Supplementary Material

Magnetic nanoparticles for eliminating endocrine-disrupting compounds in water treatment – a quantitative systematic analysis

Juliana Guimarães, Igor Taveira, Thuane Mendes Anacleto, Alex Enrich-Prast, Fernanda Abreu

# Supplementary Tables

**Supplementary Table 1.** MNPs compositions, average size (nm), adsorption time (min) and average recovery (%).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Publication | MNP composition | Average MNP size (nm) | Adsorption time (min) | Average recovery (%) |
| Bunkoed *et al*., 2016 | Alginate/magnetite | 80 | 20 | 90 |
| Liang *et al*., 2022 | Banana-peel-derived carbon powder | 35 | 20 | 90.2 |
| Ahmed *et al*., 2021 | Cobalt ferrite | 10 | 60 | 99.2 |
| Avan *et al*., 2018 | Cobalt ferrite | 15 | 3 | 99 |
| Fierascu *et al*., 2018 | Copper ferrite and nickel ferrite | 15 | 1470 | 72.5 |
| Zhao *et al*., 2018 | Fe3O4@SiO2 | 43.8 | 30 | 100 |
| Gao *et al*., 2014 | Fe3O4@SiO2 | 240 | 4 | 95.3 |
| Casado-Carmona *et al*., 2016 | Fe3O4@SiO2 | 12 | 6 | 92.9 |
| Wu *et al*., 2017 | Fe3O4@SiO2 | 250 | 5.5 | 100.5 |
| Alcudia-Leon *et al*., 2013 | Fe3O4@SiO2 | 10 | 2 | 101 |
| Liu *et al*., 2020 | Fe3O4@SiO2 | 490 | 15 | 101 |
| Chalasani *et al*., 2013 | Fe3O4@SiO2 | 9 | 60 | 100 |
| Sinha *et al*., 2013 | g-FEstradiolO3 | 7.5 | 12.5 | 80 |
| Li *et al*., 2015 | Iron nanowires | 175 | 10 | 86.6 |
| Ferreira *et al*., 2020 | Maghemite | 11 | 40 | 86 |
| Wu *et al*., 2020b | Magnetic C18 silica spheres | 215 | 5 | 90.8 |
| Tasmia *et al*., 2020a | Magnetic chitosan biopolymer | 158.64 | 25 | 94.5 |
| Tasmia *et al*., 2020b | Magnetic graphene oxide beads | 105.4 | 20 | 85 |
| Tahmasebi *et al*., 2014 | Magnetite | 40 | 15 | 90 |
| Chormey *et al*., 2019 | Magnetite | 200 | 0.5 | 90 |
| Perez *et al*., 2016 | Magnetite | 75 | 5 | 70.5 |
| Er *et al*., 2016 | Magnetite | 16.2 | 3 | 105.5 |
| Ayyildiz *et al*., 2020 | Magnetite | 50 | 5 | 97.6 |
| Wang *et al*., 2021 | Magnetite | 30 | 10 | 95.3 |
| Sheng *et al*., 2016 | Magnetite | 40 | 45 | 81.3 |
| Xie *et al*., 2015 | Magnetite | 230 | 95 | 81.3 |
| Alcudia-Leon *et al*., 2013 | Magnetite | 50 | 30 | 99 |
| Khatibikamal *et al*., 2019 | Magnetite | 80 | 60 | 66.3 |
