# APPENDIX A

Characteristics of sludge and biosoil

**Table A.1** pH of sludge and bisoil

| Type of samples | pH (1:5) | | | Average |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Sludge | 7.39 | 7.40 | 7.35 | 7.38 |
| CaO | 12.36 | 12.30 | 12.42 | 12.36 |
| Fly ash | 10.35 | 10.22 | 10.33 | 10.30 |
| MKP fertiliser | 4.28 | 4.32 | 4.27 | 4.29 |
| Organic manure | 7.12 | 7.22 | 7.26 | 7.2 |

**Table A.2** Electrical conductivity of sludge and biosoil

| Type of samples | EC (1:5) | | | Average |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Sludge | 457.2 | 462.1 | 488.8 | 469.5 |
| Biosoil | 5927 | 5915 | 5918 | 5920 |
| CaO | 7800 | 7970 | 7780 | 7850 |
| Fly ash | 837 | 854 | 832 | 841 |
| MKP fertiliser | 72100 | 72800 | 72700 | 72530 |
| Organic manure | 9975 | 9958 | 9947 | 9960 |

**Table A.3** Cation exchange capacity of sludge and biosoil

| Type of soil | Duplicate | Weight (g) | Volume of $H_2SO_4$ (mL) | Blank (mL) | CEC (meq/100g sediment) | Average |
|---|---|---|---|---|---|---|
| Sludge | 1 | 5.6193 | 33.60 | 0.3 | 12.25 | 12.37 |
| | 2 | 5.7216 | 34.90 | 0.3 | 12.49 | |
| Biosoil | 1 | 5.6073 | 10.40 | 0.3 | 3.72 | 3.59 |
| | 2 | 5.287 | 9.20 | 0.3 | 3.47 | |
| CaO | 1 | 5.0747 | 2.60 | 0.1 | 1.26 | 1.26 |
| | 2 | 5.0484 | 2.60 | 0.1 | 1.26 | |
| Fly ash | 1 | 5.9427 | 5.65 | 0.3 | 1.86 | 1.83 |
| | 2 | 5.6306 | 5.2 | 0.3 | 1.79 | |

**Table A.4** Organic Matter of sludge, biosoil and organic manure

| Type | Duplicate | Weight (g) | Blank (mL) | Volume of $FeSO_4$ (mL) | %OM | Average (%) |
|---|---|---|---|---|---|---|
| Sludge | 1 | 0.024 | 10.85 | 8.35 | 65.28 | 64.22 |
| | 2 | 0.0188 | 10.85 | 9.00 | 61.67 | |
| | 3 | 0.0186 | 10.85 | 8.90 | 65.71 | |
| Biosoil | 1 | 0.0854 | 11.2 | 7.80 | 24.17 | 24.13 |
| | 2 | 0.1285 | 11.2 | 6.15 | 23.86 | |
| | 3 | 0.0773 | 11.2 | 8.10 | 24.25 | |
| Manure | 1 | 0.0208 | 11.2 | 9.83 | 39.98 | 39.56 |
| | 2 | 0.0207 | 11.2 | 9.87 | 39.41 | |
| | 3 | 0.0208 | 11.2 | 9.86 | 39.30 | |

**Table A.5** Bulk density of sludge and biosoil

| Type soil | Duplicate | Weight (g) | Volume ($cm^3$) | Bulk density ($g/cm^3$) | Average |
|---|---|---|---|---|---|
| Sludge | 1 | 29.0 | 54.29 | 0.534 | 0.529 |
| | 2 | 28.8 | 54.29 | 0.530 | |
| | 3 | 28.4 | 54.29 | 0.523 | |
| Biosoil | 1 | 7.4 | 13.21 | 0.560 | 0.547 |
| | 2 | 7.2 | 13.21 | 0.545 | |
| | 3 | 7.1 | 13.21 | 0.537 | |

**Table A.6** Moisture of sludge and biosoil

| Type soil | Duplicate | Water content | Average (%) |
|---|---|---|---|
| Sludge | 1 | 84.95 | 84.75 |
| | 2 | 87.97 | |
| | 3 | 81.32 | |
| Biosoil | 1 | 5.99 | 5.83 |
| | 2 | 5.82 | |
| | 3 | 5.68 | |

