

## SUPPLEMENTARY MATERIALS

### **Optimizing the Influence of Novel Citric Acid-Assisted Mechanochemical Modification of Corncob on Cu<sup>2+</sup>, Pb<sup>2+</sup> and Zn<sup>2+</sup> Removal**

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**Table S1.** (1) ANOVA of MCM for (a) Cu<sup>2+</sup>, (b) Pb<sup>2+</sup>, (c) Zn<sup>2+</sup> ions removal (%); (2) ANOVA of CA-MCM for (a) Cu<sup>2+</sup>, (b) Pb<sup>2+</sup>, (c) Zn<sup>2+</sup> ions removal (%)

| (1)                                                                                                              |        |         |         |              |      | (2)                                                                                                              |        |         |         |              |      |
|------------------------------------------------------------------------------------------------------------------|--------|---------|---------|--------------|------|------------------------------------------------------------------------------------------------------------------|--------|---------|---------|--------------|------|
| (a)                                                                                                              |        |         |         |              |      | (b)                                                                                                              |        |         |         |              |      |
| Term                                                                                                             | Coef   | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                             | Coef   | SE Coef | T-Value | P-Value      | VIF  |
| Constant                                                                                                         | 40.337 | 0.694   | 58.16   | 0.000        |      | Constant                                                                                                         | 60.792 | 0.419   | 144.99  | 0.000        |      |
| RS (rpm)                                                                                                         | 4.369  | 0.460   | 9.49    | 0.000        | 1.00 | RS (rpm)                                                                                                         | 2.966  | 0.278   | 10.66   | 0.000        | 1.00 |
| B/M ratio (g/g)                                                                                                  | 0.897  | 0.460   | 1.95    | 0.061        | 1.00 | B/M ratio (g/g)                                                                                                  | 1.210  | 0.278   | 4.35    | 0.000        | 1.00 |
| t (min)                                                                                                          | 1.039  | 0.460   | 2.26    | 0.031        | 1.00 | t (min)                                                                                                          | 2.568  | 0.278   | 9.23    | 0.000        | 1.00 |
| RS (rpm)*RS (rpm)                                                                                                | 4.408  | 0.448   | 9.84    | 0.000        | 1.02 | RS (rpm)*RS (rpm)                                                                                                | -0.112 | 0.271   | -0.41   | <b>0.683</b> | 1.02 |
| B/M ratio (g/g)*B/M ratio (g/g)                                                                                  | 2.714  | 0.448   | 6.06    | 0.000        | 1.02 | B/M ratio (g/g)*B/M ratio (g/g)                                                                                  | 0.909  | 0.271   | 3.36    | 0.002        | 1.02 |
| t (min)*t (min)                                                                                                  | 1.130  | 0.448   | 2.52    | 0.017        | 1.02 | t (min)*t (min)                                                                                                  | -1.559 | 0.271   | -5.76   | 0.000        | 1.02 |
| RS (rpm)*B/M ratio (g/g)                                                                                         | 1.612  | 0.601   | -3.22   | 0.012        | 1.00 | RS (rpm)*B/M ratio (g/g)                                                                                         | 0.394  | 0.363   | 1.09    | <b>0.287</b> | 1.00 |
| RS (rpm)*t (min)                                                                                                 | 0.713  | 0.601   | -1.19   | <b>0.245</b> | 1.00 | RS (rpm)*t (min)                                                                                                 | 0.749  | 0.363   | 2.06    | 0.048        | 1.00 |
| B/M ratio (g/g)*t (min)                                                                                          | -1.034 | 0.601   | -1.72   | <b>0.096</b> | 1.00 | B/M ratio (g/g)*t (min)                                                                                          | 0.032  | 0.363   | 0.09    | <b>0.931</b> | 1.00 |
| Model summary: S= 2.40, R <sup>2</sup> = 88.67%, R <sup>2</sup> (adj)= 85.27%, R <sup>2</sup> (pred)= 76.60%     |        |         |         |              |      | Model summary: S= 1.45, R <sup>2</sup> = 90.07%, R <sup>2</sup> (adj)= 87.09%, R <sup>2</sup> (pred)= 80.06%     |        |         |         |              |      |
| For reduced model: S= 0.89, R <sup>2</sup> = 98.14%, R <sup>2</sup> (adj)= 97.73%, R <sup>2</sup> (pred)= 97.02% |        |         |         |              |      | For reduced model: S=0.29, R <sup>2</sup> = 99.50%, R <sup>2</sup> (adj)= 99.41%, R <sup>2</sup> (pred)= 99.22%  |        |         |         |              |      |
| (c)                                                                                                              |        |         |         |              |      | (d)                                                                                                              |        |         |         |              |      |
| Term                                                                                                             | Coef   | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                             | Coef   | SE Coef | T-Value | P-Value      | VIF  |
| Constant                                                                                                         | 43.61  | 1.00    | 43.47   | 0.000        |      | Constant                                                                                                         | 43.61  | 1.00    | 43.47   | 0.000        |      |
| RS (rpm)                                                                                                         | 3.032  | 0.666   | 4.55    | 0.000        | 1.00 | RS (rpm)                                                                                                         | 3.032  | 0.666   | 4.55    | 0.000        | 1.00 |
| B/M ratio (g/g)                                                                                                  | 1.211  | 0.666   | 1.17    | 0.249        | 1.00 | B/M ratio (g/g)                                                                                                  | 1.211  | 0.666   | 1.17    | 0.249        | 1.00 |
| t (min)                                                                                                          | 2.617  | 0.666   | 1.82    | 0.079        | 1.00 | t (min)                                                                                                          | 2.617  | 0.666   | 1.82    | 0.079        | 1.00 |
| RS (rpm)*RS (rpm)                                                                                                | 2.679  | 0.648   | 4.04    | 0.000        | 1.02 | RS (rpm)*RS (rpm)                                                                                                | 2.679  | 0.648   | 4.04    | 0.000        | 1.02 |
| B/M ratio (g/g)*B/M ratio (g/g)                                                                                  | 0.363  | 0.648   | 4.13    | 0.000        | 1.02 | B/M ratio (g/g)*B/M ratio (g/g)                                                                                  | 0.363  | 0.648   | 4.13    | 0.000        | 1.02 |
| t (min)*t (min)                                                                                                  | 0.356  | 0.648   | 0.56    | <b>0.580</b> | 1.02 | t (min)*t (min)                                                                                                  | 0.356  | 0.648   | 0.56    | <b>0.580</b> | 1.02 |
| RS (rpm)*B/M ratio (g/g)                                                                                         | 0.356  | 0.870   | 0.41    | <b>0.685</b> | 1.00 | RS (rpm)*B/M ratio (g/g)                                                                                         | 0.356  | 0.870   | 0.41    | <b>0.685</b> | 1.00 |
| RS (rpm)*t (min)                                                                                                 | -0.106 | -0.12   | 2.06    | <b>0.904</b> | 1.00 | RS (rpm)*t (min)                                                                                                 | -0.106 | -0.12   | 2.06    | <b>0.904</b> | 1.00 |
| B/M ratio (g/g)*t (min)                                                                                          | -0.181 | -0.21   | 0.09    | <b>0.836</b> | 1.00 | B/M ratio (g/g)*t (min)                                                                                          | -0.181 | -0.21   | 0.09    | <b>0.836</b> | 1.00 |
| Model summary: S= 3.48, R <sup>2</sup> = 65.14%, R <sup>2</sup> (adj)= 54.68%, R <sup>2</sup> (pred)= 27.16%     |        |         |         |              |      | Model summary: S= 3.48, R <sup>2</sup> = 65.14%, R <sup>2</sup> (adj)= 54.68%, R <sup>2</sup> (pred)= 27.16%     |        |         |         |              |      |
| For reduced model: S= 0.44, R <sup>2</sup> = 99.04%, R <sup>2</sup> (adj)= 98.90%, R <sup>2</sup> (pred)= 98.68% |        |         |         |              |      | For reduced model: S= 0.44, R <sup>2</sup> = 99.04%, R <sup>2</sup> (adj)= 98.90%, R <sup>2</sup> (pred)= 98.68% |        |         |         |              |      |

(2)

