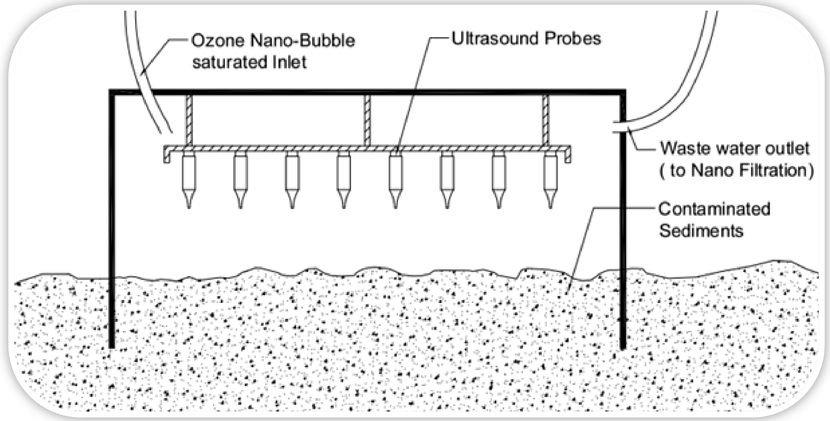
# Remediation of Contaminated Sediments with Ultrasound and Ozone Nano-bubbles (CMMI, Award No: 1634857)

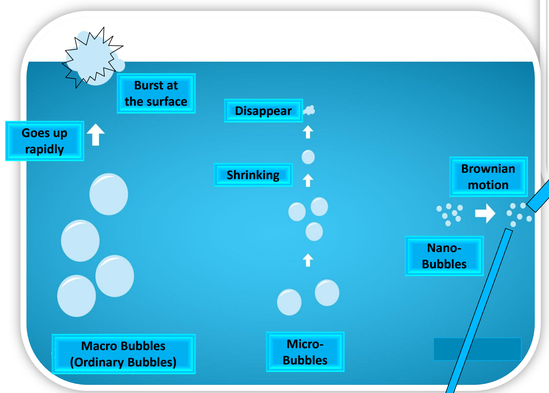
**Jay N. Meegoda, Professor, New Jersey Institute of Technology, Newark, NJ 07102-1982, USA, meegoda@njit.edu**

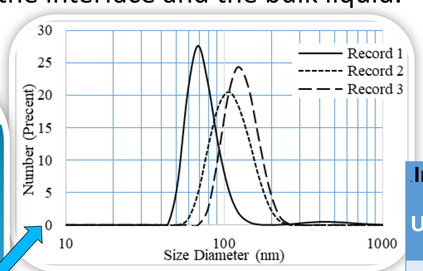
**Introduction:** Over 50% of the world population live in urban centers amalgamated to major river networks. These urban environments promote the rapid industrialization of the land adjacent to river networks, which are easily contaminated due to the effluents. Offsite treatment plants usually solidify/stabilize contaminated sediments or utilize in production of construction materials for beneficial use. However, such offsite treatment is quite expensive. Hence the common practice of remediation is dredging and disposal in a controlled landfill.

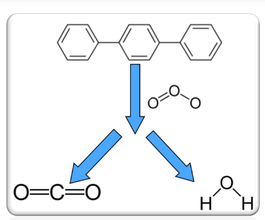


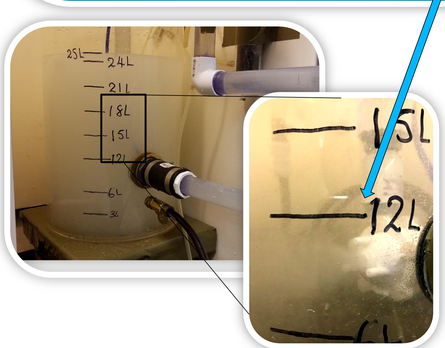

**Ultrasound:** The application and use of sound waves with frequency higher than 20 kHz is defined as ultrasound technology. Ultrasound causes high-energy acoustic cavitation: that is, the formation of microscopic vapor bubbles in the low pressure (rarefied) part of the ultrasonic wave. These bubbles collapse in the compression part of the wave creating very minute, but high energy movements of the solvent that result in localized high shear forces. The application of ultrasound energy results in generating localized high shear forces to separate and desorb organic and inorganic compounds and heavy metals from sediments or soils, thereby, increasing the mobility of contaminants in the soil water suspension. Increasing the mobility of contaminants will allow the remediation process to directly oxidize or to leaching of the contaminants using surfactants.

