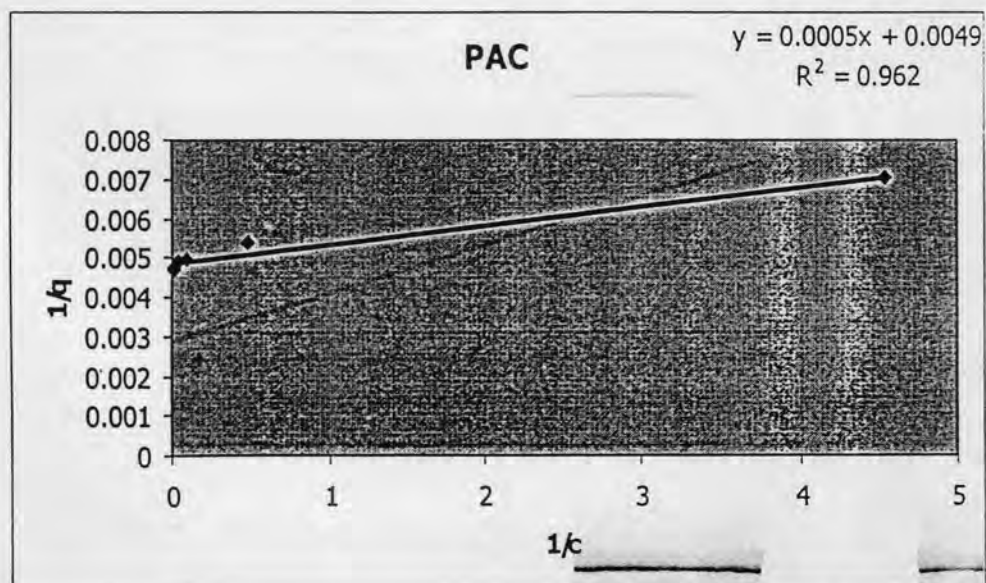
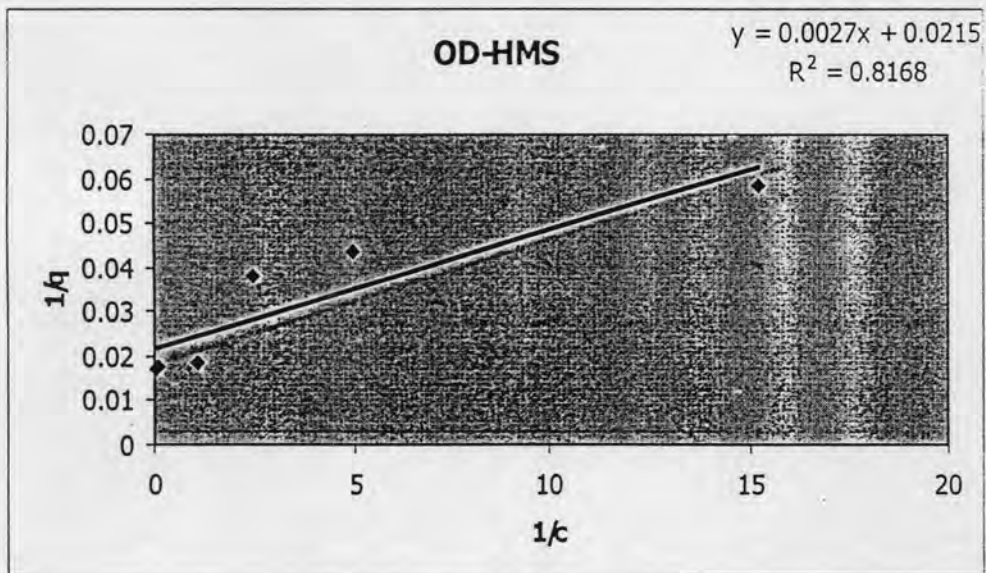
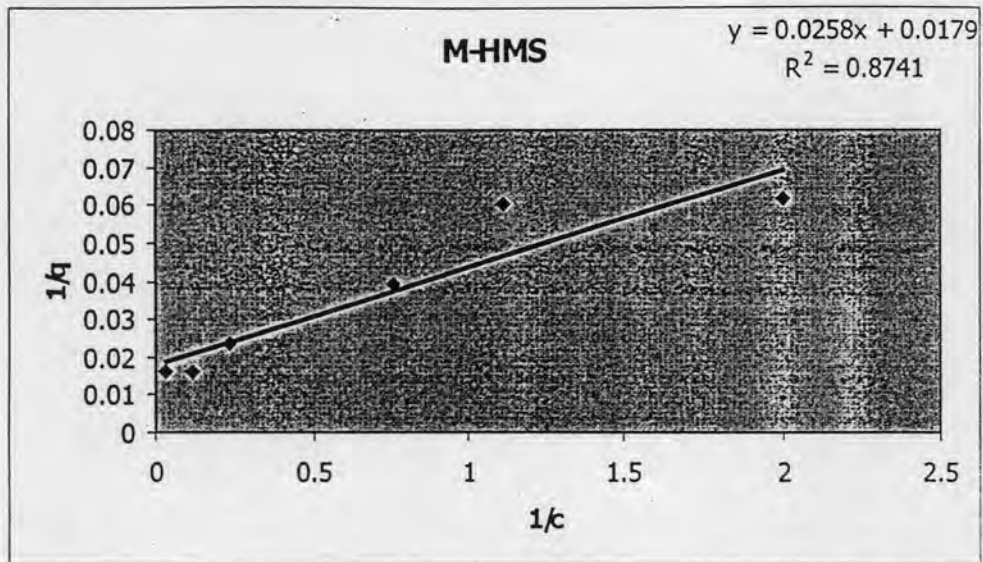
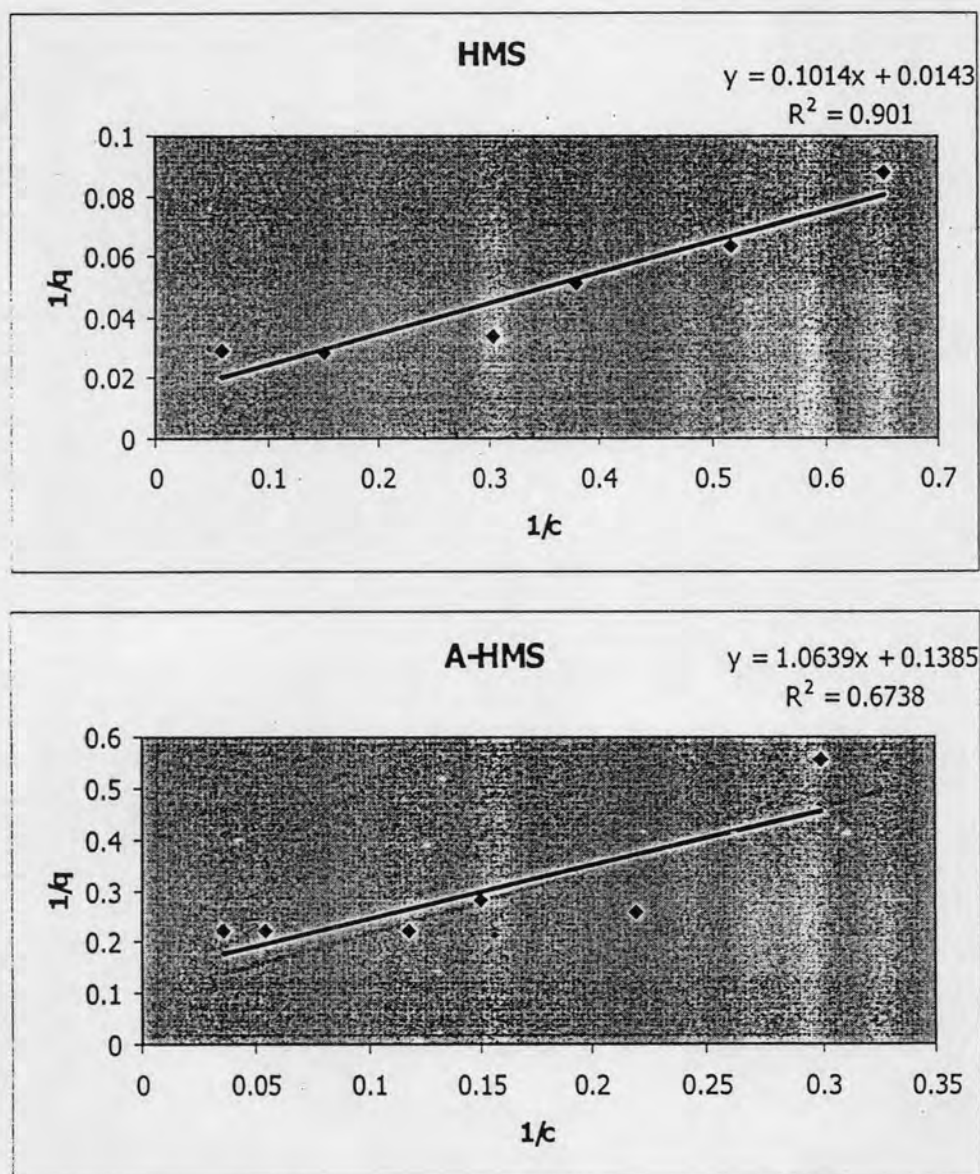
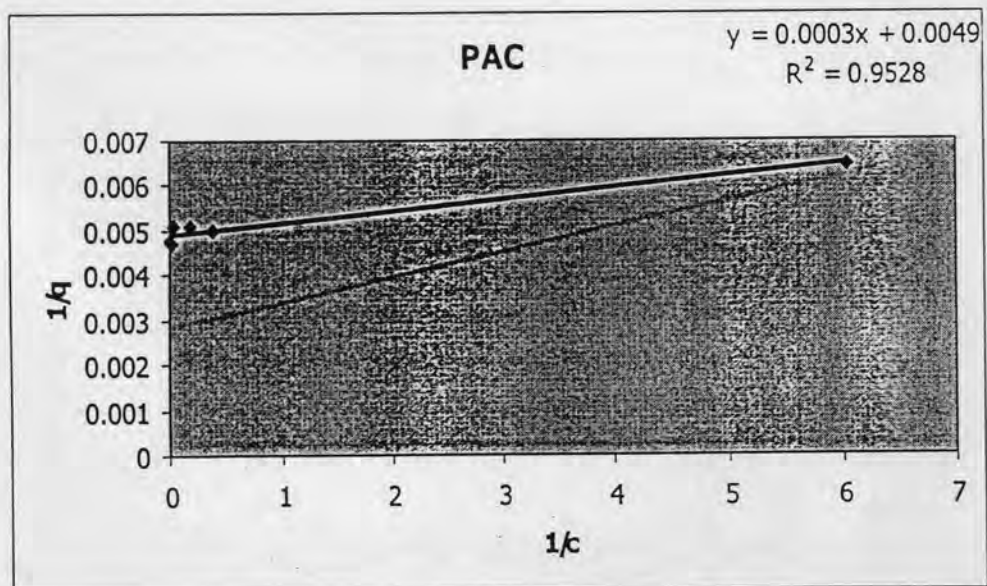