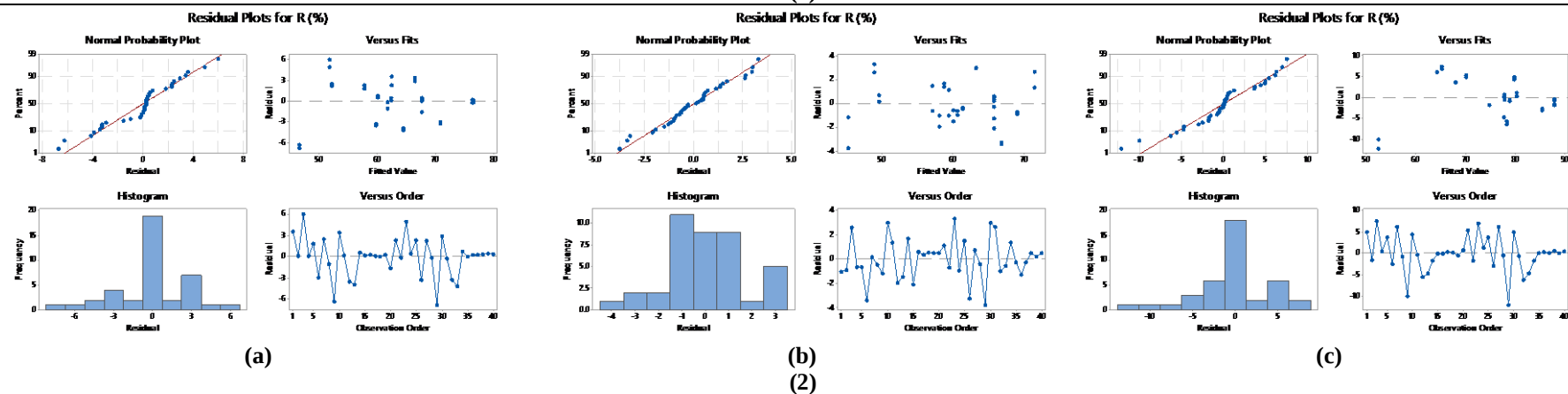
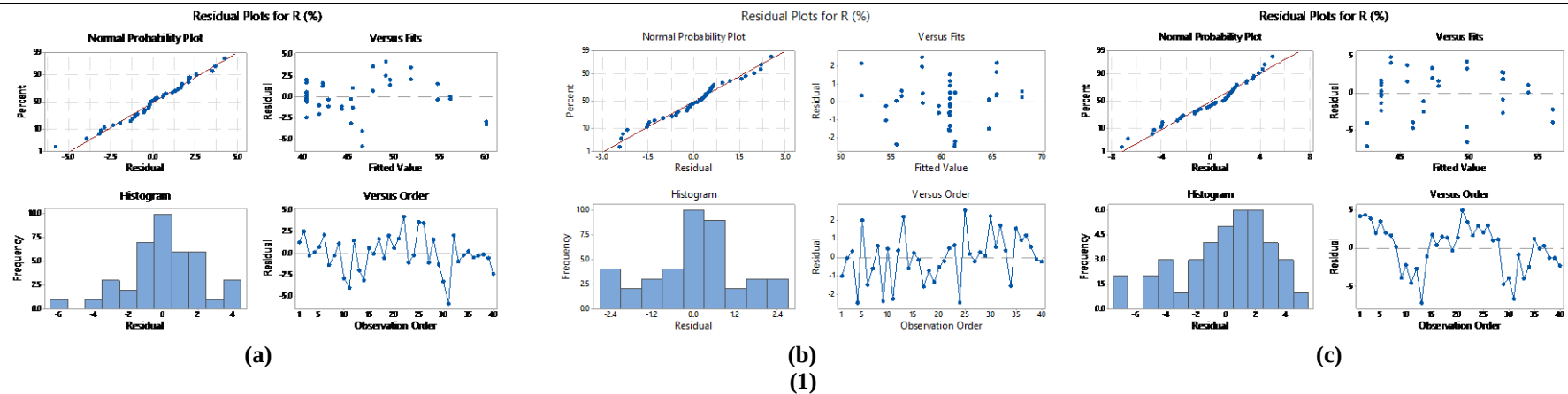
| Term                                                                                                             | Coef   | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                              | Coef   | SE Coef | T-Value | P-Value      | VIF  |
|------------------------------------------------------------------------------------------------------------------|--------|---------|---------|--------------|------|-------------------------------------------------------------------------------------------------------------------|--------|---------|---------|--------------|------|
| Constant                                                                                                         | 67.586 | 0.887   | 76.18   | 0.000        |      | Constant                                                                                                          | 65.784 | 0.554   | 118.74  | 0.000        |      |
| t (rpm)                                                                                                          | 5.901  | 0.589   | 10.03   | 0.000        | 1.00 | t (rpm)                                                                                                           | 5.333  | 0.368   | 14.51   | 0.000        | 1.00 |
| M/R ratio (g/g)                                                                                                  | -4.925 | 0.589   | -8.37   | 0.000        | 1.00 | M/R ratio (g/g)                                                                                                   | -3.977 | 0.368   | -10.82  | 0.000        | 1.00 |
| B/RM (g/g)                                                                                                       | -1.310 | 0.589   | -2.23   | 0.034        | 1.00 | B/RM (g/g)                                                                                                        | -0.384 | 0.368   | -1.04   | 0.005        | 1.00 |
| t (rpm)*t (rpm)                                                                                                  | -3.914 | 0.573   | -6.83   | 0.000        | 1.02 | t (rpm)*t (rpm)                                                                                                   | -4.075 | 0.358   | -11.39  | 0.000        | 1.02 |
| M/R ratio (g/g)*M/R ratio (g/g)                                                                                  | 0.171  | 0.573   | 0.30    | <b>0.767</b> | 1.02 | M/R ratio (g/g)*M/R ratio (g/g)                                                                                   | -0.356 | 0.358   | -1.00   | <b>0.327</b> | 1.02 |
| B/RM ratio (g/g)* B/RM ratio (g/g)                                                                               | -1.879 | 0.573   | -3.28   | 0.003        | 1.02 | B/RM ratio (g/g)* B/RM ratio (g/g)                                                                                | -2.251 | 0.358   | -6.29   | 0.000        | 1.02 |
| t (rpm)*M/R ratio (g/g)                                                                                          | -0.852 | 0.769   | -1.11   | 0.276        | 1.00 | t (rpm)*M/R ratio (g/g)                                                                                           | 0.504  | 0.480   | 1.05    | 0.302        | 1.00 |
| t (rpm)*B/RM (g/g)                                                                                               | -0.248 | 0.769   | -0.32   | <b>0.750</b> | 1.00 | t (rpm)*B/RM (g/g)                                                                                                | 0.006  | 0.480   | 0.01    | <b>0.991</b> | 1.00 |
| M/R ratio (g/g)*B/M ratio (g/g)                                                                                  | 1.263  | 0.769   | 1.64    | 0.111        | 1.00 | M/R ratio (g/g)*B/M ratio (g/g)                                                                                   | 0.741  | 0.480   | 1.54    | 0.134        | 1.00 |
| Model summary: S= 3.08, R <sup>2</sup> = 88.66%, R <sup>2</sup> (adj)= 85.25%, R <sup>2</sup> (pred)= 75.78%     |        |         |         |              |      | Model summary: S= 1,92, R <sup>2</sup> = 94,22%, R <sup>2</sup> (adj)= 92,49%, R <sup>2</sup> (pred)= 87,95%      |        |         |         |              |      |
| For reduced model: S=0.24, R <sup>2</sup> = 99.92%, R <sup>2</sup> (adj)= 98.90% , R <sup>2</sup> (pred)= 99.86% |        |         |         |              |      | For reduced model: S= 0.34, R <sup>2</sup> = 99.80%, R <sup>2</sup> (adj)= 99.75% , R <sup>2</sup> (pred)= 99.71% |        |         |         |              |      |
| (a)                                                                                                              |        |         |         |              |      | (b)                                                                                                               |        |         |         |              |      |

| Term                               | Coef   | SE Coef | T-Value | P-Value      | VIF  |
|------------------------------------|--------|---------|---------|--------------|------|
| Constant                           | 77.81  | 1.39    | 55.96   | 0.000        |      |
| t (rpm)                            | 8.125  | 0.923   | 8.81    | 0.000        | 1.00 |
| M/R ratio (g/g)                    | -2.826 | 0.923   | -3.06   | 0.005        | 1.00 |
| B/RM (g/g)                         | -0.874 | 0.923   | -0.95   | 0.351        | 1.00 |
| t (rpm)*t (rpm)                    | -4.131 | 0.898   | -4.60   | 0.000        | 1.02 |
| M/R ratio (g/g)*M/R ratio (g/g)    | 1.867  | 0.898   | 2.08    | 0.046        | 1.02 |
| B/RM ratio (g/g)* B/RM ratio (g/g) | -0.540 | 0.898   | -0.60   | 0.552        | 1.02 |
| t (rpm)*M/R ratio (g/g)            | -0.68  | 1.21    | -0.56   | 0.557        | 1.00 |
| t (rpm)*B/RM (g/g)                 | -0.10  | 1.21    | -0.08   | <b>0.938</b> | 1.00 |
| M/R ratio (g/g)*B/M ratio (g/g)    | 0.28   | 1.21    | 0.24    | <b>0.815</b> | 1.00 |

Model summary: S= 4,82, R<sup>2</sup> = 79,45%, R<sup>2</sup>(adj)= 73,29%, R<sup>2</sup>(pred)= 56,00%

For reduced model: S= 0.21, R<sup>2</sup>= 99.95%, R<sup>2</sup>(adj)= 99.93%, R<sup>2</sup>(pred)= 99.91%

(c)



**Figure S1.** Scatter plots of residues of (1) MCM for (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$  ions removal (%) and (2) CA-MCM for (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$  ions removal (%)