**Table A.7** Total phosphorus of sludge and biosoil

| Type | Duplicate | Weight (g) | Absorbance (690 nm) | µg P from curve | mg-P/kg | Average |
|---|---|---|---|---|---|---|
| Sludge | 1 | 0.0579 | 0.234 | 16.14 | 25251 | 25427 |
| | 2 | 0.0571 | 0.212 | 14.62 | 25604 | |
| Biosoil | 1 | 0.0839 | 0.166 | 11.44 | 13645 | 13649 |
| | 2 | 0.0798 | 0.158 | 10.89 | 13654 | |

**Table A.8** Soluble Phosphorus of sludge and biosoil

| Type | Duplicate | Weight (g) | Absorbance (690 nm) | µg P from curve | mg-P/kg | Average |
|---|---|---|---|---|---|---|
| Sludge | 1 | 0.8107 | 0.098 | 6.76 | 4168 | 4174 |
| | 2 | 1.0887 | 0.132 | 9.10 | 4180 | |
| Biosoil | 1 | 1.0363 | 0.018 | 1.24 | 19.96 | 19.51 |
| | 2 | 1.0254 | 0.017 | 1.17 | 19.06 | |

**Table A.9** Available Phosphorus of sludge and biosoil

| Type | Duplicate | Weight (g) | Absorbance (690 nm) | µg P from curve | mg-P/kg | Average |
|---|---|---|---|---|---|---|
| Sludge | 1 | 0.1711 | 0.222 | 15.31 | 2982 | 2976 |
| | 2 | 0.3249 | 0.420 | 28.96 | 2971 | |
| Biosoil | 1 | 0.5264 | 0.375 | 25.86 | 1637 | 1635 |
| | 2 | 0.5582 | 0.397 | 27.38 | 1634 | |

**Table A.9** Concentration of soluble cadmium in sludge, bisoil and MKP fertiliser

| Type of samples | Total Cd (mg/kg) | | | Average |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Sludge | 0 | 0 | 0 | 0 |
| Bisoil | 0 | 0 | 0 | 0 |
| MKP fertiliser | 0.474 | 0.482 | 0.472 | 0.476 |

# APPENDIX C

Adsorption Isotherm Tests

**Table C.1** Equilibrium time of Cd onto biosoil

| Type | Time (min) | Dup. | Cd(II) (mg/L) | Average (mg/L) |
|---|---|---|---|---|
| Biosoil | 0 | 1 | 98.621 | 98.621 |

| | | | | |
|---|---|---|---|---|
| | | 2 | 98.621 | |
| | | 3 | 98.621 | |
| | 5 | 1 | 25.124 | 25.694 |
| | | 2 | 25.746 | |
| | | 3 | 26.212 | |
| | 10 | 1 | 23.228 | 23.843 |
| | | 2 | 24.642 | |
| | | 3 | 23.661 | |
| | 15 | 1 | 22.627 | 22.545 |
| | | 2 | 23.735 | |
| | | 3 | 21.273 | |
| | 20 | 1 | 20.845 | 20.727 |
| | | 2 | 22.822 | |
| | | 3 | 18.514 | |
| | 25 | 1 | 15.977 | 16.055 |
| | | 2 | 16.246 | |
| | | 3 | 15.943 | |
| | 30 | 1 | 15.331 | 14.089 |
| | | 2 | 14.142 | |
| | | 3 | 12.795 | |
| | 50 | 1 | 11.027 | 11.334 |
| | | 2 | 10.413 | |
| | | 3 | 12.562 | |
| | 60 | 1 | 10.067 | 9.693 |
| | | 2 | 9.574 | |
| | | 3 | 9.440 | |
| | 90 | 1 | 6.118 | 6.214 |
| | | 2 | 6.593 | |
| | | 3 | 5.931 | |
| | 120 | 1 | 6.262 | 6.143 |
| | | 2 | 6.133 | |
| | | 3 | 6.035 | |

