Nanoparticles in Potable and Aquatic Freshwater: Stockholm Junior Water Prize Outreach

F. D. Josifovski*, T. G. Schneider*, and M. Gajdardziska-Josifovska**

* Nicolet High School, Glendale, WI 53217 USA
** Physics Department, University of Wisconsin-Milwaukee, Milwaukee, WI 53211 USA

Freshwater is critically important for human life, and Wisconsin’s shores of Lake Michigan provide ready access to this invaluable natural resource. A novel investigation was designed to address two environmental and public health questions related to water quality: Are nanoparticles present in natural freshwater in observable quantities and do they persist in potable water produced by a modern municipal water treatment facility? This study quantifies the size and shape distribution of nanoparticles in freshwater using transmission electron microscopy (TEM). Elemental composition of representative nanoparticles was determined by energy dispersive X-Ray spectroscopy (EDX). An analysis methodology was developed to achieve the first experimental measurement of number of nanoparticles in a glass of drinking water created by state-of-the-art municipal waterworks treatments. The reported work was presented at the Nicolet High School Science Fair, and at the Badger State Science and Engineering Fair. The paper won the Wisconsin Stockholm Junior Water Prize (SJWP) award, and was also presented at the National SJWP event in Boston in June 2012. The first two co-authors were freshmen in high school at the time of the experimental work. The paper is presented as late breaking poster both for its scientific content and to draw attention to the possibilities for outreach created by state, national, and international science fairs.

Water samples were taken directly from Lake Michigan and from a new building at the University of Wisconsin – Milwaukee and studied in the as-collected state and after passing through 200nm pore filters. Amplitude contrast TEM was used to study multiple areas on samples prepared by drying 2.5 or 10 mL of water (1 or 4 drops) on 400 mesh copper grids spanned by 3 nm thick amorphous carbon films. Figure 1 shows examples of images from as-collected freshwater and potable samples. These types of digital micrographs were analyzed for qualitative comparisons and to quantify sizes and aspect ratios of ~200 nanoparticles, as illustrated in Figure 2, showing that nanoparticles were found both in lake and in tap water with similar average length, width, and aspect ratio, suggesting that modern city filtration processes cannot eliminate nanoparticles in the 10-300 nm size range.

Histogram analysis of the projected particle areas (Figure 3) shows that potable water has a higher percentage of smaller nanoparticles than lake water. Approximately 70% of nanoparticles in potable water had projected areas of 10,000 nm², compared to only 54% of nanoparticles in lake water, however the shape of the size distribution is essentially the same as that for nanoparticles in lake water. Figure 4 illustrates a proof of principle methodology that produced first experimental results for area ($10^{12}$ nanoparticles/m²) and volume density ($10^{15}$ nanoparticles/m³) for potable water, placing ~$10^{11}$ nanoparticles in an 8oz cup of water. The dietary consumption of nanoparticles in developed countries is estimated around $10^{12}$ particles per person per day [1], showing that the methodology produces results with realistic order of magnitude. In conclusion, nanoparticles were found in both lake and potable water with similar average lengths, widths, and aspect ratios, suggesting that modern city filtration processes cannot eliminate nanoparticles in the 10-300 nm size range. Elemental composition of representative nanoparticles (not shown here) found mostly light elements such as C, O, Si, Na, Cl, and Ca.

Figure 1. Example TEM images obtained from: a) one drop of lake water recorded at a range of magnifications; b) one and four drops (two images at bottom right) of potable water recorded at 10,000× magnification.

Figure 2. Graphs showing experimentally measured nanoparticle lengths (upper curves) and widths (lower curves) from lake (a) and potable (b) water in the 10-300nm size range. The average length and standard deviation are very similar for lake (138±66) nm and potable (122±56) nm water, as are the average experimental widths of (111±58) nm for lake and (99±54) nm for potable water. Graph of calculated aspect ratios L/W (c) show nearly identical average aspect ratios and standard deviations are (0.79±.14) for lake and (0.81±0.16) for potable water.

Figure 3. Histogram of projected areas showing similar size distributions with small shift towards smaller nanoparticles in the potable water.

Figure 4. TEM image from potable water with threshold used to determine relative area (1.97%) of image covered by nanoparticles.