| Miah *et al*., 2015 | Magnetite | 75 | 0.1 | 71.1 |
| Es'haghi *et al*., 2016 | Magnetite | 50 | 15 | 88.1 |
| Lopes *et al*., 2019 | Magnetite | 204.5 | 50 | 99.8 |
| Hao *et al*., 2015 | Magnetite | 80 | 30 | 94.2 |
| Socas-Rodriguez *et al*., 2015 | Magnetite | 27 | 10 | 93.8 |
| Wu *et al*., 2020 | Magnetite | 11.4 | 6 | 96.3 |
| Perez *et al*., 2014 | Magnetite | 50 | 14.6 | 83.7 |
| Zhao *et al*., 2019 | Magnetite | 420 | 6.6 | 86.7 |
| Xia *et al*., 2013 | Magnetite | 140.8 | 5 | 61.4 |
| Capriotti *et al*., 2016 | Magnetite | 12.5 | 6.8 | 70.4 |
| Jiang *et al*., 2015 | Magnetite | 100 | 5 | 99.9 |
| Ardao *et al*., 2015 | Magnetite | 50 | 5 | 90 |
| Gorji *et al*., 2019 | Magnetite | 77.5 | 40 | 96 |
| Park *et al*., 2018 | Magnetite | 260 | 15 | 47.2 |
| Rostamifasih *et al*., 2019 | Magnetite | 28.5 | 32.1 | 54.5 |
| Li *et al*., 2017 | Magnetite | 12 | 10 | 98 |
| Yusoff *et al*., 2018 | Magnetite | 18 | 80 | 77.1 |
| Abdolmohammad-Zadeh *et al*., 2020 | Magnetite | 17 | 15 | 100.2 |
| Chen *et al*., 2016 | Magnetite | 300 | 10 | 98.4 |
| Gong *et al*., 2017 | Magnetite | 10 | 6 | 97.2 |
| Li *et al*., 2020 | Magnetite | 15.3 | 60 | 75 |
| Wang *et al*., 2015 | Magnetite | 15.3 | 30 | 70 |
| Wang *et al*., 2022 | Magnetite | 250 | 15 | 70 |
| Wang *et al*., 2018 | Magnetite | 15 | 30 | 82 |
| Liu *et al*., 2019 | Magnetite | 100 | 120 | 90 |
| Yan *et al*., 2018 | Magnetite | 30 | 20 | 90 |
| Li *et al*., 2018 | Magnetite | 10 | 35 | 75 |
| Khadgi *et al*., 2016 | Magnetite | 7.5 | 240 | 70 |
| Fachina *et al*., 2022 | Magnetite | 10 | 240 | 70 |
| Pan *et al*., 2017 | Magnetite | 15 | 360 | 70 |
| Peng *et al*., 2016 | Magnetite | 25 | 15 | 90 |
| Yuan *et al*., 2020 | Magnetite | 100 | 30 | 47.5 |
| Bergamin *et al*., 2019 | Magnetite | 225 | 30 | 85.6 |
| Huang *et al*., 2021 | Magnetite | 100 | 15 | 80 |
| Tian *et al*., 2021 | Magnetite | 100 | 20 | 90 |
| He *et al*., 2016 | Magnetite | 20 | 10 | 80 |
| Zhou *et al*., 2017 | SiO2@Fe | 200 | 30 | 95.2 |
| Attia *et al*., 2013 | Zeolite | 15 | 10 | 95 |
| Li *et al*., 2020 | Zinc ferrite | 200 | 10 | 91.1 |
| del Rio *et al*., 2022 | Zinc-Iron mixed metal magnetic nanoparticles | 30 | 1440 | 98.1 |
| Wang *et al*., 2020 | γ-FEstradiolO3 | 21 | 150 | 94.7 |