**Table C.2** Equilibrium time of biosoil with MKP fertiliser

| Type | Time (min) | Dup. | Concentration of available phosphorus (mg/L) | Average (mg-P/L) |
|---|---|---|---|---|

| | | | Abs. | µg P from curve | mg-P/L | |
|---|---|---|---|---|---|---|
| Biosoil | 0 | 1 | 0.934 | 64.414 | 1610.344 | 1622.41 |
| | | 2 | 0.937 | 64.620 | 1615.517 | |
| | | 3 | 0.952 | 65.655 | 1641.379 | |
| | 5 | 1 | 0.868 | 59.862 | 1496.552 | 1506.89 |
| | | 2 | 0.872 | 60.137 | 1503.448 | |
| | | 3 | 0.882 | 60.827 | 1520.689 | |
| | 10 | 1 | 0.433 | 29.862 | 746.552 | 736.21 |
| | | 2 | 0.419 | 28.896 | 722.414 | |
| | | 3 | 0.429 | 29.586 | 739.655 | |
| | 15 | 1 | 0.251 | 17.310 | 432.759 | 425.86 |
| | | 2 | 0.242 | 16.689 | 417.241 | |
| | | 3 | 0.248 | 17.103 | 427.586 | |
| | 20 | 1 | 0.212 | 14.620 | 365.517 | 339.65 |
| | | 2 | 0.184 | 12.689 | 317.241 | |
| | | 3 | 0.195 | 13.448 | 336.206 | |
| | 25 | 1 | 0.193 | 13.310 | 332.758 | 315.52 |
| | | 2 | 0.175 | 12.069 | 301.724 | |
| | | 3 | 0.181 | 12.483 | 312.069 | |
| | 30 | 1 | 0.193 | 13.310 | 332.758 | 313.79 |
| | | 2 | 0.174 | 12.000 | 300.000 | |
| | | 3 | 0.179 | 12.344 | 308.621 | |
| | 40 | 1 | 0.172 | 11.862 | 296.552 | 289.65 |
| | | 2 | 0.162 | 11.172 | 279.310 | |
| | | 3 | 0.170 | 11.724 | 293.103 | |
| | 50 | 1 | 0.168 | 11.582 | 289.655 | 284.48 |
| | | 2 | 0.161 | 11.103 | 277.586 | |
| | | 3 | 0.166 | 11.448 | 286.207 | |
| | 60 | 1 | 0.159 | 10.965 | 274.138 | 262.07 |
| | | 2 | 0.146 | 10.069 | 251.724 | |
| | | 3 | 0.151 | 10.414 | 260.344 | |
| | 90 | 1 | 0.157 | 10.827 | 270.689 | 256.89 |
| | | 2 | 0.141 | 9.724 | 243.103 | |
| | | 3 | 0.149 | 10.275 | 256.896 | |
| | 120 | 1 | 0.139 | 9.586 | 239.655 | 220.69 |
| | | 2 | 0.125 | 8.621 | 215.517 | |
| | | 3 | 0.120 | 8.276 | 206.896 | |

**Table C.3** Equilibrium time of biosoil with organic manure fertiliser

| Type | Time (min) | Dup. | Concentration of available | Average (mg- |
|---|---|---|---|---|

