Title: Arsenic Removal by Novel Nanoporous Adsorbents-Kinetics, Equilibrium, and Regenerability

Statement of Critical Regional Water Problems:

Arsenic contamination of groundwater is caused by weathering process and human activities and it is a serious problem because of the toxic and carcinogenic characteristics of inorganic arsenic species. Some groundwater in the Ogallala and Gulf coast aquifers in Texas have arsenic concentrations above 50 ppb that are caused by natural uranium mineralization and agricultural activities (Regner et al., 2004). To reduce the health risk of arsenic, the US EPA adopted a revised maximum contaminant level of 10 ppb for arsenic on January 22, 2001 (US EPA, 2003). To meet this new standard by January 2006, enhanced treatment technologies for arsenic removal must be developed and implemented at thousands of water supply systems. There are many enhanced treatment technologies such as precipitation, adsorption, ion exchange, membrane filtration, lime softening, and oxidative filtration that can remove arsenic from drinking water (US EPA, 2003). Among these technologies, adsorption is considered to be more effective, less expensive, easier to apply and safer to control than other treatment processes. However, the adsorbents that are usually employed (e.g., activated alumina or carbon, ferric hydroxide, silica, zeolite) have been shown to have slow sorption kinetics, low sorption capacities, and low abilities to be regenerated. These characteristics result from irregular pore structure, low density of surface functional groups, and physico-chemical instability. Therefore, improved adsorbents are needed that have higher surface areas, larger pore volumes, more well-defined and regular pores, higher densities of surface functional groups and higher physico-chemical stability.

Nature, Scope, and Objectives of the Research:

The objective of this research is to develop and characterize novel nanoporous titania and nano-sized titania incorporated mesoporous silica (i.e., Ti-SBA-15) as adsorbents for arsenic. The physico-chemical properties of such nanoporous adsorbents include high surface area, well-ordered framework of nanosized pores, large pore volumes, ability to easily incorporate catalytic components (e.g., transition metals), and high density of surface functional groups. These characteristics would provide high arsenic removal efficiency and low cost. In order to develop novel nanoporous adsorbents and investigate their ability to remove arsenic, the following specific tasks will be pursued.

- **Task 1.** Synthesize nanoporous adsorbents

Three novel nanoporous adsorbents will be synthesized. One will be a mesoporous silica (i.e., SBA-15) (Zhao et al., 1998), one will be the mesoporous silica incorporated with titania, and the other will be a nanoporous titania. The optimal synthesis conditions that result in high arsenic removal will be studied and evaluated. The characteristics of the surface of the adsorbents (e.g., surface area, pore size distribution, nanopore morphology, surface charge, etc) will be investigated by N_2 adsorption-desorption, XRD, SEM, TEM, and Zeta-meter. The Figure 1 shows preliminary results for SBA-15, Ti-SBA-15, and nanoporous titania.

■ **Task 2**. Determine kinetics of arsenic removal

Kinetics of arsenic removal using nanoporous titania and Ti-SBA-15 will be studied in batch experiments. Figure 2 represents preliminary results for As(III) removal by Ti-SBA-15 and nanoporous titania.

■ **Task 3**. Determine equilibrium characteristics of arsenic removal

A variety of sorption isotherms (Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich) will be used to describe results of adsorption equilibrium tests. The resulting isotherms will be used to estimate maximum arsenic sorption capacity, binding energy of adsorbate-adsorbent, and sorption free energy.

■ **Task 4**. Optimize conditions for arsenic removal

The effect of pH and ionic strength on arsenic removal efficiency will be evaluated. In addition, the results of these experiments will be interpreted using the concepts of surface charge and zeta potential of the adsorbents.

■ **Task 5**. Determine capacity of nanoporous adsorbents to be regenerated

To estimate log-term performance of nanoporous adsorbents studied here, cyclic desorption-adsorption will be conducted. Regeneration will be investigated using appropriate solutions of sodium hydroxide (0.01-1 M).