**Supplementary Table 2.** Linear regression of all magnetic particles’, magnetite and MOP concentration, size and adsorption time impact in EDC recovery rate.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameters** | **Category** | **Function** | **Adjusted R2** | **n** |
| Particle concentration | All MNPs | *r* = -0.07*c* + 87.57 | 0.0120 | 691 |
| Particle size | *r* = -0.00*s* + 87.19 | 0.0037 | 691 |
| Adsorption time | *r* = 0.01*t* + 85.54 | 0.0141 | 691 |
| Particle concentration | Magnetite | *r* = -0.05*c* + 83.15 | 0.0059 | 437 |
| Particle size | *r* = 0.01*s* + 81.04 | 0.0107 | 437 |
| Adsorption time | r = -0.06*t* + 83.82 | 0.0049 | 437 |
| Particle concentration | Metallic oxides | *r* = 0.53*c* + 94.63 | 0.1165 | 226 |
| Particle size | *r* = 0.00*s* + 94.03 | 0.0428 | 226 |
| Adsorption time | *r* = -0.01*t* + 95.84 | 0.1570 | 226 |

**Legend:** r: recovery; c: concentration; t: adsorption time; and s: size.

**Supplementary Table 3.** Linear regression of MNP concentration, size and adsorption time impact in EDC recovery rate.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EDC** | **Category** | **Function** | **Adjusted R2** | **n** |
| Parabens | Concentration | *r* = 4.60*c* + 78.28 | 0.2031 | 123 |
| Phenols | *r* = -0.25*c* + 87.46 | 0.1042 | 86 |
| Natural hormones | *r* = 0.03*c* + 82.84 | 0.0004 | 129 |
| Phthalates | *r* = -0.18*c* + 97.21 | 0.4970 | 31 |
| Synthetic hormones | *r* = -0.06*c* + 90.41 | 0.0090 | 47 |
| Bisphenols | *r* = -0.07*c* + 93.35 | 0.0240 | 160 |
| Parabens | Particle size | *r* = -2.44*s* + 126.2 | 0.7103 | 123 |
| Phenols | *r* = 0.02*s* + 81.51 | 0.0316 | 86 |
| Natural hormones | *r* = 0.03*s* + 78.37 | 0.0888 | 129 |
| Phthalates | *r* = -0.20*s* + 99.16 | 0.8290 | 31 |
| Synthetic hormones | *r* = 0.00*s* + 89.92 | 0.0001 | 47 |
| Bisphenols | *r* = 0.01*s* + 90.95 | 0.0529 | 160 |
| Parabens | Adsorption time | *r* = -0.93*t* + 99.00 | 0.4618 | 123 |
| Phenols | *r* = 0.20*t* + 81.92 | 0.0220 | 86 |
| Natural hormones | *r* = -0.00*t* + 83.15 | 0.0026 | 129 |
| Phthalates | *r* = -0.59*t* + 99.91 | 0.5243 | 31 |
| Synthetic hormones | *r* = -0.37*t* + 196.6 | 0.0004 | 47 |
| Bisphenols | *r* = -0.19*t* + 96.18 | 0.2006 | 160 |

**Legend:** r: recovery; c: concentration; t: adsorption time; and s: size.

# Supplementary Figures

# \Chart  Description automatically generated

**Supplementary Figure 1.** Synthesis methods of MNPs according to their different chemical compositions.



**Supplementary Figure 2.** Statistical analysis regarding MNPs size. recovery rate. adsorption time and MNPs concentration. A. Principal component analysis (PCA). B. Pearson's correlation analysis.

# References

‌ Abdolmohammad-Zadeh, H., Zamani, A. and Shamsi, Z. (2020) 'Extraction of four endocrine-disrupting chemicals using a Fe3O4/graphene oxide/di-(2-ethylhexyl) phosphoric acid nano-composite, and their quantification by HPLC-UV,' Microchemical Journal, 157, p. 104964. <https://doi.org/10.1016/j.microc.2020.104964>.

Ahmed, A. et al. (2021) 'Heterogeneous activation of peroxymonosulfate using superparamagnetic β-CD-CoFe2O4 catalyst for the removal of endocrine-disrupting bisphenol A: Performance and degradation mechanism,' Separation and Purification Technology, 279, p. 119752. <https://doi.org/10.1016/j.seppur.2021.119752>.

Alcudia-León, M.C. et al. (2013) 'Determination of parabens in waters by magnetically confined hydrophobic nanoparticle microextraction coupled to gas chromatography/mass spectrometry,' Microchemical Journal, 110, pp. 643–648. https://doi.org/10.1016/j.microc.2013.07.011. Alcudia-León, M. C. et al. (2013) 'Magnetically confined hydrophobic nanoparticles for the microextraction of endocrine-disrupting phenols from environmental waters,' Analytical and Bioanalytical Chemistry/Analytical & Bioanalytical Chemistry, 405(8), pp. 2729–2734. <https://doi.org/10.1007/s00216-012-6683-2>.

