Supplementary Information

Recent developments in polysaccharide-based technologies for phosphorus removal and recovery from wastewater: A review

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Table S1 Benefits and drawbacks of different techniques for P recovery and removal

Techniques	Advantages	Disadvantages	Refs.
Adsorption	– less costly, rapid, and extremely effective – Reduced disposal issues as a result of little sludge/waste formation – Possibility of recovery of adsorbed phosphate – Variety of adsorbents available – Reusability of adsorbent – Low-concentration phosphate removal	– Foreign ion interference with adsorption – Low selectivity	1-5
Chemical precipitation	– Easy to setup – Reliable and flexible – A well-established procedure – Easy to implement and operate. – Can achieve high P removal	– Slow reaction – Produce additional amount of sludge – High chemical consumption – Require continuous neutralization of the Effluent – Low efficiency for dilute P solutions – Difficult to recover bonded P recovery	6-8
Biological processes	– Less chemicals required – Less expensive method – Low waste production – Effective in removing of amounts of P	– Need a source of carbon and nitrogen – Ineffective with low concentrations of phosphate – Expensive infrastructure	2, 9-11
Membrane filtration	– Highly effective – Less waste production – pH sensitive – possible recovery of phosphate	– Expensive – Require extensive pretreatment – Less selective in the presence of interfering anions	5, 12
Crystallization	– Recyclable – Low nitrogen loss – Possible to utilize struvite as a fertilizer directly	– Heavy metal can coprecipitate at times. – Slow process – High production costs for struvite	13, 14
Ion Exchange	– Effective for low phosphate concentration – Less waste production	– Regeneration cost is high – Disposal of waste/sludge is difficult – Need a significant quantity of resins. – Lifetime of resin is limited – Regeneration requires significant amount of Chemicals	15, 16

Table S2 Absorbent materials for P removal and recovery

Materials	Examples	Refs.
Minerals	Hydroxy-aluminum (Al) pillared, zeolites, calcite, tourmaline, opoka, bentonite, bentonite, dolomite, sepiolite, gibbsite, La-modified	17-26
Industrial byproducts	Slag, including fly ash, modified steel slag, bottom ash, sludge, red mud, iron oxide (Fe_2O_3) tailing skin split waste, and alum sludge	27-37
Natural materials	Rice, marble dust, soil, and sawdust	38-42
Building waste	Bricks, cement which rich in calcium (Ca), magnesium (Mg), Al, Fe	43
Composites	Casium (Ce)− zirconium (Zr) binary oxide, Fe−manganese (Mn) binary oxide, Fe−copper (Cu) binary oxide, tertiary-metal Fe−Mg−Al composites, Fe−titanium (Ti) bimetal oxide, Fe−Zr binary oxide	44-54
Nanoparticles (NPs)	Zirconium oxide (ZrO_2) NPs, ferrihydrite ($Fe_{10}O_{14}(OH)_2{\cdot}nH_2O$) NPs	11, 16, 55-58
Magnetic adsorbents	Magnetic Ca, magnetic Fe_3O_4@C@ZrO_2, amine functionalized silicamagnetite, Mg modified iron oxide	56, 59-61
Polymeric adsorbents	Polypropylene-g-N,N-dimethylamino ethyl methacrylate, chitosan, Duolite C 466	62-66
Metal oxide/hydroxide	Bayoxide (B33), lanthanum hydroxide ($La(OH)_3$), aluminum oxide (Al_2O_3)	7, 67-69
Carbonaceous materials (Modified and unmodified)	Activated carbon, metal-doped activated carbon, graphene oxide (GO), carbon nanotubes (CNTs), graphite, graphite oxide, graphene, charcoal, carbon nanofibers, biochar and its derivatives,	11, 55, 70-78
Bioadsorbents	Wood particles, oyster shell, fruit juice residue, eucalyptus, palm fiber, wheat residue, okara	4, 8, 41, 42, 52, 79-85

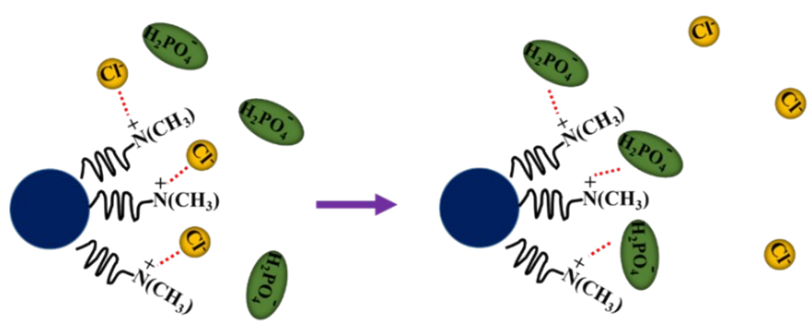

Fig.S1 Schematic representation of phosphate adsorption mechanisms via ion-exchange.