**Nano-Bubbles:** Nano-bubbles are nano-scopic gaseous (typically air) cavities in aqueous solutions that have the ability to change the normal characteristics of water. Ordinary bubbles have a diameter which range from 1 µm and larger and in equilibrium due to capillary and buoyant forces. Nano-bubbles which are <100 nm in diameter can remain in liquids for an extended period of time. The stability of nano-bubbles is supported by the electrically charged liquid-gas interface, which creates repulsion to prevent bubble coalescence, and by the high dissolved gas concentration in the water by maintaining a small concentration gradient between the interface and the bulk liquid.



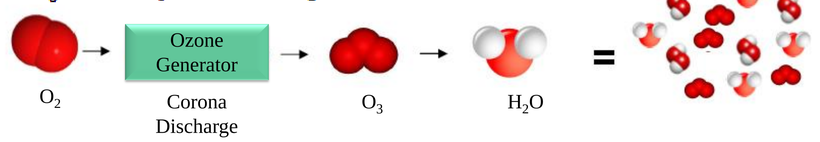





**Proposed Technology:** Proposed field application consists of containment chamber that will be designed to house ultrasound probes, which will include an ozone delivery system and a water extraction system that will incorporate a nano filtration unit to remove dissolved pollutants.

**Oxidizing using Ozone:** Ozone is a widely used common oxidizer as an in-situ remediation technology. It is also a common and a successful oxidizing method used by numerous industries. Oxidizing organic compounds using ozone will create harmless byproducts, where the main two byproducts of PAHs being $CO_2$ and $H_2O$. The radicals (OH*) formed during the decomposition of ozone in water are highly unstable with a very short life span. Due to the high instability of the radicals, it possess strongest oxidation capabilities.

$$H_2O + O_3 \xrightarrow{\Delta} OH^- + O_2 + OH^*$$
$$O_3 + OH^- \xrightarrow{\Delta} HO_2 + O_2^-$$
$$HO_2 \xrightarrow{\Delta} H^+ + O_2^-$$
$$O_3 + O_2^- \xrightarrow{\Delta} O_3^{-} + O_2$$
$$H^+ + O_3^- \xrightarrow{\Delta} HO_3 \xrightarrow{\Delta} OH^* + O_2$$




**Results:** The initial testing started by treating the contaminated sediments by purging ozone while applying ultrasound. The initial tests indicated high efficiencies at lower temperatures. However, treatment of contaminated sediments with nano ozone bubbles and ultrasound provided much improved removal efficiency at much elevated temperatures. The preliminary results of this study indicated promising data using ozone nano-bubbles and ultrasound to remove PAH from sediments. The preliminary research also showed high removal efficiencies of PAH from the contaminated sediments at lower temperatures and high ultrasound power levels. The highest removal efficiency was obtained at 1050W power output.

**Initial trials with lower water temperatures with ozone purging**

| Ultrasound (Freq. 20 kHz) | | Temp. (C°) | | |
|---|---|---|---|---|
| Sonication time (min.) | Ultrasound Power (W) | Pre | Post | Efficiency (%) |
| 10 | 750 | 8 | 19.6 | 36.07 |
| 10 | 900 | 8.4 | 22.8 | 51.73 |
| 10 | 900 | 6.1 | 16.7 | 61.90 |
| 10 | 900 | 6.8 | 13 | 63.77 |

**. Initial trials with lower water temperatures with ozone Nano-bubbles**

| Ultrasound (Freq. 20 kHz) | | Temp. (°C) | | |
|---|---|---|---|---|
| Sonication time (min) | Power (W) | Pre | Post | Efficiency (%) |
| 15 | 900 | 16.4 | 22 | 52.07 |
| 15 | 900 | 13 | 19 | 58.97 |
| 24 | 900 | 15.3 | 24.3 | 55.87 |
| 12 | 900 | 8.2 | 16.3 | 53.19 |
| 36 | 1050 | 13.2 | 17 | 92.99 |

**Summary and Conclusions:** Over 100 industrial facilities have discharged chemicals to the Passaic River, making it a superfund site. The contaminants in the river included PAHs, PCDD/F, PCBs, DDT, pesticides and their byproducts, and heavy metals including Hg, Cr, and Pb. An Insitu remediation technology is proposed using ultrasound with ozone nano bubbles. The preliminary results of this study indicated promising data using nano ozone bubbles and ultrasound to remove PAH from the sediments. The preliminary research also showed high removal efficiencies of PAH from the contaminated sediments at lower temperatures and high ultrasound power levels. With the encouraging preliminary results the proposed technology can be used in the winter months when the river is not used for recreation purposes.

**Acknowledgements:** The authors acknowledge the assistance provided by Dr. Wen Zhang and Dr. Larisa Krishtopa, the Director of Material Testing Laboratory, York Center, NJIT.