**Table S2.** ANOVA of (a) Cu<sup>2+</sup>, (b) Pb<sup>2+</sup>, (c) Zn<sup>2+</sup> ions removal with CC (%)

| Term            | Coef  | SE Coef | T-Value | P-Value      | VIF  |
|-----------------|-------|---------|---------|--------------|------|
| Constant        | 28.77 | 1.73    | 16.59   | 0.000        |      |
| pH              | 12.57 | 1.15    | 10.92   | 0.000        | 1.00 |
| Co (mM)         | -4.19 | 1.15    | -3.65   | 0.001        | 1.00 |
| m (g)           | 4.13  | 1.15    | 3.59    | 0.001        | 1.00 |
| pH*pH           | -3.32 | 1.12    | -2.97   | 0.006        | 1.02 |
| Co (mM)*Co (mM) | 0.77  | 1.12    | 0.68    | <b>0.499</b> | 1.02 |
| m (g)*m (g)     | -3.73 | 1.12    | -3.33   | 0.002        | 1.02 |
| pH*Co (mM)      | -4.84 | 1.50    | -3.22   | 0.003        | 1.00 |
| pH*m (g)        | 1.96  | 1.50    | 1.31    | 0.201        | 1.00 |
| Co (mM)*m (g)   | 1.95  | 1.50    | 1.30    | 0.204        | 1.00 |

Model summary: S= 6.01, R<sup>2</sup> = 81.64%, R<sup>2</sup>(adj)= 81.33%, R<sup>2</sup>(pred)= 69.24%  
For reduced model: S= 0.95, R<sup>2</sup> = 99.90%, R<sup>2</sup>(adj)= 99.88%, R<sup>2</sup>(pred)= 99.81%

**(a)**

| Term            | Coef  | SE Coef | T-Value | P-Value      | VIF  |
|-----------------|-------|---------|---------|--------------|------|
| Constant        | 18.68 | 1.75    | 10.66   | 0.000        |      |
| pH              | 8.38  | 1.16    | 7.20    | 0.000        | 1.00 |
| Co (mM)         | -7.82 | 1.16    | -6.72   | 0.000        | 1.00 |
| m (g)           | 1.52  | 1.16    | 1.31    | 0.201        | 1.00 |
| pH*pH           | -1.41 | 1.13    | -1.24   | 0.224        | 1.02 |
| Co (mM)*Co (mM) | 0.19  | 1.13    | 0.17    | 0.869        | 1.02 |
| m (g)*m (g)     | -3.35 | 1.13    | -2.96   | 0.006        | 1.02 |
| pH*Co (mM)      | -3.13 | 1.52    | -2.06   | 0.048        | 1.00 |
| pH*m (g)        | -0.08 | 1.52    | -0.05   | <b>0.960</b> | 1.00 |
| Co (mM)*m (g)   | -0.21 | 1.52    | -0.14   | <b>0.889</b> | 1.00 |

Model summary: S= 6.08, R<sup>2</sup>= 79.02%, R<sup>2</sup>(adj)= 72.73% , R<sup>2</sup>(pred)= 55.09%  
For reduced model: S= 0.16, R<sup>2</sup>= 99.98%, R<sup>2</sup>(adj)= 99.98% , R<sup>2</sup>(pred)= 99.97%

**(b)**

| Term            | Coef   | SE Coef | T-Value | P-Value      | VIF  |
|-----------------|--------|---------|---------|--------------|------|
| Constant        | 23.11  | 1.03    | 22.52   | 0.000        |      |
| pH              | 12.470 | 0.681   | 18.32   | 0.000        | 1.00 |
| Co (mM)         | -3.349 | 0.681   | -4.92   | 0.000        | 1.00 |
| m (g)           | 3.539  | 0.681   | 5.20    | 0.000        | 1.00 |
| pH*pH           | -2.730 | 0.663   | -4.12   | 0.000        | 1.02 |
| Co (mM)*Co (mM) | 2.425  | 0.663   | 3.66    | 0.001        | 1.02 |
| m (g)*m (g)     | -3.245 | 0.663   | -4.90   | 0.000        | 1.02 |
| pH*Co (mM)      | -3.144 | 0.890   | -3.53   | 0.001        | 1.00 |
| pH*m (g)        | 2.961  | 0.890   | 3.33    | 0.002        | 1.00 |
| Co (mM)*m (g)   | -0.171 | 0.890   | -0.19   | <b>0.849</b> | 1.00 |

Model summary: S= 0.56, R<sup>2</sup>= 93.98%, R<sup>2</sup>(adj)= 92.17% , R<sup>2</sup>(pred)= 97.06%  
For reduced model: S= 0.12, R<sup>2</sup>= 99.99%, R<sup>2</sup>(adj)= 99.99% , R<sup>2</sup>(pred)= 99.99%

