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Efficient metal adsorption and microbial reduction from Rawal Lake wastewater using metal nanoparticle coated cotton

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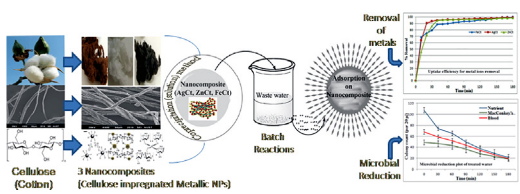
HIGHLIGHTS

- Iron, zinc and silver oxide NPs were impregnated on cotton and characterized by XRD, FTIR, SEM.
- Nanocomposite was used for metal removal from Rawal Lake water.
- Adsorption follows Langmuir isotherm and pseudo-second order kinetic models.
- Microbial reduction efficiency was also carried on by nanocomposite material.

GRAPHICAL ABSTRACT



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ABSTRACT

This study was designed to investigate removal of toxic metals and reduction of bacterial count from Rawal Lake wastewater with novel nanocomposite sorbents. Iron, zinc and silver oxide nanoparticles (NPs) were attached on cotton. The nanocomposites (iron NPs on cotton (FeCt), zinc NPs on cotton (ZnCt) and silver NPs on cotton (AgCt)) were characterized by FTIR, XRD and SEM, which showed successful adsorption of 10–30 nm size nanoparticles. Batch experiments were performed to determine the adsorption capacity of nanocomposite for metal removal. All the three adsorbents demonstrated 100% adsorption efficiency for Ag^{+}, Co^{2+}, Fe^{3+}, Zn^{2+} and Cu^{2+} whereas less adsorption for Cd^{2+} and Cr^{3+}. The maximum adsorbance (qe) was exhibited by Co^{2+} on ZnCt, FeCt and AgCt as 125.0, 111.1 and 100.0 mg g^{-1}, respectively. The efficiency of adsorbents for metal ions sorption was found as AgCt > ZnCt > FeCt while the order of adsorption for metals was observed as $Fe^{3+} > Co^{2+} > Zn^{2+} > Cu^{2+} > Ag^{+} > Cr^{3+} > Cd^{2+}$. The adsorption mechanism mostly follow Langmuir isotherm and pseudo-second order kinetic model. The maximum microbial reduction was exhibited by AgCt followed by ZnCt and FeCt. The microbes were further processed for staining and biochemical characteristics to evaluate resistance and sensitive microbes. The study concludes that the NPs doped on cotton can be effectively used for adsorption of heavy metals and reduction of microbial count from natural wastewater making it valuable for human consumption. In addition, the nanoparticles impregnated cotton can be efficiently used in water filtration plants.

1. Introduction

Lakes and reservoirs are main source of potable water that are linked with rainwater, ground water, and others that join the catchment area. There are approximately 27 million anthropogenic reservoirs (henceforth together called as lakes) on Earth with surface areas larger than 0.01 km^2 and cover <4% of Earth's terrestrial land (Verpoorter et al., 2014). Lakes supply essential economic and social resources e.g., drinking reservoir, irrigation, fisheries, energy production and recreation (Dugan et al., 2017). Increase of chemicals and microbe concentration make the water pollutant. This is a physical process that occurs owing to anthropogenic activities i.e. industrialization and increase in growing population (Surendhiran et al., 2017).

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In Pakistan, approximately 50% of illnesses and 40% of fatalities arise owing to polluted drinking water (Daud et al., 2017). Improper discharge of sewage and industrial effluents also greatly affect the water quality of fresh water ecosystems (Ghumman, 2011; Surendhiran et al., 2017). The Rawal Lake of Pakistan is an important artificial reservoir (created in 1962), covers an area of 8.8 km^2 known for its ecological significance and is the sole source of drinking water for the third largest city of Pakistan, i.e. Rawalpindi and Islamabad (Malik and Zeb, 2009; Malik and Hashmi, 2017; Islam et al., 2018). It has been found that the Rawal Lake water samples contain different microbial populations which may be responsible for dysentery typhoid, hepatitis, cholera etc. (Farooq et al., 2008). Recent investigations also reveal that there are significant contamination of the toxic metals especially Cd, Co, Cr and Pb in deposited sediments and surface water (Iqbal et al., 2013a; Iqbal et al., 2013b; Malik and Hashmi, 2017).