| | | | phosphorus (mg/L) | | | P/L) |
|---|---|---|---|---|---|---|
| | | | **Abs.** | **µg P from curve** | **mg-P/L** | |
| Biosoil | 0 | 1 | 0.792 | 54.621 | 54.621 | 54.896 |
| | | 2 | 0.794 | 54.758 | 54.758 | |
| | | 3 | 0.802 | 55.310 | 55.310 | |
| | 5 | 1 | 0.341 | 23.517 | 11.758 | 11.069 |
| | | 2 | 0.324 | 22.344 | 11.172 | |
| | | 3 | 0.298 | 20.551 | 10.275 | |
| | 10 | 1 | 0.179 | 12.344 | 6.172 | 5.758 |
| | | 2 | 0.169 | 11.655 | 5.827 | |
| | | 3 | 0.153 | 10.552 | 5.275 | |
| | 15 | 1 | 0.073 | 5.034 | 2.517 | 2.310 |
| | | 2 | 0.062 | 4.275 | 2.138 | |
| | | 3 | 0.066 | 4.552 | 2.275 | |
| | 20 | 1 | 0.041 | 2.827 | 1.413 | 1.551 |
| | | 2 | 0.043 | 2.965 | 1.482 | |
| | | 3 | 0.051 | 3.517 | 1.758 | |
| | 25 | 1 | 0.042 | 2.896 | 1.448 | 1.517 |
| | | 2 | 0.048 | 3.310 | 1.655 | |
| | | 3 | 0.042 | 2.896 | 1.448 | |
| | 30 | 1 | 0.049 | 3.379 | 1.689 | 1.448 |
| | | 2 | 0.043 | 2.965 | 1.482 | |
| | | 3 | 0.034 | 2.344 | 1.172 | |
| | 40 | 1 | 0.036 | 2.482 | 1.241 | 1.344 |
| | | 2 | 0.041 | 2.827 | 1.413 | |
| | | 3 | 0.040 | 2.758 | 1.379 | |
| | 50 | 1 | 0.037 | 2.552 | 1.275 | 1.241 |
| | | 2 | 0.033 | 2.275 | 1.138 | |
| | | 3 | 0.038 | 2.621 | 1.310 | |
| | 60 | 1 | 0.033 | 2.276 | 1.138 | 1.172 |
| | | 2 | 0.034 | 2.344 | 1.172 | |
| | | 3 | 0.035 | 2.413 | 1.207 | |
| | 90 | 1 | 0.028 | 1.931 | 0.965 | 1.103 |
| | | 2 | 0.037 | 2.551 | 1.275 | |
| | | 3 | 0.031 | 2.137 | 1.068 | |
| | 120 | 1 | 0.028 | 1.931 | 0.965 | 1.068 |
| | | 2 | 0.032 | 2.206 | 1.103 | |
| | | 3 | 0.033 | 2.275 | 1.137 | |

**Table C.4** Sorption of biosoil with Cd

| Type | Weight of OM (g.) | Concentration of solution at $C_0$ (mg/L) | Dup. | Concentration of solution at $C_t$ (mg/L) | Average |
|---|---|---|---|---|---|
| Biosoil | 2.42 | 13.42 | 1 | 0.512 | 0.533 |
| | 2.42 | 13.42 | 2 | 0.549 | |
| | 2.42 | 13.42 | 3 | 0.538 | |
| | 2.42 | 36.63 | 1 | 1.547 | 1.562 |
| | 2.42 | 36.63 | 2 | 1.603 | |
| | 2.42 | 36.63 | 3 | 1.536 | |
| | 2.42 | 55.21 | 1 | 2.762 | 2.838 |
| | 2.42 | 55.21 | 2 | 2.905 | |
| | 2.42 | 55.21 | 3 | 2.847 | |
| | 2.42 | 72.84 | 1 | 4.357 | 4.647 |
| | 2.42 | 72.84 | 2 | 4.677 | |
| | 2.42 | 72.84 | 3 | 4.907 | |
| | 2.42 | 94.12 | 1 | 5.342 | 5.580 |
| | 2.42 | 94.12 | 2 | 5.574 | |
| | 2.42 | 94.12 | 3 | 5.824 | |

**Table C.5** Sorption of biosoil with MKP fertiliser

| Type | Weight of OM (g) | Dup. | Concentration of available phosphorus (mg/L) | | | Average (mg-P/L) |
|---|---|---|---|---|---|---|
| | | | Abs. | µg P from curve | mg-P/L | |
| Biosoil | 1.22 | 1 | 0.01 | 0.689 | 1.38 | 1.103 |
| | | 2 | 0.007 | 0.483 | 0.97 | |
| | | 3 | 0.007 | 0.483 | 0.97 | |
| | 0.97 | 1 | 0.084 | 5.793 | 23.17 | 23.724 |
| | | 2 | 0.089 | 6.138 | 24.55 | |
| | | 3 | 0.085 | 5.862 | 23.45 | |
| | 0.74 | 1 | 0.132 | 9.103 | 91.03 | 88.965 |
| | | 2 | 0.131 | 9.034 | 90.34 | |
| | | 3 | 0.124 | 8.552 | 85.52 | |
| | 0.49 | 1 | 0.163 | 11.241 | 281.03 | 281.034 |
| | | 2 | 0.164 | 11.310 | 282.76 | |
| | | 3 | 0.162 | 11.172 | 279.31 | |
| | 0.25 | 1 | 0.317 | 21.862 | 546.55 | 543.103 |
| | | 2 | 0.313 | 21.586 | 539.66 | |
| | | 3 | 0.315 | 21.724 | 543.10 | |