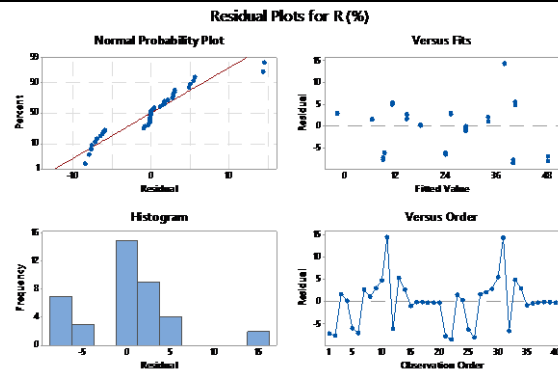
**(c)**

**Table S3.** ANOVA of (a) Cu<sup>2+</sup>, (b) Pb<sup>2+</sup>, (c) Zn<sup>2+</sup> ions removal with MCM-CC (%)

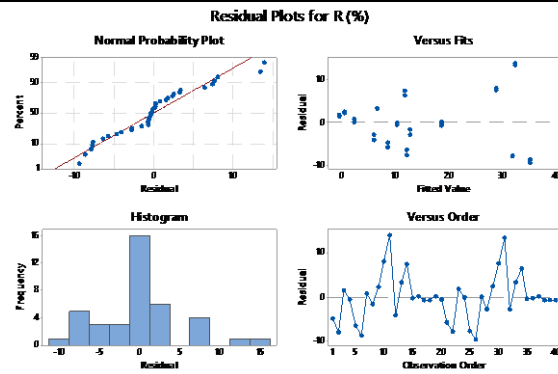
| Term                                                                                                                | Coef  | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                                | Coef    | SE Coef | T-Value | P-Value      | VIF  |
|---------------------------------------------------------------------------------------------------------------------|-------|---------|---------|--------------|------|---------------------------------------------------------------------------------------------------------------------|---------|---------|---------|--------------|------|
| Constant                                                                                                            | 45.34 | 1.75    | 25.86   | 0.000        |      | Constant                                                                                                            | 33.29   | 1.23    | 27.01   | 0.000        |      |
| pH                                                                                                                  | 24.41 | 1.16    | 20.98   | 0.000        | 1.00 | pH                                                                                                                  | 18.373  | 0.818   | 22.46   | 0.000        | 1.00 |
| Co (mM)                                                                                                             | -7.61 | 1.16    | -6.54   | 0.000        | 1.00 | Co (mM)                                                                                                             | -10.719 | 0.818   | -13.10  | 0.000        | 1.00 |
| m (g)                                                                                                               | 1.90  | 1.16    | 1.63    | 0.113        | 1.00 | m (g)                                                                                                               | 3.187   | 0.818   | 3.90    | 0.001        | 1.00 |
| pH*pH                                                                                                               | -5.51 | 1.13    | -4.86   | 0.000        | 1.02 | pH*pH                                                                                                               | -0.859  | 0.796   | -1.08   | 0.290        | 1.02 |
| Co (mM)*Co (mM)                                                                                                     | 1.63  | 1.13    | 1.44    | 0.161        | 1.02 | Co (mM)*Co (mM)                                                                                                     | 1.570   | 0.796   | 1.97    | 0.058        | 1.02 |
| m (g)*m (g)                                                                                                         | -3.05 | 1.13    | -2.69   | 0.012        | 1.02 | m (g)*m (g)                                                                                                         | -3.593  | 0.796   | -4.51   | 0.000        | 1.02 |
| pH*Co (mM)                                                                                                          | -3.92 | 1.52    | -2.58   | 0.015        | 1.00 | pH*Co (mM)                                                                                                          | -5.56   | 1.07    | -5.20   | 0.000        | 1.00 |
| pH*m (g)                                                                                                            | 0.43  | 1.52    | 0.29    | <b>0.777</b> | 1.00 | pH*m (g)                                                                                                            | 2.28    | 1.07    | -2.13   | 0.041        | 1.00 |
| Co (mM)*m (g)                                                                                                       | -0.70 | 1.52    | -0.46   | <b>0.647</b> | 1.00 | Co (mM)*m (g)                                                                                                       | -0.89   | 1.07    | -0.83   | <b>0.413</b> | 1.00 |
| Model summary: S= 6.07, R <sup>2</sup> = 94.60%, R <sup>2</sup> (adj)= 92.98%, R <sup>2</sup> (pred)= 88.46%        |       |         |         |              |      | Model summary: S= 4.27, R <sup>2</sup> = 96.16%, R <sup>2</sup> (adj)= 95.00%, R <sup>2</sup> (pred)= 91.74%        |         |         |         |              |      |
| For reduced model: S= 0.58, R <sup>2</sup> = 99.94%, R <sup>2</sup> (adj)= 99.93%, R <sup>2</sup> (pred)= 99.91%    |       |         |         |              |      | For reduced model: S= 0.64, R <sup>2</sup> = 99.91%, R <sup>2</sup> (adj)= 99.88%, R <sup>2</sup> (pred)= 99.83%    |         |         |         |              |      |
| <b>(a)</b>                                                                                                          |       |         |         |              |      | <b>(b)</b>                                                                                                          |         |         |         |              |      |
| Term                                                                                                                | Coef  | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                                | Coef    | SE Coef | T-Value | P-Value      | VIF  |
| Constant                                                                                                            | 46.55 | 1.77    | 26.33   | 0.000        |      | Constant                                                                                                            | 46.55   | 1.77    | 26.33   | 0.000        |      |
| pH                                                                                                                  | 20.83 | 1.17    | 17.75   | 0.000        | 1.00 | pH                                                                                                                  | 20.83   | 1.17    | 17.75   | 0.000        | 1.00 |
| Co (mM)                                                                                                             | -5.97 | 1.17    | -5.09   | 0.000        | 1.00 | Co (mM)                                                                                                             | -5.97   | 1.17    | -5.09   | 0.000        | 1.00 |
| m (g)                                                                                                               | 4.65  | 1.17    | 3.97    | 0.000        | 1.00 | m (g)                                                                                                               | 4.65    | 1.17    | 3.97    | 0.000        | 1.00 |
| pH*pH                                                                                                               | -5.82 | 1.14    | -5.10   | 0.000        | 1.02 | pH*pH                                                                                                               | -5.82   | 1.14    | -5.10   | 0.000        | 1.02 |
| Co (mM)*Co (mM)                                                                                                     | -1.62 | 1.14    | -1.42   | 0.167        | 1.02 | Co (mM)*Co (mM)                                                                                                     | -1.62   | 1.14    | -1.42   | 0.167        | 1.02 |
| m (g)*m (g)                                                                                                         | -6.66 | 1.14    | -5.83   | 0.000        | 1.02 | m (g)*m (g)                                                                                                         | -6.66   | 1.14    | -5.83   | 0.000        | 1.02 |
| pH*Co (mM)                                                                                                          | -5.79 | 1.53    | -3.78   | 0.001        | 1.00 | pH*Co (mM)                                                                                                          | -5.79   | 1.53    | -3.78   | 0.001        | 1.00 |
| pH*m (g)                                                                                                            | -0.04 | 1.53    | -0.03   | <b>0.977</b> | 1.00 | pH*m (g)                                                                                                            | -0.04   | 1.53    | -0.03   | <b>0.977</b> | 1.00 |
| Co (mM)*m (g)                                                                                                       | 0.16  | 1.53    | -0.10   | <b>0.917</b> | 1.00 | Co (mM)*m (g)                                                                                                       | 0.16    | 1.53    | -0.10   | <b>0.917</b> | 1.00 |
| Model summary: S= 6.13, R <sup>2</sup> = 93.42%, R <sup>2</sup> (adj)= 91.45%, R <sup>2</sup> (pred)= 85.92%        |       |         |         |              |      | Model summary: S= 6.13, R <sup>2</sup> = 93.42%, R <sup>2</sup> (adj)= 91.45%, R <sup>2</sup> (pred)= 85.92%        |         |         |         |              |      |
| For reduced model: S= 0.12, R <sup>2</sup> = 100.00%, R <sup>2</sup> (adj)= 100.00%, R <sup>2</sup> (pred)= 100.00% |       |         |         |              |      | For reduced model: S= 0.12, R <sup>2</sup> = 100.00%, R <sup>2</sup> (adj)= 100.00%, R <sup>2</sup> (pred)= 100.00% |         |         |         |              |      |
| <b>(c)</b>                                                                                                          |       |         |         |              |      | <b>(c)</b>                                                                                                          |         |         |         |              |      |

**Table S4.** ANOVA of (a) Cu<sup>2+</sup>, (b) Pb<sup>2+</sup>, (c) Zn<sup>2+</sup> ions removal with CA-MCM-CC (%)

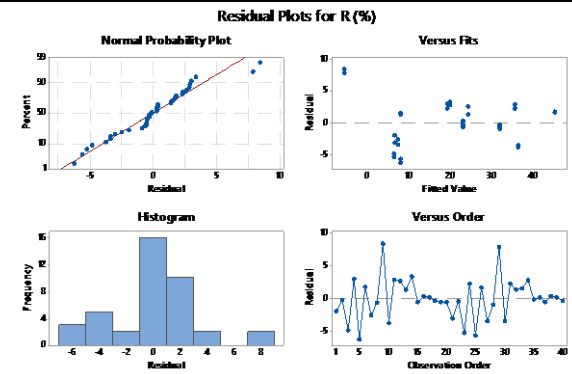
| Term                                                                                                                                                                                                                             | Coef  | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                                                                                                                                          | Coef   | SE Coef | T-Value | P-Value      | VIF  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------|---------|--------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|---------|---------|--------------|------|
| Constant                                                                                                                                                                                                                         | 56.25 | 2.52    | 22.33   | 0.000        |      | Constant                                                                                                                                                                                                                      | 55.18  | 2.52    | 21.93   | 0.000        |      |
| pH                                                                                                                                                                                                                               | 28.80 | 1.67    | 17.24   | 0.000        | 1.00 | pH                                                                                                                                                                                                                            | 23.36  | 1.67    | 13.99   | 0.000        | 1.00 |
| Co (mM)                                                                                                                                                                                                                          | -6.54 | 1.67    | -3.91   | 0.000        | 1.00 | Co (mM)                                                                                                                                                                                                                       | -10.44 | 1.67    | -6.25   | 0.000        | 1.00 |
| m (g)                                                                                                                                                                                                                            | 5.23  | 1.67    | 3.13    | 0.004        | 1.00 | m (g)                                                                                                                                                                                                                         | 3.31   | 1.67    | 1.98    | 0.056        | 1.00 |
| pH*pH                                                                                                                                                                                                                            | -7.12 | 1.63    | -4.38   | 0.000        | 1.02 | pH*pH                                                                                                                                                                                                                         | -9.25  | 1.63    | -5.69   | 0.000        | 1.02 |
| Co (mM)*Co (mM)                                                                                                                                                                                                                  | 1.93  | 1.63    | 1.18    | 0.246        | 1.02 | Co (mM)*Co (mM)                                                                                                                                                                                                               | -2.47  | 1.63    | 1.52    | 0.139        | 1.02 |
| m (g)*m (g)                                                                                                                                                                                                                      | -8.32 | 1.63    | -5.11   | 0.000        | 1.02 | m (g)*m (g)                                                                                                                                                                                                                   | -6.38  | 1.63    | -3.92   | 0.000        | 1.02 |
| pH*Co (mM)                                                                                                                                                                                                                       | -1.65 | 2.18    | -0.75   | 0.457        | 1.00 | pH*Co (mM)                                                                                                                                                                                                                    | -6.18  | 2.18    | -2.83   | 0.008        | 1.00 |
| pH*m (g)                                                                                                                                                                                                                         | 1.55  | 2.18    | 0.71    | 0.482        | 1.00 | pH*m (g)                                                                                                                                                                                                                      | 0.54   | 2.18    | 0.25    | <b>0.806</b> | 1.00 |
| Co (mM)*m (g)                                                                                                                                                                                                                    | -1.32 | 2.18    | -0.46   | <b>0.550</b> | 1.00 | Co (mM)*m (g)                                                                                                                                                                                                                 | -0.52  | 2.18    | -0.24   | <b>0.812</b> | 1.00 |
| Model summary: S= 8.73, R <sup>2</sup> = 92.48%, R <sup>2</sup> (adj)= 90.23%, R <sup>2</sup> (pred)= 83.89%<br>For reduced model: S= 0.95, R <sup>2</sup> = 99.90%, R <sup>2</sup> (adj)= 99.88%, R(pred)= 99.81%               |       |         |         |              |      | Model summary: S= 8.72, R <sup>2</sup> = 90.66%, R <sup>2</sup> (adj)= 87.85%, R <sup>2</sup> (pred)= 80.01%<br>For reduced model: 0.53, R <sup>2</sup> = 99.96%, R <sup>2</sup> (adj)= 99.95%, R <sup>2</sup> (pred)= 99.93% |        |         |         |              |      |
| <b>(a)</b>                                                                                                                                                                                                                       |       |         |         |              |      | <b>(b)</b>                                                                                                                                                                                                                    |        |         |         |              |      |
| Term                                                                                                                                                                                                                             | Coef  | SE Coef | T-Value | P-Value      | VIF  | Term                                                                                                                                                                                                                          | Coef   | SE Coef | T-Value | P-Value      | VIF  |
| Constant                                                                                                                                                                                                                         | 57.74 | 2.61    | 22.16   | 0.000        |      | Constant                                                                                                                                                                                                                      | 57.74  | 2.61    | 22.16   | 0.000        |      |
| pH                                                                                                                                                                                                                               | 28.41 | 1.73    | 16.43   | 0.000        | 1.00 | pH                                                                                                                                                                                                                            | 28.41  | 1.73    | 16.43   | 0.000        | 1.00 |
| Co (mM)                                                                                                                                                                                                                          | -4.59 | 1.73    | -2.65   | 0.013        | 1.00 | Co (mM)                                                                                                                                                                                                                       | -4.59  | 1.73    | -2.65   | 0.013        | 1.00 |
| m (g)                                                                                                                                                                                                                            | 2.73  | 1.73    | 1.58    | 0.125        | 1.00 | m (g)                                                                                                                                                                                                                         | 2.73   | 1.73    | 1.58    | 0.125        | 1.00 |
| pH*pH                                                                                                                                                                                                                            | -7.75 | 1.68    | -4.60   | 0.000        | 1.02 | pH*pH                                                                                                                                                                                                                         | -7.75  | 1.68    | -4.60   | 0.000        | 1.02 |
| Co (mM)*Co (mM)                                                                                                                                                                                                                  | 0.75  | 1.68    | 0.45    | <b>0.658</b> | 1.02 | Co (mM)*Co (mM)                                                                                                                                                                                                               | 0.75   | 1.68    | 0.45    | <b>0.658</b> | 1.02 |
| m (g)*m (g)                                                                                                                                                                                                                      | -5.82 | 1.68    | -3.46   | 0.002        | 1.02 | m (g)*m (g)                                                                                                                                                                                                                   | -5.82  | 1.68    | -3.46   | 0.002        | 1.02 |
| pH*Co (mM)                                                                                                                                                                                                                       | -5.13 | 2.26    | -2.27   | 0.030        | 1.00 | pH*Co (mM)                                                                                                                                                                                                                    | -5.13  | 2.26    | -2.27   | 0.030        | 1.00 |
| pH*m (g)                                                                                                                                                                                                                         | 3.36  | 2.26    | 1.49    | 0.148        | 1.00 | pH*m (g)                                                                                                                                                                                                                      | 3.36   | 2.26    | 1.49    | 0.148        | 1.00 |
| Co (mM)*m (g)                                                                                                                                                                                                                    | -2.04 | 2.26    | -0.90   | 0.373        | 1.00 | Co (mM)*m (g)                                                                                                                                                                                                                 | -2.04  | 2.26    | -0.90   | 0.373        | 1.00 |
| Model summary: S= 9.03, R <sup>2</sup> = 91.42%, R <sup>2</sup> (adj)= 88.84%, R <sup>2</sup> (pred)= 81.61%<br>For reduced model: S= 0.73, R <sup>2</sup> = 99.94%, R <sup>2</sup> (adj)= 99.92%, R <sup>2</sup> (pred)= 99.91% |       |         |         |              |      |                                                                                                                                                                                                                               |        |         |         |              |      |
| <b>(c)</b>                                                                                                                                                                                                                       |       |         |         |              |      |                                                                                                                                                                                                                               |        |         |         |              |      |



