**Supplementary Material**

# Phosphate and ammonia nitrogen recovery from sewage sludge supernatants by coupled MgO-biomass ash and its potential as heavy metal adsorbent

**Zhen Ruana, Junzhen Dia, \*, Yanrong Donga, Xueying Suna, Jianxin Zhanga, Bofu Yuana, Sihang Baob**

a College of Civil Engineering, Liaoning Technical University, Fuxin, 123000, Liaoning, China

b College of Mining, Liaoning Technical University, Fuxin 123000, Liaoning, China

\*Corresponding Author: Junzhen Di; Email: dijunzhen@lntu.edu.cn; Telephone: +86-13941889524

**Table S1.** Characteristics of sewage sludge supernatants.

|  |
| --- |
| Parameter |
| pH | 8.1 |
| COD (mg/L) | 1300 |
| PO43- (mg/L) | 85 |
| NH4+ (mg/L) | 140 |
| Ca2+ (mg/L) | 15 |
| Mg2+ (mg/L) | 19 |

**Table S2. BBD levels, test design and the responses.**

|  |  |  |
| --- | --- | --- |
| Variation | Unit | Levels |
| Low (−1) | Central(0) | High(1) |
| *X*1 | pH | dimensionless | 6 | 7 | 8 |
| *X*2 | Adsorbent dosages | g/L | 0.6 | 0.7 | 0.8 |
| *X*3 | Initial concentration | mg/L | 40 | 60 | 80 |
| Run | Factors | Phosphate removal rate (%) | Ammonia nitrogen removal rate (%) |
| $$X\_{1}$$ | $$X\_{2}$$ | $$X\_{3}$$ | Observed | Predicated | Observed | Predicated |
| 1 | 6 | 0.6 | 60 | 75.52 | 75.84 | 29.48 | 29.37 |
| 2 | 8 | 0.6 | 60 | 74.88 | 75.23 | 29.00 | 28.91 |
| 3 | 6 | 0.8 | 60 | 91.85 | 91.50 | 35.31 | 35.40 |
| 4 | 8 | 0.8 | 60 | 91.15 | 90.83 | 34.56 | 34.68 |
| 5 | 6 | 0.7 | 40 | 91.42 | 90.45 | 35.17 | 35.18 |
| 6 | 8 | 0.7 | 40 | 90.34 | 89.35 | 34.41 | 34.40 |
| 7 | 6 | 0.7 | 80 | 90.85 | 91.84 | 34.53 | 34.54 |
| 8 | 8 | 0.7 | 80 | 90.68 | 91.65 | 34.15 | 34.14 |
| 9 | 7 | 0.6 | 40 | 76.20 | 76.84 | 30.90 | 31.01 |
| 10 | 7 | 0.8 | 40 | 94.49 | 95.80 | 36.24 | 36.14 |
| 11 | 7 | 0.6 | 80 | 83.32 | 82.01 | 29.69 | 29.79 |
| 12 | 7 | 0.8 | 80 | 94.95 | 94.31 | 36.57 | 36.46 |
| 13 | 7 | 0.7 | 60 | 97.26 | 96.71 | 39.50 | 39.22 |
| 14 | 7 | 0.7 | 60 | 95.80 | 96.71 | 39.00 | 39.22 |
| 15 | 7 | 0.7 | 60 | 96.72 | 96.71 | 38.63 | 39.22 |
| 16 | 7 | 0.7 | 60 | 96.20 | 96.71 | 39.36 | 39.22 |
| 17 | 7 | 0.7 | 60 | 97.56 | 96.71 | 39.59 | 39.22 |