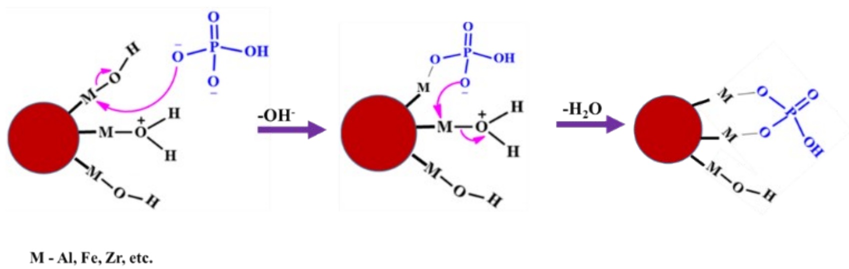

Fig.S2 Schematic representation of phosphate adsorption mechanisms via ligand exchange.

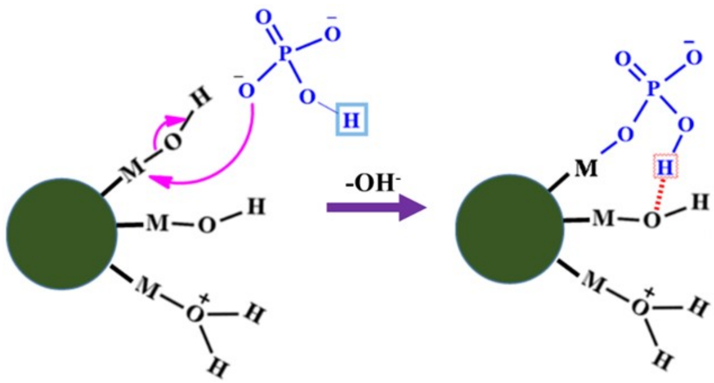

Fig.S3 Schematic representation of phosphate adsorption mechanisms via H-bonding.

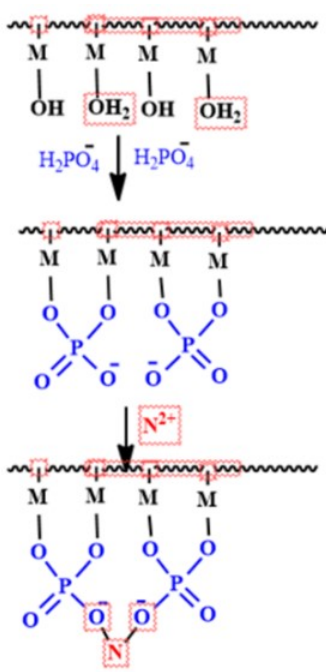

Fig.S4 Schematic representation of phosphate adsorption mechanisms via surface precipitation.

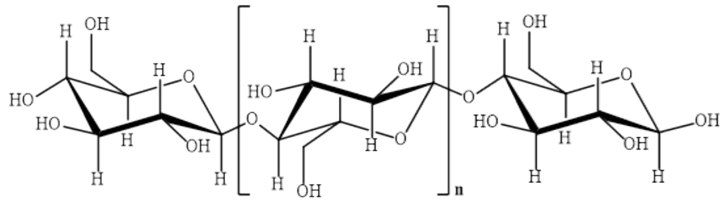

Fig.S5 Chemical structure of cellulose.