The most common and conventional water treatment technique is the chlorination that is applied everywhere without focusing on the source area and pollutant specific risks. Although, chlorine (as disinfectant) inactivates the micro-organisms but the treatment of unrelenting contaminants such as heavy metals in water is an exigent problem (Abbar et al., 2017; Charpentier et al., 2016; Corsi et al., 2018). Therefore, with the emerging scientific technologies, the impact of toxic metal ions can be minimized by different tools and approaches, viz., chemical precipitation, membrane filtration, oxidation, reverse osmosis, flotation, and adsorption. Among all these techniques, adsorption has been found as a very efficient and common due to its effectiveness to even lower concentration of metal (Mahmood et al., 2012; Rajala et al., 2003; Sun et al., 2013; Zhang and Farahbakhsh, 2007). Recently, the nano-based materials have been extensively explored for adsorption applications because of their low cost, good chemical stability, structural diversity, low density, and suitability applied for the decontamination of wastewaters from organic pollutants, dyes and heavy metals (Ahmad and Hasan, 2016; Ali et al., 2016c; Battin et al., 2009; Charpentier et al., 2016; Mahdavi et al., 2012a). Furthermore, metal and metal oxide nanoparticles functionality can be altered by change in physical conditions i.e. pH, temperature, surface modifications etc.

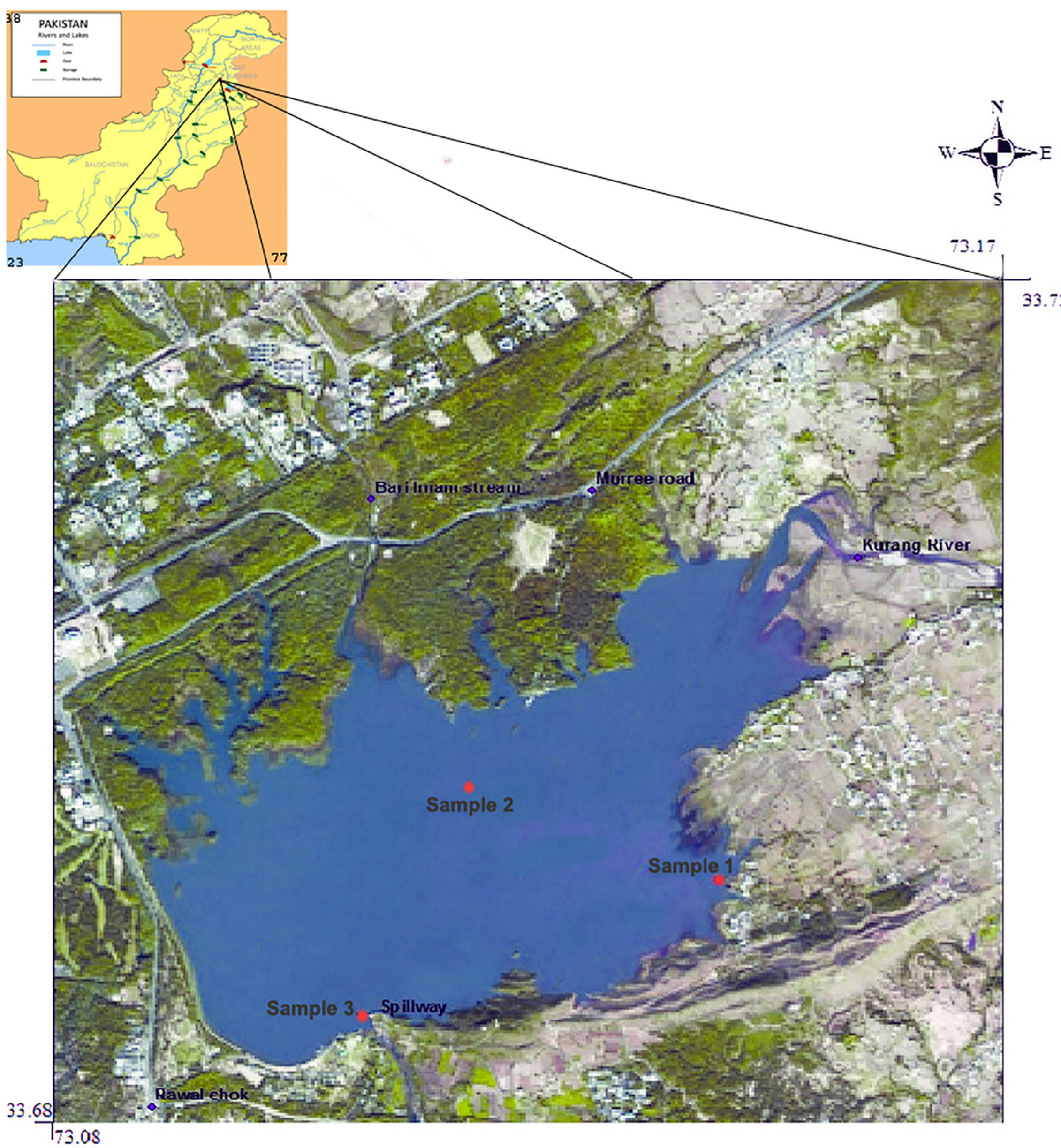

Fig. 1. Map showing sampling locations (1–3) from Rawal Lake.