(a)

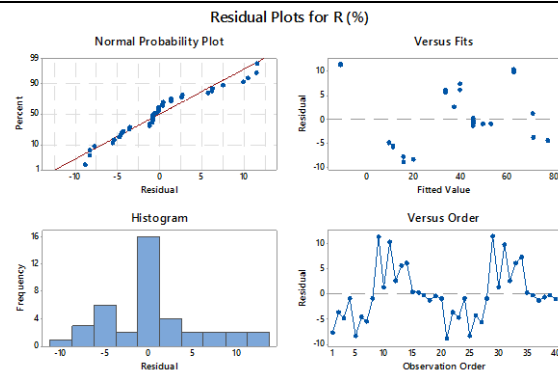


(b)

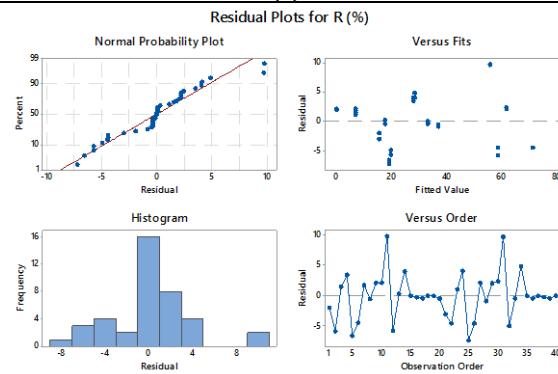


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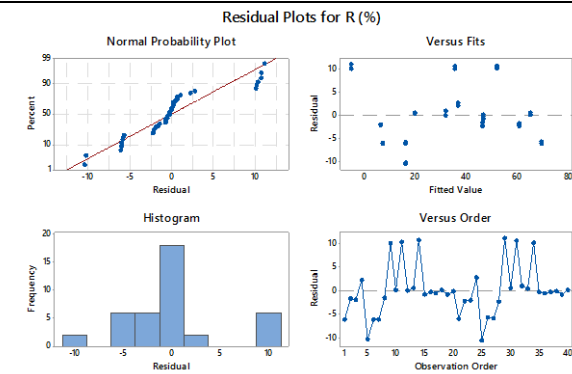
(1)



(a)

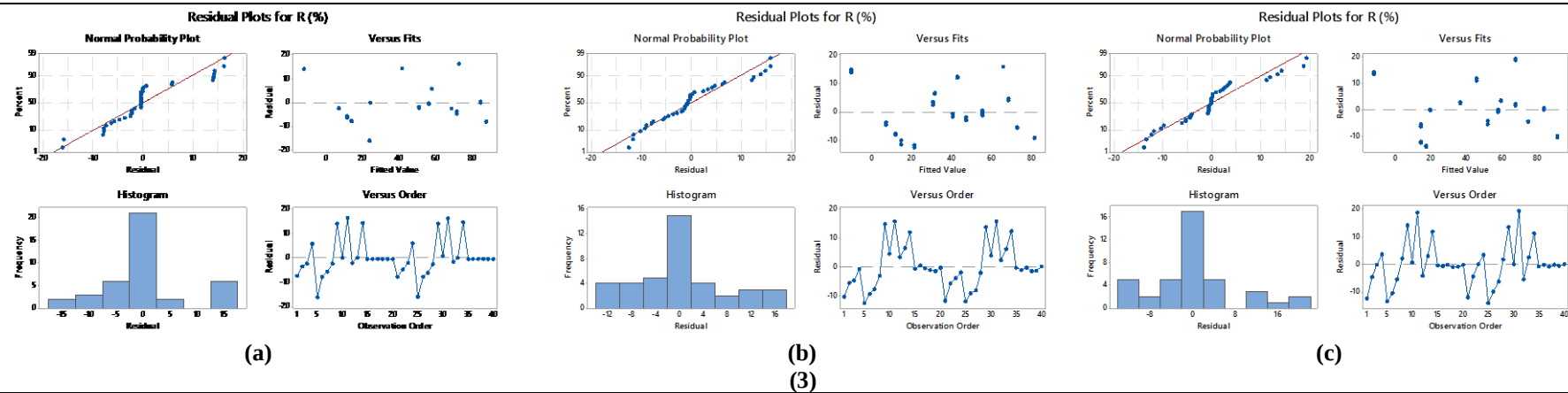


(b)