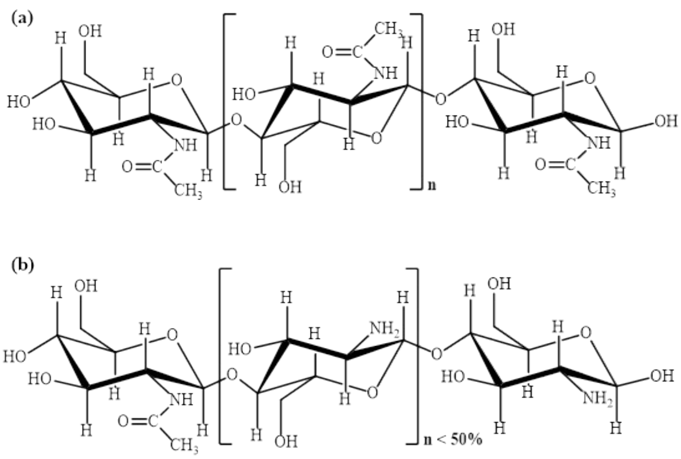

Fig. S6 Chemical structure of (a) Chitin (< 50% acetylated) and (b) Chitosan (< 50% acetylated).

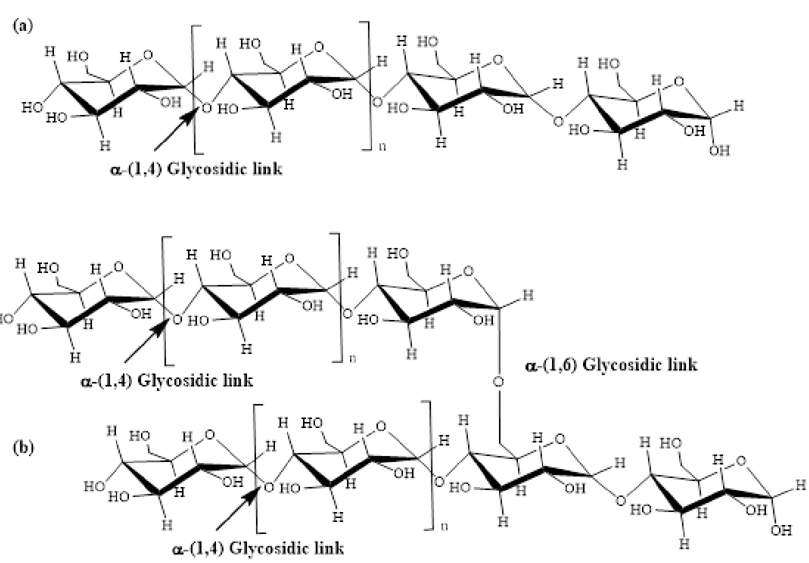

Fig.S7 Chemical structure of (a) amylose and (b) amylopectin.

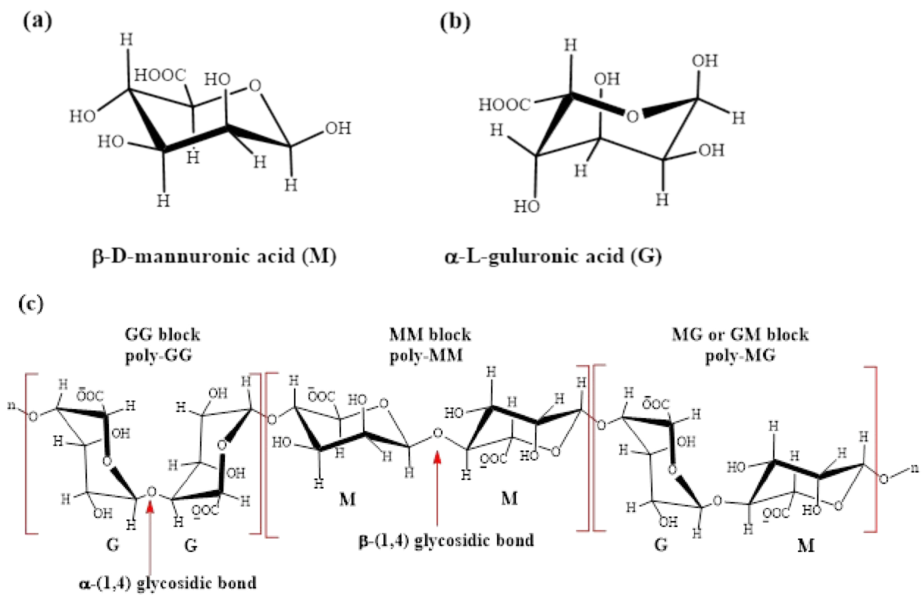

Fig.S8 Chemical structures of (a) β-D-mannuronic acid, (b) α-L-guluronic acid, and (c) alginate.

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