Ardao, I., Magnin, D. and Agathos, S.N. (2015) 'Bioinspired production of magnetic laccase‐biotitania particles for the removal of endocrine disrupting chemicals,' Biotechnology and Bioengineering, 112(10), pp. 1986–1996. <https://doi.org/10.1002/bit.25612>.

Attia, T.M.S., Hu, X.L. and Yin, D.Q. (2013) 'Synthesized magnetic nanoparticles coated zeolite for the adsorption of pharmaceutical compounds from aqueous solution using batch and column studies,' Chemosphere, 93(9), pp. 2076–2085. <https://doi.org/10.1016/j.chemosphere.2013.07.046>.

Avan, A.A. and Filik, H. (2018) 'CoFe2O4-MWCNTs Modified Screen Printed Carbon Electrode Coupled with Magnetic CoFe2O4-MWCNTs Based Solid Phase Microextraction for the detection of Bisphenol A,' Current Nanoscience, 14(3), pp. 199–208. <https://doi.org/10.2174/1573413713666171109160816>.

Ayyıldız, M.F. et al. (2020) 'A simple and efficient preconcentration method based on vortex assisted reduced graphene oxide magnetic nanoparticles for the sensitive determination of endocrine disrupting compounds in different water and baby food samples by GC-FID,' Journal of Food Composition and Analysis, 88, p. 103431. <https://doi.org/10.1016/j.jfca.2020.103431>.

Bergamin, B. et al. (2019) 'A New Electrochemical Platform Based on a Polyurethane Composite Electrode Modified with Magnetic Nanoparticles Coated with Molecularly Imprinted Polymer for the Determination of Estradiol Valerate in Different Matrices,' Journal of the Brazilian Chemical Society [Preprint]. <https://doi.org/10.21577/0103-5053.20190142>.

Bunkoed, O. et al. (2016) 'Polypyrrole‐coated alginate/magnetite nanoparticles composite sorbent for the extraction of endocrine‐disrupting compounds,' Journal of Separation Science, 39(18), pp. 3602–3609. <https://doi.org/10.1002/jssc.201600647>.

Capriotti, A.L. et al. (2016) 'Polydopamine-coated magnetic nanoparticles for isolation and enrichment of estrogenic compounds from surface water samples followed by liquid chromatography-tandem mass spectrometry determination,' Analytical and Bioanalytical Chemistry/Analytical & Bioanalytical Chemistry, 408(15), pp. 4011–4020. <https://doi.org/10.1007/s00216-016-9489-9>.

Casado-Carmona, F.A. et al. (2016) 'Magnetic nanoparticles coated with ionic liquid for the extraction of endocrine disrupting compounds from waters,' Microchemical Journal, 128, pp. 347–353. <https://doi.org/10.1016/j.microc.2016.05.011>.

Chalasani, R. and Vasudevan, S. (2013) 'Cyclodextrin-Functionalized FE3O4@TIO2: reusable, magnetic nanoparticles for photocatalytic degradation of Endocrine-Disrupting chemicals in water supplies,' ACS Nano, 7(5), pp. 4093–4104. <https://doi.org/10.1021/nn400287k>.

Chen, F. et al. (2015) 'Magnetic molecularly imprinted polymers synthesized by surface‐initiated reversible addition‐fragmentation chain transfer polymerization for the enrichment and determination of synthetic estrogens in aqueous solution,' Journal of Separation Science, 38(15), pp. 2670–2676. <https://doi.org/10.1002/jssc.201500407>.

Chormey, D.S. et al. (2019) 'Oleic and stearic acid-coated magnetite nanoparticles for sonication-assisted binary micro-solid phase extraction of endocrine disrupting compounds, and their quantification by GC-MS,' Mikrochimica Acta, 186(12). <https://doi.org/10.1007/s00604-019-3821-y>.