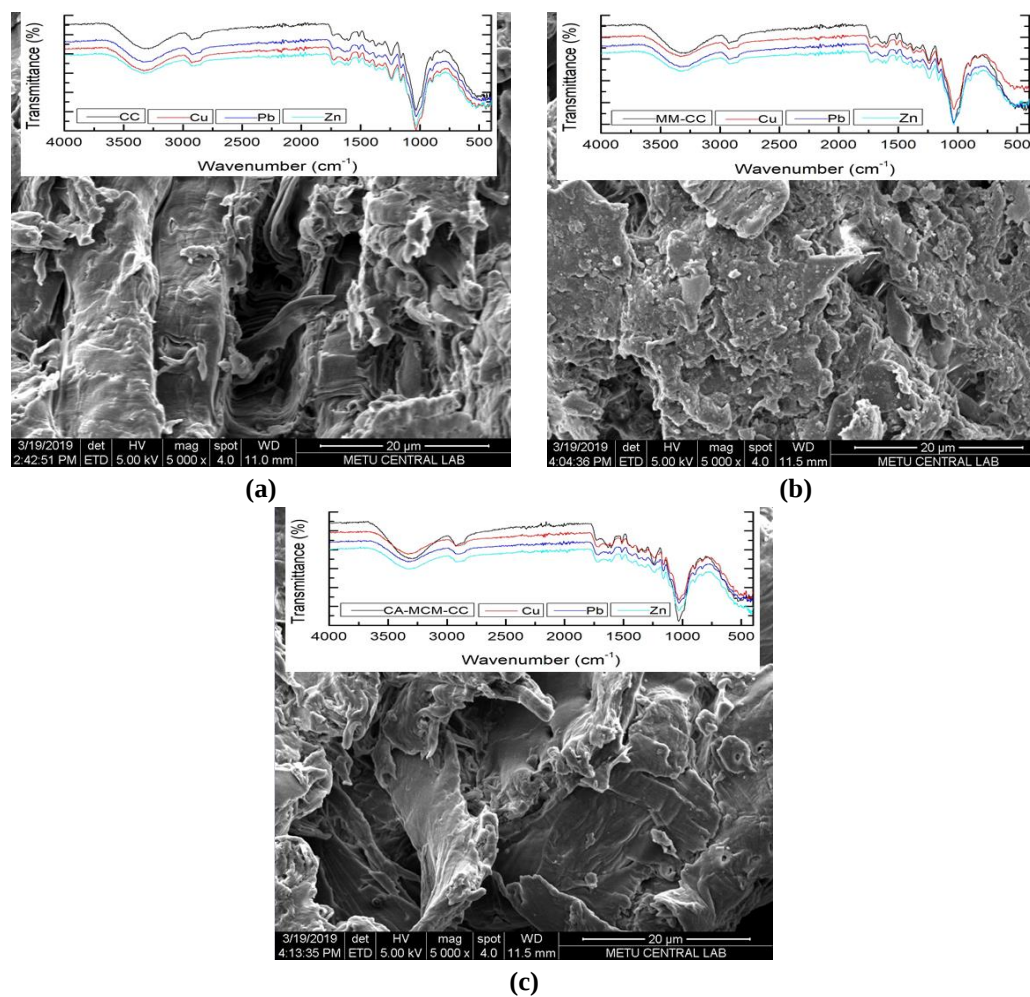


(c)

(2)



**Figure S2.** Scatter plots of residues of (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$  ions removal (%) with (1) CC, (2) MCM-CC and (3) CA-MCM-CC



**Figure S3.** FTIR spectrums of (a) CC, (b) MCM-CC, (c) CA-MCM-CC after metal adsorption and SEM images of (a) CC, (b) MCM-CC, (c) CA-MCM-CC after  $\text{Pb}^{2+}$  adsorption

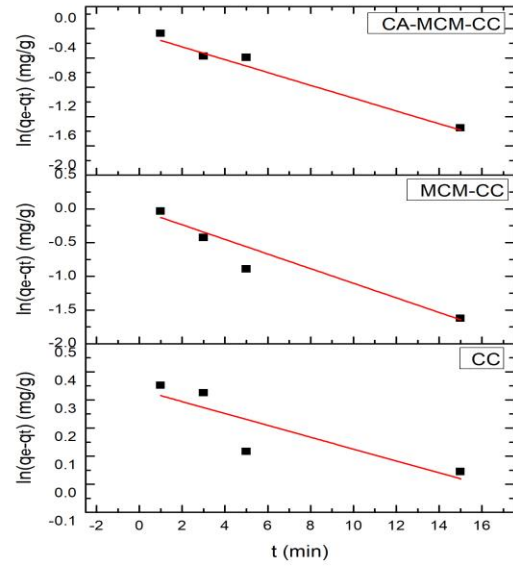
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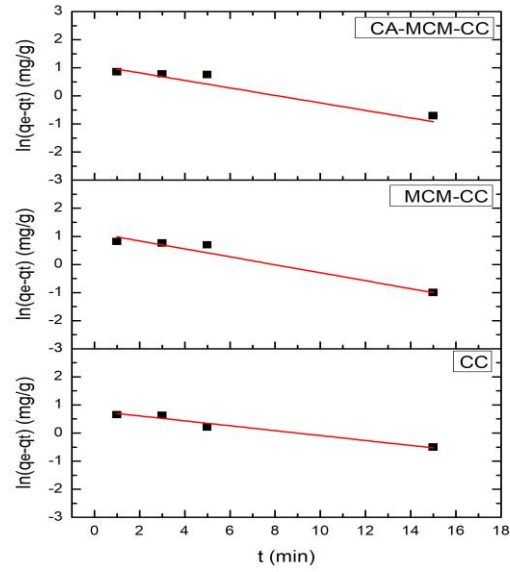
(1)

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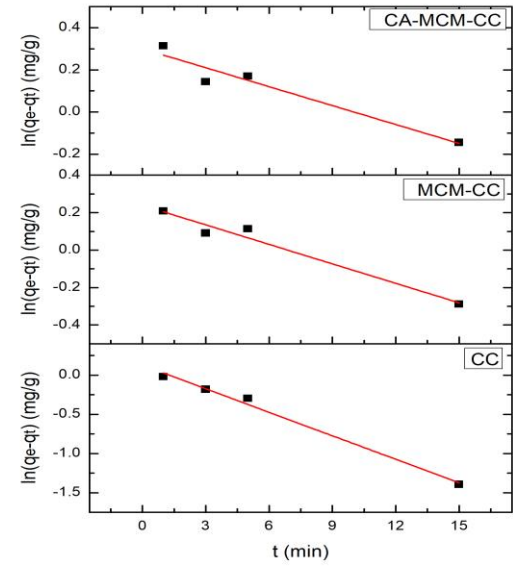
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(a)

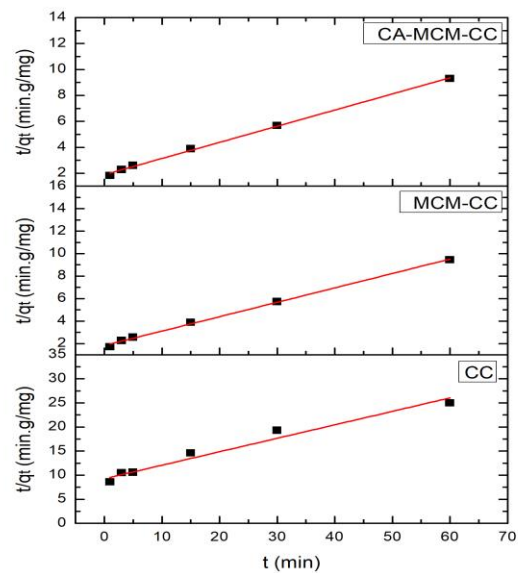


(b)