**Table S3.** ANOVA results for adsorption of phosphate by 400CMBA.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | *Sum of Squares* | *Degree of Freedom* | *Mean Square* | *F-value* | *P-value* |
| Model | 942.50 | 9 | 104.72 | 68.92 | < 0.0001 |
| $$X\_{1}$$ | 0.84 | 1 | 0.84 | 0.55 | 0.48 |
| $$X\_{2}$$ | 488.59 | 1 | 488.59 | 321.55 | < 0.0001 |
| $$X\_{3}$$ | 6.75 | 1 | 6.75 | 4.44 | 0.07 |
| $$X\_{1}X\_{2}$$ | 0.0009 | 1 | 0.0009 | 0.0006 | 0.98 |
| $$X\_{1}X\_{3}$$ | 0.21 | 1 | 0.21 | 0.14 | 0.72 |
| $$X\_{2}X\_{3}$$ | 11.09 | 1 | 11.09 | 7.30 | 0.03 |
| $$X\_{1}^{2}$$ | 100.59 | 1 | 100.59 | 66.20 | < 0.0001 |
| $$X\_{2}^{2}$$ | 302.08 | 1 | 302.08 | 198.80 | < 0.0001 |
| $$X\_{3}^{2}$$ | 4.19 | 1 | 4.19 | 2.76 | 0.14 |
| *Residual* | 10.64 | 7 | 1.52 |  |  |
| *Lack of Fit* | 8.52 | 3 | 2.84 | 5.38 | 0.07 |
| *Pure Error* | 2.11 | 4 | 0.53 |  |  |
| *Cor Total* | 953.13 | 16 |  |  |  |
| *R-Squared* = 0.9888 | *Adj R-Squared* =0 .9745 |
| *Adequate Precision* = 22.7217 | *C.V. %* = 1.37 |

**Table S4.** ANOVA results for adsorption of ammonia nitrogen by 400CMBA.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | *Sum of Squares* | *Degree of Freedom* | *Mean Square* | *F-value* | *P-value* |
| Model | 205.81 | 9 | 22.87 | 222.79 | < 0.0001 |
| $$X\_{1}$$ | 0.70 | 1 | 0.70 | 6.84 | 0.03 |
| $$X\_{2}$$ | 69.68 | 1 | 69.68 | 678.85 | < 0.0001 |
| $$X\_{3}$$ | 0.40 | 1 | 0.40 | 3.86 | 0.09 |
| $$X\_{1}X\_{2}$$ | 0.02 | 1 | 0.02 | 0.18 | 0.69 |
| $$X\_{1}X\_{3}$$ | 0.04 | 1 | 0.04 | 0.35 | 0.57 |
| $$X\_{2}X\_{3}$$ | 0.59 | 1 | 0.59 | 5.78 | 0.04 |
| $$X\_{1}^{2}$$ | 36.81 | 1 | 36.81 | 358.62 | < 0.0001 |
| $$X\_{2}^{2}$$ | 73.28 | 1 | 73.28 | 713.92 | < 0.0001 |
| $$X\_{3}^{2}$$ | 12.09 | 1 | 12.09 | 117.75 | < 0.0001 |
| *Residual* | 0.72 | 7 | 0.10 |  |  |
| *Lack of Fit* | 0.09 | 3 | 0.03 | 0.18 | 0.90 |
| *Pure Error* | 0.63 | 4 | 0.16 |  |  |
| *Cor Total* | 206.52 | 16 |  |  |  |
| *R-Squared* = 0.9965 | *Adj R-Squared* = 0.9920 |
| *Adequate Precision* = 41.9524 | *C.V. %* = 0.9137 |

**Table S5.** Kinetic parameters for adsorption of phosphate and ammonia nitrogen onto 400CMBA.

|  |  |  |
| --- | --- | --- |
| Nutrient elements | Phosphate | Ammonia nitrogen |
| Initial concentration (mg/L) | 20 | 60 | 100 | 20 | 60 | 100 |
| IPD | Ⅰ | *K*id1 | 3.574 | 10.464 | 16.600 | 0.912 | 3.445 | 5.484 |
| *C*1 | -4.19 | -9.81 | -24.44 | –0.42 | –3.74 | –3.75 |
| $$R^{2}\_{adj}$$ | 0.9980 | 0.9937 | 0.9960 | 0.9892 | 0.9944 | 0.9971 |
| Ⅱ | *K*id2 | 0.710 | 1.773 | 5.013 | 1.731 | 1.515 | 1.731 |
| *C*2 | 18.54 | 60.13 | 67.90 | 26.47 | 12.61 | 26.471 |
| $$R^{2}\_{adj}$$ | 0.9225 | 0.9600 | 0.9551 | 0.9932 | 0.9986 | 0.9851 |
| Ⅲ | *K*id3 | 0.115 | 0.240 | 0.203 | 0.015 | 0.055 | 0.118 |
| *C*3 | 26.15 | 80.67 | 133.39 | 8.12 | 33.05 | 49.14 |
| $$R^{2}\_{adj}$$ | 0.9806 | 0.9976 | 0.9966 | 0.8909 | 0.7518 | 0.9353 |