Del Rio, M. et al. (2022) 'Zinc/Iron mixed-metal MOF-74 derived magnetic carbon nanorods for the enhanced removal of organic pollutants from water,' Chemical Engineering Journal, 428, p. 131147. <https://doi.org/10.1016/j.cej.2021.131147>.

Er, E.Ö. et al. (2019) 'Ultrasound-assisted dispersive solid phase extraction based on Fe3O4/reduced graphene oxide nanocomposites for the determination of 4-tert octylphenol and atrazine by gas chromatography–mass spectrometry,' Microchemical Journal, 146, pp. 423–428. <https://doi.org/10.1016/j.microc.2019.01.040>.

Fachina, Y.J. et al. (2020) 'Graphene oxide functionalized with cobalt ferrites applied to the removal of bisphenol A: ionic study, reuse capacity and desorption kinetics,' Environmental Technology, 43(9), pp. 1388–1404. <https://doi.org/10.1080/09593330.2020.1830183>.

Fierăscu, R.C. et al. (2018) 'INORGANIC/ORGANIC CORE-SHELL MAGNETIC MATERIALS FOR REMOVAL OF ENDOCRINE DISRUPTING PHARMACEUTICALS FROM WATER,' FARMACIA, 66(2), pp. 316–317. <https://farmaciajournal.com/arhiva/201802/art-18-Fierascu_Fierascu_Anuta_316-322.pdf>.

Gao, R. et al. (2014) 'Novel magnetic multi-template molecularly imprinted polymers for specific separation and determination of three endocrine disrupting compounds simultaneously in environmental water samples,' RSC Advances, 4(100), pp. 56798–56808. <https://doi.org/10.1039/c4ra09825k>.

Gong, S. et al. (2017) 'Aminosilanized magnetic carbon microspheres for the magnetic solid‐phase extraction of bisphenol A, bisphenol AF, and tetrabromobisphenol A from environmental water samples,' Journal of Separation Science, 40(8), pp. 1755–1764. <https://doi.org/10.1002/jssc.201601228>.

Hao, Y. et al. (2015) 'Water-compatible magnetic imprinted nanoparticles served as solid-phase extraction sorbents for selective determination of trace 17beta-estradiol in environmental water samples by liquid chromatography,' Journal of Chromatography a/Journal of Chromatography, 1396, pp. 7–16. <https://doi.org/10.1016/j.chroma.2015.03.083>.

He, X.-P. et al. (2016) 'Preparation and characterization of magnetic molecularly imprinted polymers for selective trace extraction of dienestrol in seawater,' Journal of Chromatography a/Journal of Chromatography, 1469, pp. 8–16. <https://doi.org/10.1016/j.chroma.2016.09.052>.

Huang, Y. et al. (2021) 'One-step preparation of functional groups-rich graphene oxide and carbon nanotubes nanocomposite for efficient magnetic solid phase extraction of glucocorticoids in environmental waters,' Chemical Engineering Journal, 406, p. 126785. <https://doi.org/10.1016/j.cej.2020.126785>.

Jiang, X. et al. (2015) 'Polyaniline-coated chitosan-functionalized magnetic nanoparticles: Preparation for the extraction and analysis of endocrine-disrupting phenols in environmental water and juice samples,' Talanta, 141, pp. 239–246. <https://doi.org/10.1016/j.talanta.2015.04.017>.

Khadgi, N. et al. (2016) 'Enhanced photocatalytic degradation of 17Α‐Ethinylestradiol exhibited by multifunctional ZNFE2O4–AG/RGO nanocomposite under visible light,' Photochemistry and Photobiology, 92(2), pp. 238–246. <https://doi.org/10.1111/php.12565>.

Khatibikamal, V. et al. (2019) 'Optimized poly(amidoamine) coated magnetic nanoparticles as adsorbent for the removal of nonylphenol from water,' Microchemical Journal, 145, pp. 508–516. <https://doi.org/10.1016/j.microc.2018.11.018>.