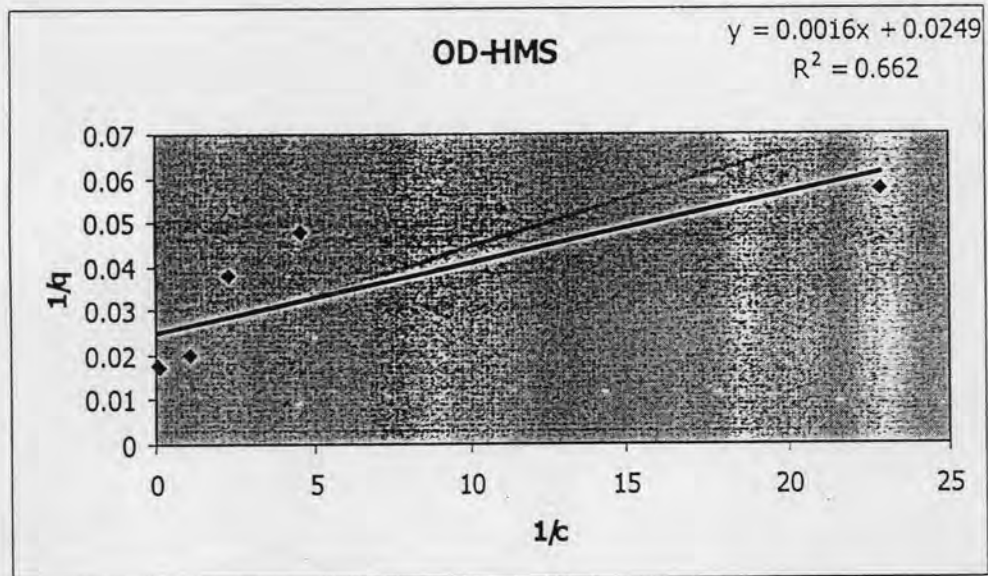
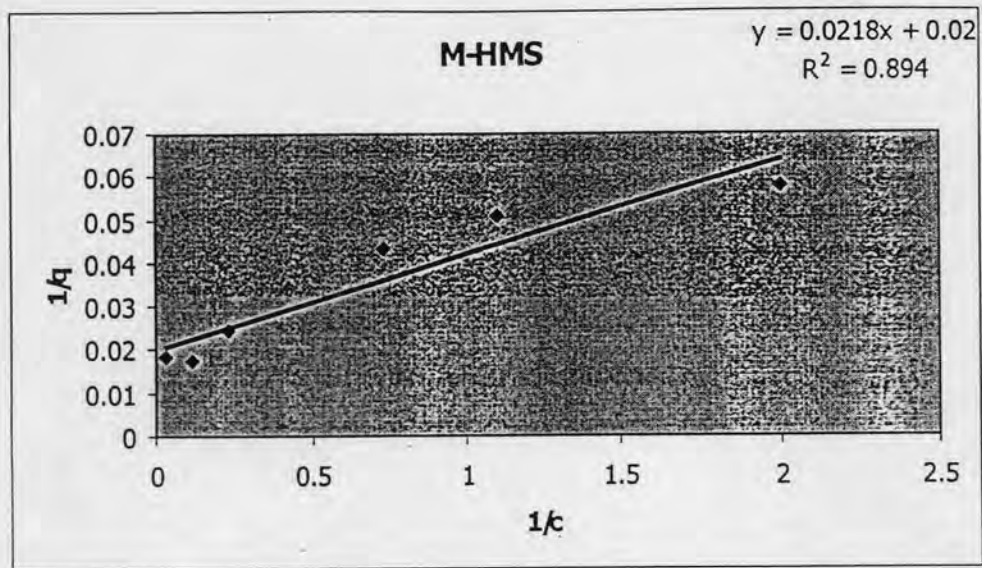


Figure G20 Langmuir model for methylene blue adsorption isotherm at pH 9 on all adsorbents





## BIOGRAPHY

Mr. Worachat Paisanjit was born on 27<sup>th</sup> February, 1985 in Bangkok. After he graduated high school in Assumption College, Bangkok, he studied in Faculty of Science at Mahidol University. He graduated Bachelor's degree of Science in Biotechnology in 2007. After that he continued his study for a Master's Degree of Science in Environmental Management (International Program) at Chulalongkorn University in May, 2007.

