regeneration process comprising passing a dilute aqueous solution of an acid (for example, sulfuric acid or hydrochloric acid) or a base (for example, sodium hydroxide), through the cartridge. This regeneration protocol allows the cartridges to be reused, which provides a sustainability benefit that cannot be achieved using prior art activated carbon-based filters, which must be disposed of after reaching their filtration capacity is reached.

[0081] The graphene oxide-chitosan composite employed in the M1 filter cartridge was found to be an efficient adsorbent of heavy metals while also being readily regenerated for repeated use.

[0082] For the adsorption of heavy metals and subsequent regeneration of the chitosan-based adsorbent, an effective, fast, and easy way to regenerate the adsorbents saturated by heavy metals is through adjustment of the pH to the point where desorption can occur. The adsorption can be physisorption or chemisorption. In terms of adsorbent regeneration, physical adsorption is the desirable type due to its reversibility. In contrast, the chemical adsorption is usually an irreversible reaction which makes it impossible or very hard to desorb the adsorbates from the adsorbents surface. Fortunately, the dominant part of heavy metals adsorption on the chitosan surface is physical and reversible. According to zeta potential results reported for chitosan materials in different studies, the surface of chitosan material is expected to be positively charged at pH<7 and it turns to negative at pH>7 (Mukherjee *et al.*, "Sustainable and Affordable Composites Built Using Microstructures Performing Better than Nanostructures for Arsenic Removal," *ACS Sustain. Chem. Eng.*, vol. 7, no. 3, pp. 3222–3233, December 10, 2018). Furthermore, the behavior of heavy metals in aqueous media at different pH levels depends on their surface charges. Therefore, the most efficient regeneration can occur in a certain range of pH where desorption is maximum.

[0083] For Cr, As, and Fe cations which have surface charges of 3+ or more, some complex compounds are generated at different pH (Mukherjee *et al.*, *ACS Sustain. Chem. Eng.*; Hadi Najafabadi *et al*., "Removal of Cu2+, Pb2+ and Cr6+ from aqueous solutions using a chitosan/graphene oxide composite nanofibrous adsorbent," *RSC Adv.*, vol. 5, no. 21, pp. 16532–16539, 2015). At pH of lower than 2, the complex compounds have no charges on their surface results in lower adsorption rate. By increasing the pH, the components with more negative charges appear in the aquatic media. Therefore, at basic pH repulsion between the charges on the surface of complex heavy metal compounds and the surface of adsorbent will be stronger which results in desorption or precipitation of heavy metals. While, the maximum adsorbent can occur between pH range of 2-7 in which the chitosan surface is positive and the

WE CLAIM:

1. A portable multi-stage filter system for remediation of water from a contaminated water source to provide a purified water product, the system comprising:

- a first filter stage configured to remove solid contaminants larger than 0.1 mm, the first filter stage comprising:

an intake port for placement into the contaminated water source;

at least one strainer element; and

a pump configured to draw water from the contaminated water source into the intake port and through the strainer element to provide a first filtrate;

- a second filter stage configured to remove contaminants larger than 20 nm to 40 nm to provide a second filtrate;

- a third filter stage configured to remove dissolved chemical contaminants from the second filtrate to provide a third filtrate, the third filter stage comprising at least one graphene-based filter containing at least one graphene-based material;

- a fourth filter stage configured to remove residual nanoparticle contaminants from the third filtrate to provide the purified water product;

- an outflow structure configured to convey the purified water product from the fourth filter stage for discharge; and

a portable system housing, wherein the first filter stage, the second filter stage, the third filter stage and fourth filter stage are contained within the portable system housing.

2. The system of claim 1, wherein the contaminated water source is contaminated groundwater, industrial wastewater, mine tailings, natural flowing fresh water, lake water, pond water, rain water runoff, or a source of fresh water with unknown dissolved or dispersed contaminants.

3. The system of claim 1 or 2, wherein the system further comprises a power source.

4. The system of any one of claims 1 to 3, wherein the first filter stage further comprises a coarse strainer element configured to remove coarse solid contaminants larger than 0.2 cm, wherein the coarse strainer element is located at the intake end of the intake port.

5. The system any one of claims 1 to 4, wherein the second filter stage comprises a filter element having an average pore opening diameter of 10 nm to 40 nm, preferably 10 nm to 20 nm.

6. The system of any one of claims 1 to 5, wherein the second filter stage comprises an ultrafiltration device, wherein the ultrafiltration device is preferably a ceramic filter or a hollow fiber membrane, and wherein the second filter stage optionally comprises a booster pump to pull the first filtrate through the filter.

7. The system of claim 6, wherein the second filter stage is regenerated by flushing with clean water in a reverse flow or crossflow direction.

8. The system of claim 7, wherein the second filter stage is regenerated automatically once the second filter stage has reached filtration capacity.

9. The system of any one of claims 1 to 8, wherein the graphene-based material in the third filter stage is graphene, preferably few layer graphene, and/or graphene-oxide, preferably few layer graphene oxide.

10. The system of any one of claims 1 to 8, wherein the at least one graphene-based filter in the third filter stage comprises a combination of few-layer graphene powder and pellets comprising a mixture of polyether sulfone, graphene oxide, and dimethylformamide.

11. The system of any one of claims 1 to 8, wherein the at least one graphene-based filter in the third filter stage comprises few-layer graphene powder.

12. The system of any one of claims 1 to 8, wherein the at least one graphene-based filter in the third filter stage comprises a composite comprising chitosan, 0.1% to 10% by weight of few layer graphene oxide, sodium sulfate, and ferric chloride hexahydrate.

13. The system of any one of claims 1 to 8, wherein the at least one graphene-based filter in the third filter stage comprises few-layer graphene powder, a composite comprising chitosan, 0.1% to 10% by weight of few layer graphene oxide, sodium sulfate, and ferric chloride hexahydrate, and granular activated carbon.

14. The system of any one of claims 10 to 13, wherein the at least one graphene-based filter is regenerated by flushing with a dilute aqueous acid solution.

15. The system of any one of claims 1 to 14, wherein the fourth filter stage comprises a filter membrane having an average pore opening diameter of from 8 nm to 20 nm.

16. The system of any one of claims 1 to 15, wherein the fourth filter stage comprises a hollow fiber membrane filter.

17. The system of any one of claims 1 to 16, wherein each of the first filter stage, the second filter stage, the third filter stage and the fourth filter stage is removable and replaceable.