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Nano-enhanced bacterial stimulation of *microorganism*: a new pathway for sustainable degradation of Phthalates

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Phthalates are environmental pollutant that are prominently used as plasticizers in plastic and cosmetic industries. These plasticizers leach out from plastics and various product due to non-covalent binding, which results in accumulation in environment and are linked to adverse health conditions, including endocrine disruption and various carcinogenic effects. Natural degradation of phthalate is very slow process which can take decades to degrade naturally. Bioremediation is a promising approach, as microbes consume phthalate for their growth and convert it into metabolites which is non-toxic. While use of microbes seems to be promising, but it requires extensive use of nutrient rich media which can cause algal bloom and secondary contamination limiting its applicability on real field. Here we provide a solution to this by designing a multi-nutrient nano-phosphate as replacement of mineral media for bacterial growth during bioremediation of phthalate. The results show that using nano-phosphates, bacteria can grow and degrade phthalate by consuming it as sole carbon and energy source. Complete degradation of phthalate was observed with faster and equivalent biomass growth compared to mineral rich medium. To further test the efficiency of using nano-phosphate in real world, experiments were conducted with specified amount of nano-phosphate in distilled water, water, and river water containing phthalate as a sole carbon and energy source. Complete degradation of phthalate was achieved comparable to mineral rich medium. Scanning Electron Microscopy reveals enhanced biofilm formation and bacterial aggregation on nano-phosphates. Using nano-phosphate can be cost-effective and environmentally friendly as it utilizes significantly fewer nutrients, as seen by various material characterization techniques. Our study establishes nano-phosphate as a sustainable and scalable alternative, advancing efficient and economically viable nano-enabled bioremediation strategy for environmental cleanup.