■ **Preliminary Results:**

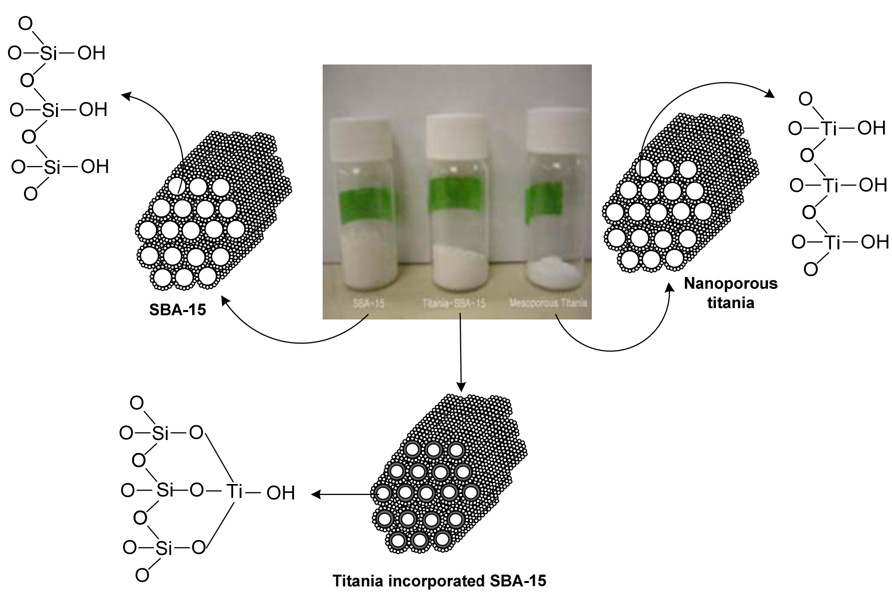

Figure 1. Preliminary synthesis of mesoporous SBA-15 and nanoporous titania.

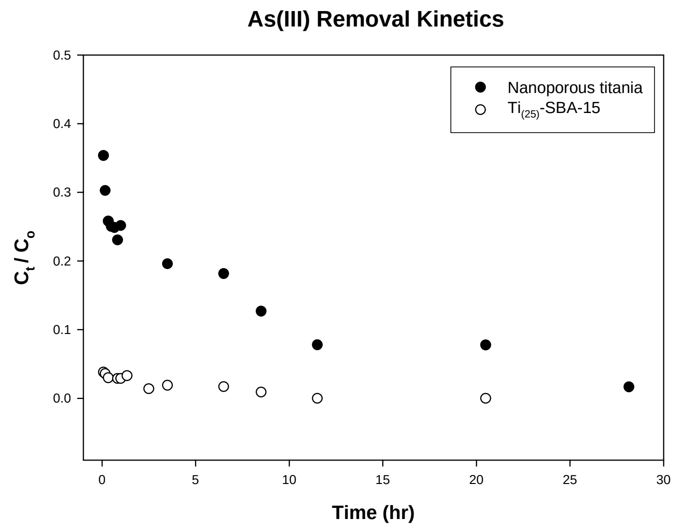

Figure 2. The kinetics of As(III) removal by nanoporous titania (dark circle) and $Ti_{(25)}$-SBA-15 (open circle).

Results Expected from this Project:

Significant improvements in arsenic removal efficiency are expected for nanoporous titania compared to other conventional treatment technologies (i.e., iron (oxyhydr) oxide, activated carbon or alumina, ion exchange). Specifically, experimental data on kinetics, equilibrium, and regenerability will provide strong evidence for the potential of using these adsorbents in effective and cost-efficient treatment processes for removing arsenic from water. The results of this study will be presented at meetings of the American Chemical Society (ACS) or the American Water Works Association (AWWA).

Reference:

1. Regner, G., Court, M., Krieg, K. 2004. Health effects and occurrence of arsenic in Texas' public water supplies. Presentation document, DWQ/SWAP Programs, Texas Commission on Environmental Quality.

2. US EPA. 2003. Arsenic treatment technology evaluation handbook for small systems. EPA 816-R-03-014, p.126.

3. Zhao, D., Feng, J., Huo, Q., Melosh, N., Fredrickson, G.H., Chmelka, B.F., Stucky, G.D. 1998. Triblock copolymer syntheses of mesoporous silica with periodic 50 to 300 angstrom pores. *Science*. 279, 548-552.