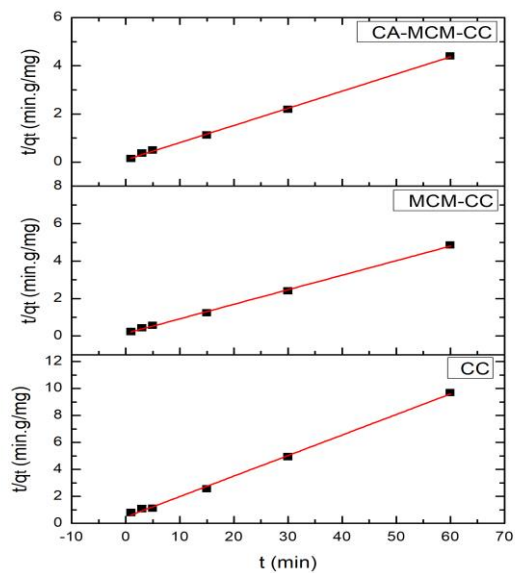


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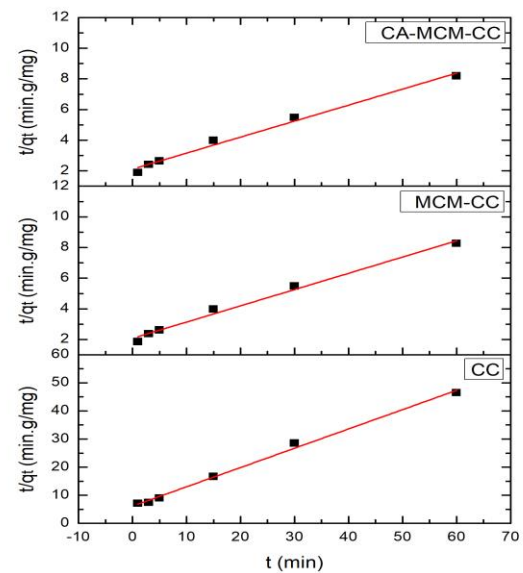
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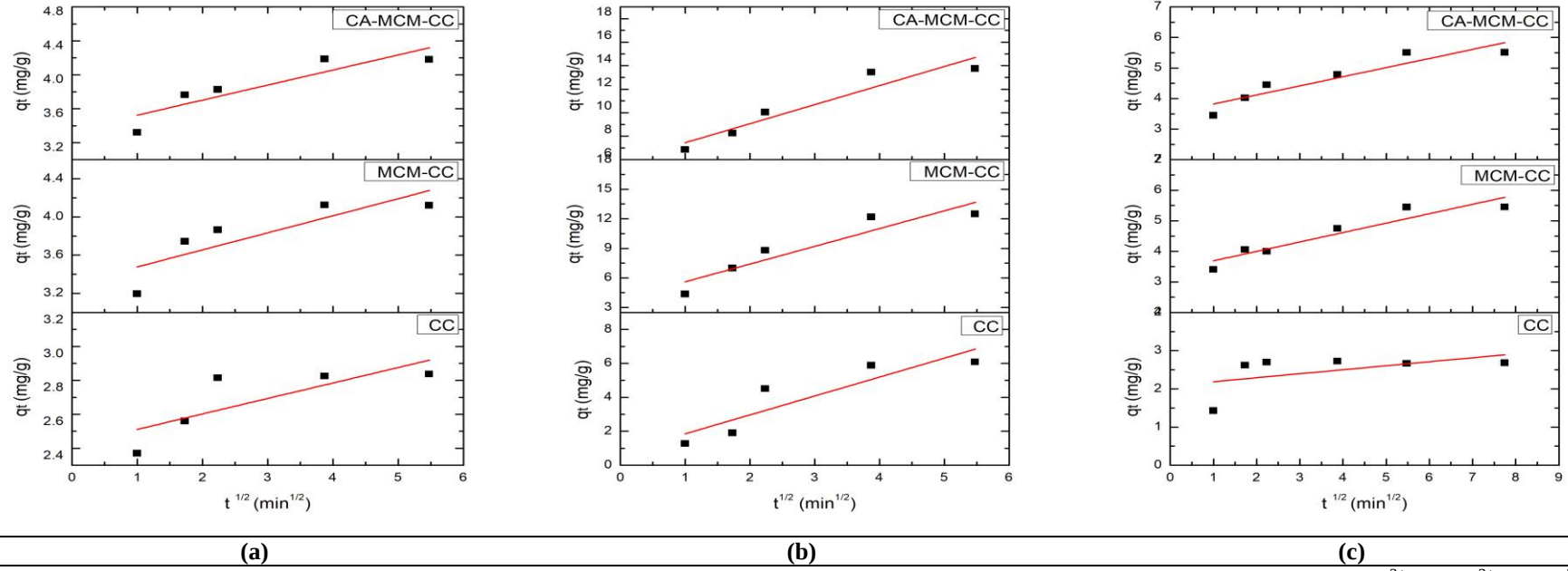
(a)



(b)

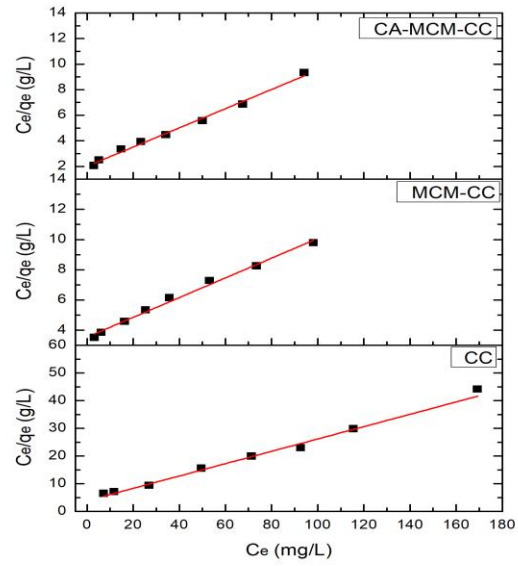


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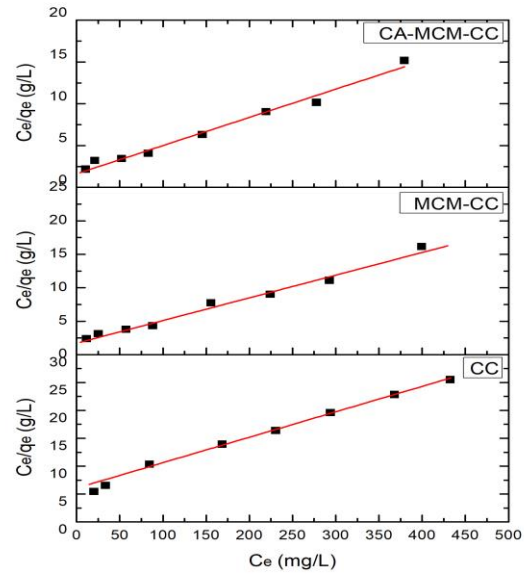


**Figure S4.** (1) Pseudo first order, (2) Pseudo second order, (3) Intraparticle diffusion models of CC, MCM-CC and CA-MCM-CC for (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$

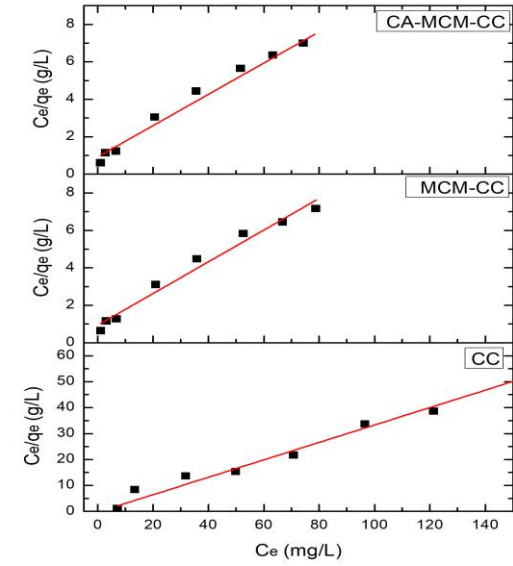
(1)



(a)

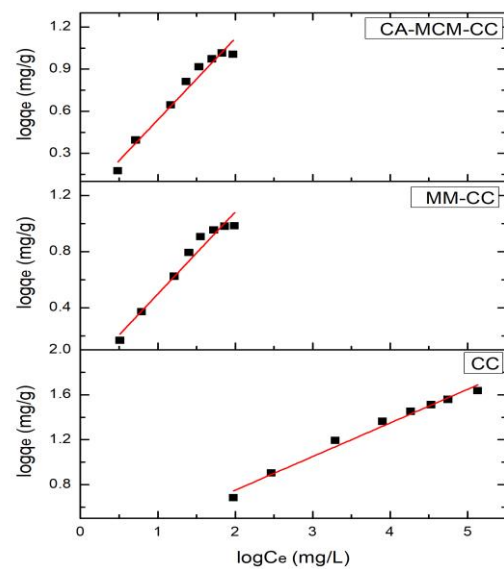


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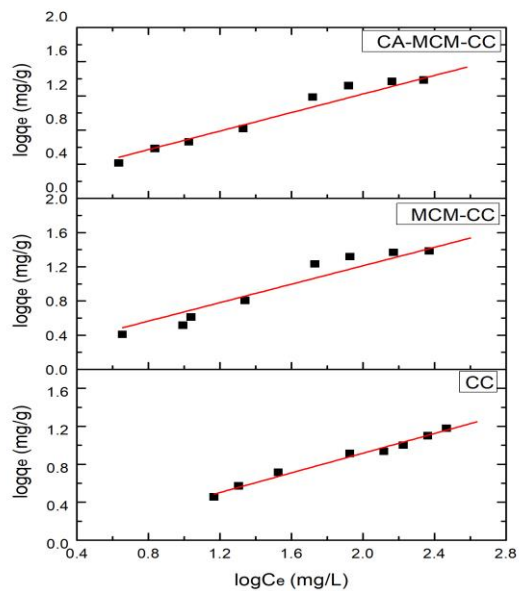


(c)

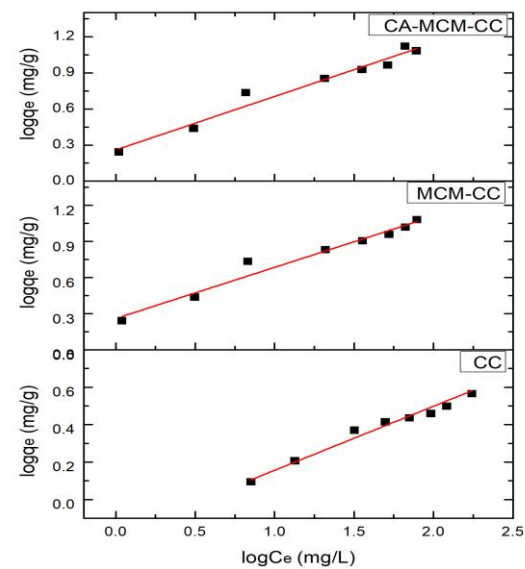
(2)



(a)

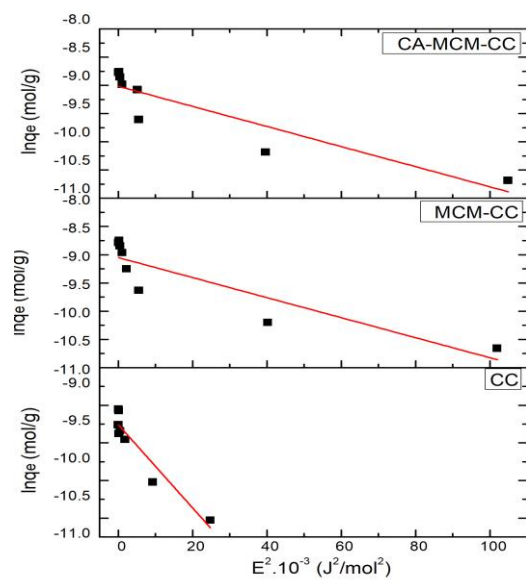


(b)