Li, D. et al. (2016) 'Determination of trace bisphenol A in environmental water by high-performance liquid chromatography using magnetic reduced graphene oxide based solid-phase extraction coupled with dispersive liquid–liquid microextraction,' Analytical and Bioanalytical Chemistry/Analytical & Bioanalytical Chemistry, 409(5), pp. 1165–1172. <https://doi.org/10.1007/s00216-016-0087-7>.

Li, F. et al. (2015) 'Extraction of endocrine disrupting phenols with iron-ferric oxide core-shell nanowires on graphene oxide nanosheets, followed by their determination by HPLC,' Mikrochimica Acta, 182(15–16), pp. 2503–2511. <https://doi.org/10.1007/s00604-015-1619-0>.

Li, J. et al. (2018) 'Investigation of nanoscale zerovalent iron-based magnetic and thermal dual-responsive composite materials for the removal and detection of phenols,' Chemosphere, 195, pp. 472–482. <https://doi.org/10.1016/j.chemosphere.2017.12.093>.

Li, W. et al. (2020) 'Facile preparation of reduced graphene oxide/ZnFe2O4 nanocomposite as magnetic sorbents for enrichment of estrogens,' Talanta, 208, p. 120440. <https://doi.org/10.1016/j.talanta.2019.120440>.

Liu, J. et al. (2020) 'Zeolitic imidazolate framework-8 coated Fe3O4@SiO2 composites for magnetic solid-phase extraction of bisphenols,' New Journal of Chemistry, 44(14), pp. 5324–5332. <https://doi.org/10.1039/d0nj00006j>.

Liu, S. et al. (2019) 'Core–Shell FE3O4@MIL-100(FE) magnetic nanoparticle for effective removal of meloxicam and naproxen in aqueous solution,' Journal of Chemical and Engineering Data/Journal of Chemical & Engineering Data, 64(7), pp. 2997–3007. <https://doi.org/10.1021/acs.jced.9b00061>.

Lopes, D. et al. (2019) 'Histamine functionalized magnetic nanoparticles (HIS-MNP) as a sorbent for thin film microextraction of endocrine disrupting compounds in aqueous samples and determination by high performance liquid chromatography-fluorescence detection,' Journal of Chromatography a/Journal of Chromatography, 1602, pp. 41–47. <https://doi.org/10.1016/j.chroma.2019.05.032>.

Miah, M., Iqbal, Z. and Lai, E.P.C. (2014) 'Comparative Binding of Endocrine Disrupting Compounds and Pharmaceuticals with Polydopamine‐ and Polypyrrole‐coated Magnetic Nanoparticles,' Clean, 43(2), pp. 173–181. <https://doi.org/10.1002/clen.201300210>.

Pan, X. et al. (2017) 'Degradation of UV-filter benzophenone-3 in aqueous solution using persulfate catalyzed by cobalt ferrite,' Chemical Engineering Journal, 326, pp. 1197–1209. <https://doi.org/10.1016/j.cej.2017.06.068>.

Park, C.M. et al. (2018) 'Heterogeneous activation of persulfate by reduced graphene oxide–elemental silver/magnetite nanohybrids for the oxidative degradation of pharmaceuticals and endocrine disrupting compounds in water,' Applied Catalysis. B, Environmental, 225, pp. 91–99. <https://doi.org/10.1016/j.apcatb.2017.11.058>.

Peng, H. et al. (2016) 'Preparation of photonic-magnetic responsive molecularly imprinted microspheres and their application to fast and selective extraction of 17β-estradiol,' Journal of Chromatography a/Journal of Chromatography, 1442, pp. 1–11. <https://doi.org/10.1016/j.chroma.2016.03.003>.

Pérez, R.A. et al. (2014) 'Analysis of steroid hormones in water using Palmitate-Coated magnetite nanoparticles Solid-Phase extraction and gas Chromatography–Tandem mass spectrometry,' Chromatographia, 77(11–12), pp. 837–843. https://doi.org/10.1007/s10337-014-2688-7.