**Table C.6** Sorption of biosoil with organic manure

| Type | Weight (g OM) | Dup. | Concentration of available phosphorus (mg/L) | | | Average (mg-P/L) |
|---|---|---|---|---|---|---|
| | | | Abs. | µg P from curve | mg-P/L | |
| Biosoil | 0.72 | 1 | 0.027 | 1.862 | 0.621 | 0.713 |
| | | 2 | 0.037 | 2.552 | 0.850 | |
| | | 3 | 0.029 | 2.000 | 0.667 | |
| | 0.60 | 1 | 0.051 | 3.517 | 1.172 | 1.034 |
| | | 2 | 0.047 | 3.241 | 1.080 | |
| | | 3 | 0.037 | 2.552 | 0.850 | |
| | 0.48 | 1 | 0.069 | 4.758 | 1.586 | 1.540 |
| | | 2 | 0.062 | 4.275 | 1.425 | |
| | | 3 | 0.070 | 4.827 | 1.609 | |
| | 0.36 | 1 | 0.094 | 6.482 | 2.161 | 2.344 |
| | | 2 | 0.109 | 7.517 | 2.505 | |
| | | 3 | 0.103 | 7.103 | 2.368 | |
| | 0.24 | 1 | 0.224 | 15.448 | 5.149 | 5.310 |
| | | 2 | 0.241 | 16.621 | 5.540 | |
| | | 3 | 0.228 | 15.724 | 5.241 | |

**Table C.7** Sorption of Cd on saturated biosoil with P from MKP-fertiliser

| Type | Weight of g P | Concentration of solution at $C_0$ (mg/L) | Dup. | Concentration of solution at $C_t$ (mg/L) | Average |
|---|---|---|---|---|---|
| Biosoil | 0.1637 | 52.38 | 1 | 0.232 | 0.247 |
| | | 52.38 | 2 | 0.281 | |
| | | 52.38 | 3 | 0.228 | |
| | | 68.90 | 1 | 0.347 | 0.350 |
| | | 68.90 | 2 | 0.362 | |
| | | 68.90 | 3 | 0.341 | |
| | | 78.89 | 1 | 0.406 | 0.412 |
| | | 78.89 | 2 | 0.417 | |
| | | 78.89 | 3 | 0.413 | |
| | | 90.84 | 1 | 0.584 | 0.573 |
| | | 90.84 | 2 | 0.592 | |
| | | 90.84 | 3 | 0.543 | |

**Table C.8** Sorption of Cd on saturated biosoil with P from organic manure

| Type | Weight of g P | Concentration of solution at $C_0$ (mg/L) | Dup. | Concentration of solution at $C_t$ (mg/L) | Average |
|---|---|---|---|---|---|
| Biosoil | 0.011 | 52.38 | 1 | 3.124 | 3.161 |
| | | 52.38 | 2 | 3.182 | |
| | | 52.38 | 3 | 3.177 | |
| | | 68.90 | 1 | 4.764 | 4.621 |
| | | 68.90 | 2 | 4.816 | |
| | | 68.90 | 3 | 4.283 | |
| | | 78.89 | 1 | 5.923 | 5.610 |
| | | 78.89 | 2 | 5.891 | |
| | | 78.89 | 3 | 5.061 | |
| | | 90.84 | 1 | 6.902 | 7.030 |
| | | 90.84 | 2 | 7.162 | |
| | | 90.84 | 3 | 7.026 | |