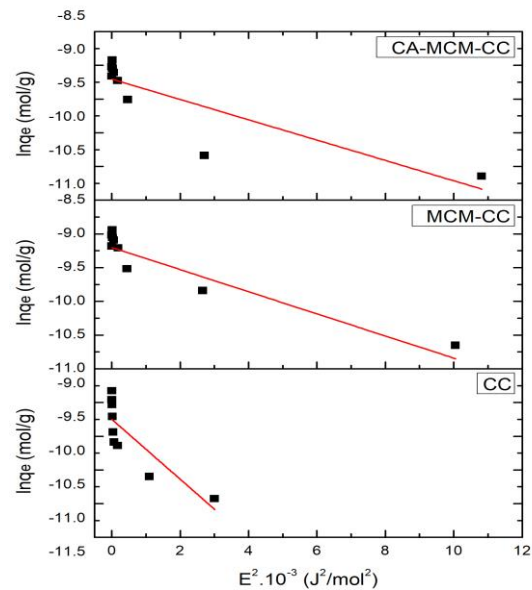


(c)

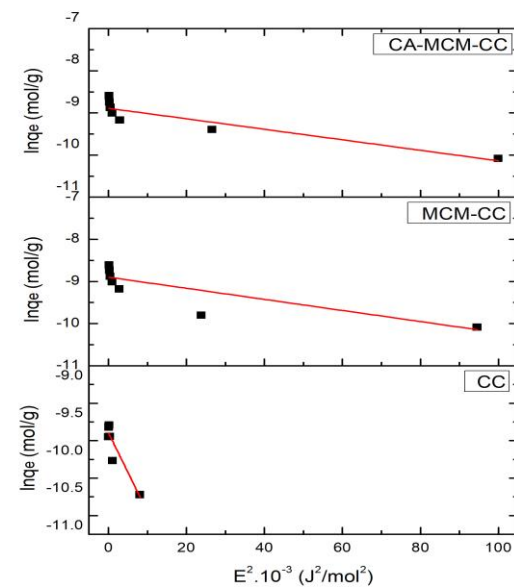
(3)



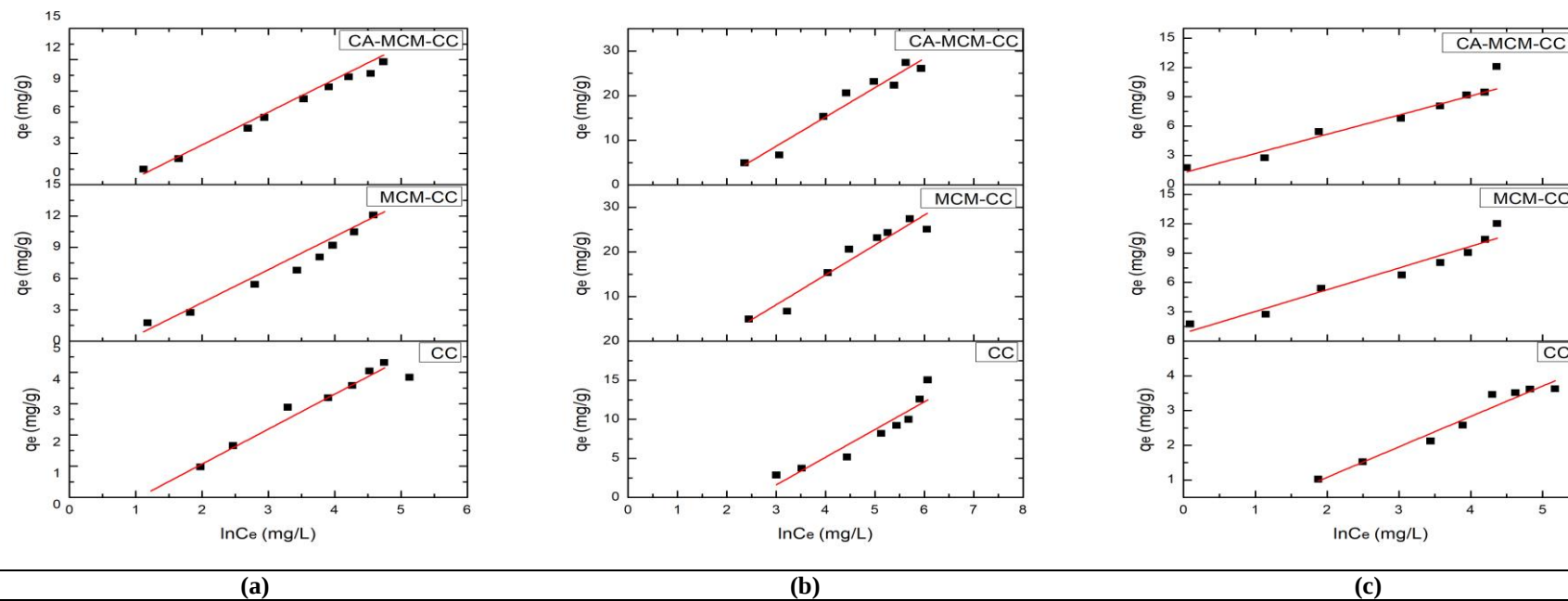
(a)



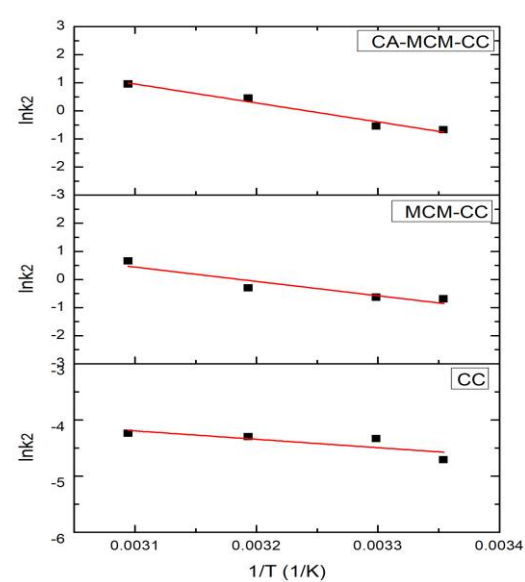
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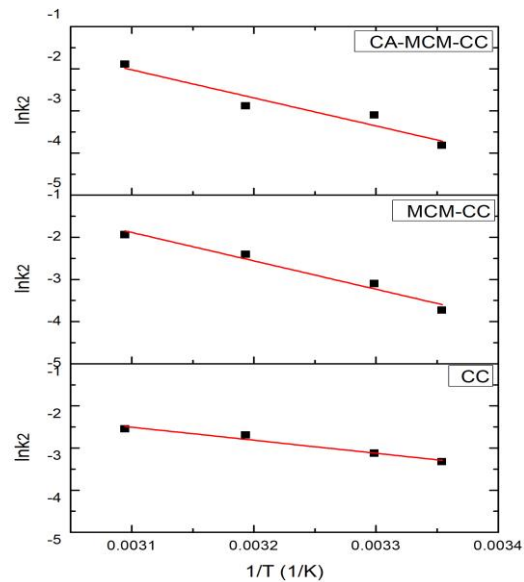
(c)



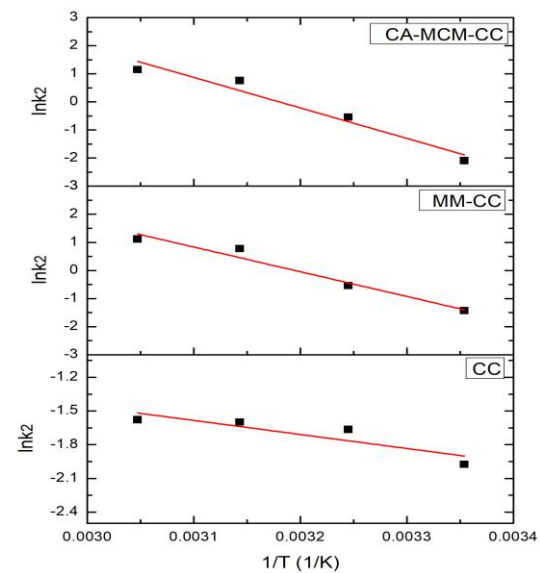
**Figure S5.** (1) Langmuir, (2) Freundlich, (3) Dubinin–Raduskhevich, (4) Temkin isotherm models of CC, MCM-CC and CA-MCM-CC for (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$



(a)



(b)



(c)

**Figure S6.** Thermodynamic graphics ( $\ln k_2$  versus  $1/T$ ) of CC, MCM-CC and CA-MCM-CC for (a)  $\text{Cu}^{2+}$ , (b)  $\text{Pb}^{2+}$ , (c)  $\text{Zn}^{2+}$