Pérez, R.A. et al. (2016) 'Determination of endocrine-disrupting compounds in water samples by magnetic nanoparticle-assisted dispersive liquid–liquid microextraction combined with gas chromatography–tandem mass spectrometry,' Analytical and Bioanalytical Chemistry/Analytical & Bioanalytical Chemistry, 408(28), pp. 8013–8023. <https://doi.org/10.1007/s00216-016-9899-8>.

Rostamifasih, Z. et al. (2019) 'Heterogeneous catalytic degradation of methylparaben using persulfate activated by natural magnetite; optimization and modeling by response surface methodology,' Journal of Chemical Technology and Biotechnology/Journal of Chemical Technology & Biotechnology, 94(6), pp. 1880–1892. <https://doi.org/10.1002/jctb.5964>.

Sheng, Y. et al. (2016) 'Double-functionalised magnetic nanoparticles for efficient extraction of bisphenol A from river water,' Environmental Chemistry, 13(1), p. 43. <https://doi.org/10.1071/en15024>.

Sinha, A. and Jana, N.R. (2013) 'Graphene‐Based Composite with γ‐Fe2O3 Nanoparticle for the High‐Performance Removal of Endocrine‐Disrupting Compounds from Water,' Chemistry - an Asian Journal, 8(4), pp. 786–791. <https://doi.org/10.1002/asia.201201084>.

Socas-Rodríguez, B. et al. (2015) 'Core–shell polydopamine magnetic nanoparticles as sorbent in micro-dispersive solid-phase extraction for the determination of estrogenic compounds in water samples prior to high-performance liquid chromatography–mass spectrometry analysis,' Journal of Chromatography a/Journal of Chromatography, 1397, pp. 1–10. <https://doi.org/10.1016/j.chroma.2015.04.010>.

Tahmasebi, E. and Yamini, Y. (2014) 'Extraction and preconcentration of 17α-ethynylestradiol as an endocrine-disrupting agent from environmental water samples by a modified magnetic nanosorbent,' Journal of the Iranian Chemical Society, 11(6), pp. 1681–1686. <https://doi.org/10.1007/s13738-014-0441-7>.

Tasmia, N., Shah, J. and Jan, M.R. (2020) 'Microextraction of Selected Endocrine Disrupting Phenolic Compounds using Magnetic Chitosan Biopolymer Graphene Oxide Nanocomposite,' Journal of Polymers and the Environment, 28(6), pp. 1673–1683. <https://doi.org/10.1007/s10924-020-01714-x>.

Tian, Xing et al. (2020) 'Hydrophilic magnetic molecularly imprinted nanobeads for efficient enrichment and high performance liquid chromatographic detection of 17beta-estradiol in environmental water samples,' Talanta, 220, p. 121367. <https://doi.org/10.1016/j.talanta.2020.121367>.

Torres, N.H. et al. (2021) 'Environmental aspects of hormones estriol, 17β-estradiol and 17α-ethinylestradiol: Electrochemical processes as next-generation technologies for their removal in water matrices,' Chemosphere, 267, p. 128888. <https://doi.org/10.1016/j.chemosphere.2020.128888>.

Wang, L. et al. (2021) 'Facile covalent preparation of carbon nanotubes / amine-functionalized Fe3O4 nanocomposites for selective extraction of estradiol in pharmaceutical industry wastewater,' Journal of Chromatography a/Journal of Chromatography, 1638, p. 461889. <https://doi.org/10.1016/j.chroma.2021.461889>.

Wang, X. et al. (2018) 'Adsorption of trace estrogens in ultrapure and wastewater treatment plant effluent by magnetic graphene oxide,' International Journal of Environmental  Research and Public Health/International Journal of Environmental Research and Public Health, 15(7), p. 1454. <https://doi.org/10.3390/ijerph15071454>.

Wang, X. and Deng, C. (2015) 'Preparation of magnetic graphene @polydopamine @Zr-MOF material for the extraction and analysis of bisphenols in water samples,' Talanta, 144, pp. 1329–1335. <https://doi.org/10.1016/j.talanta.2015.08.014>.

Wang, Y. et al. (2022) 'Preparation of lightweight daisy-like magnetic molecularly imprinted polymers via etching synergized template immobilization for enhanced rapid detection of trace 17β-estradiol,' Journal of Hazardous Materials, 424, p. 127216. <https://doi.org/10.1016/j.jhazmat.2021.127216>.

Wu, M. et al. (2020a) 'Determination of estrogens by solid-phase quadruplex stable isotope dansylation coupled with liquid chromatography-high resolution mass spectrometry in environmental samples,' Talanta, 219, p. 121272. <https://doi.org/10.1016/j.talanta.2020.121272>.

Wu, M. et al. (2020b) 'Determination of estrogens by solid-phase quadruplex stable isotope dansylation coupled with liquid chromatography-high resolution mass spectrometry in environmental samples,' Talanta, 219, p. 121272. <https://doi.org/10.1016/j.talanta.2020.121272>.

Wu, X. et al. (2017) 'Dummy molecularly imprinted magnetic nanoparticles for dispersive solid-phase extraction and determination of bisphenol A in water samples and orange juice,' Talanta, 162, pp. 57–64. <https://doi.org/10.1016/j.talanta.2016.10.007>.

Xia, X., Lai, E.P.C. and Örmeci, B. (2012) 'Duo-molecularly imprinted polymer-coated magnetic particles for class-selective removal of endocrine-disrupting compounds from aqueous environment,' Environmental Science and Pollution Research International, 20(5), pp. 3331–3339. <https://doi.org/10.1007/s11356-012-1262-9>.

Xie, X. et al. (2015) 'Development and characterization of magnetic molecularly imprinted polymers for the selective enrichment of endocrine disrupting chemicals in water and milk samples,' Analytical and Bioanalytical Chemistry/Analytical & Bioanalytical Chemistry, 407(6), pp. 1735–1744. <https://doi.org/10.1007/s00216-014-8425-0>.

Yan, Y. et al. (2018) 'Facile preparation of a hydrophilic magnetic hybrid nanomaterial with solid-phase extraction capability for highly efficient enrichment of phthalates in environmental water,' Analytical Methods, 10(24), pp. 2924–2930. <https://doi.org/10.1039/c8ay00883c>.

Yuan, Y. et al. (2020) 'Development of a hydrophilic magnetic amino-functionalized metal-organic framework for the highly efficient enrichment of trace bisphenols in river water samples,' Talanta, 211, p. 120713. <https://doi.org/10.1016/j.talanta.2020.120713>.

Yusoff, M.M. et al. (2018) 'A study on the removal of propyl, butyl, and benzyl parabensvianewly synthesised ionic liquid loaded magnetically confined polymeric mesoporous adsorbent,' RSC Advances, 8(45), pp. 25617–25635. <https://doi.org/10.1039/c8ra03408g>.

Zhao, W.-R. et al. (2018) 'Magnetic surface molecularly imprinted poly(3-aminophenylboronic acid) for selective capture and determination of diethylstilbestrol,' RSC Advances, 8(24), pp. 13129–13141. <https://doi.org/10.1039/c8ra01250d>.

Zhao, Y. et al. (2019) 'Determination of environmental estrogens and bisphenol A in water samples by ultra-high performance liquid chromatography coupled to Q-Exactive high resolution mass spectrometry after magnetic solid-phase extraction,' Microchemical Journal, 151, p. 104212. <https://doi.org/10.1016/j.microc.2019.104212>.

Zhou, Q. et al. (2017) 'Sensitive determination of typical phenols in environmental water samples by magnetic solid‐phase extraction with polyaniline@SiO2@Fe as the adsorbents before HPLC,' Journal of Separation Science, 40(20), pp. 4032–4040. https://doi.org/10.1002/jssc.201700644.