Multi-disciplinary Research Experiences Integrated with Industry –Field Experiences

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ABSTRACT

The purpose of this environmentally inquiry-based lab was to allow the students to engage into real-world concepts that integrate industry setting (Ohio Aggregate Industrial Mineral Association) with the academia setting. Our students are engaged into a field trip where mining occurs to start the problem based learning of how the heavy metals leak in the mining process. These heavy metals such as lead and indium in the groundwater are a serious concern for the environment (Environmental Protection Agency) from the mining process. The field experiences at the mining process assist in building our students interest in developing sensors to detect heavy metals of concern such as lead and indium simultaneously by a unique electrochemistry technique called Square Wave Anodic Stripping Voltammetry (SWASV). The field experience assists building the students interest in real –world application and what qualities do they want the electrochemical sensor to possess to be successful for real world usage. During the field trip the students are engaged into learning novel instrumentation such as an SEM (Scanning Electron Microscope) to study the working electrode sensor developed to understand the sensor surface morphology properties better as well. The integration of industry setting with academia has been a positive experience for our students that has allowed their understanding of real-world science research needs to succeed in an industrial setting of research.

Keywords: Industrial applications, environmental issues, inquiry-based chemistry modules and academia

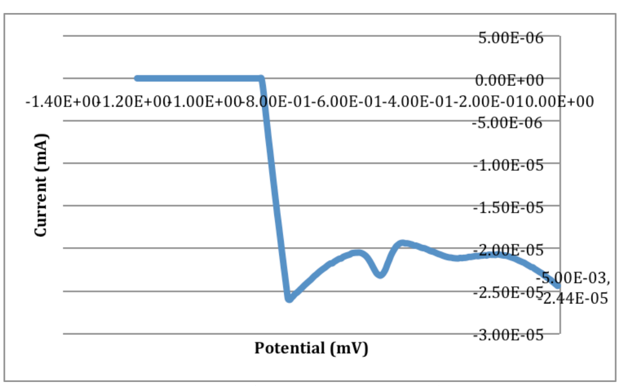
Mining and The Real World

It has been noted that industry and academia collaboration is an investment and an assessment of the innovation and collaboration has been studied by Lee [1] . The multi-disciplinary research experiences between the aggregate industries to the field of academia have been found to be prosperous for our students to resolve real-world environmental issues (heavy metal contamination). The mining industry with rare earth mining connection to the environmental impacts were a focus of our inquiry-based experience lab modules developed to enhance our students content knowledge in chemistry (electrochemistry/sensors). China started mining the rare earth elements over 30 years ago where there was an absence of environmental regulations. In the 1990's rare earth production was jolted off in China and the impact of environmental contamination was catastrophic where there was no tap water and drinking from wells was carried out. The well water visually looked okay but there was a bad smell of the well water and the sheep, the cabbage crops withered and there were several people in this area of China that died from cancer.

Our inquiry-based labs are developed to meet the 21st century where these rare earth mining applications connected with environmental concerns are vital to many evolving applications such as electric cars [rechargeable batteries], computer hard drives, DVD's, cell phones [rechargeable batteries], MRI instruments, microphones, fiber optics, lasers, and defense applications (GPS, military-homeland security). The critical defense applications of the rare earth metals are the main ingredients for synthesizing hard alloys that are used to make armored vehicles, and projectiles that shatter upon impact. The following elements are utilized accordingly Lanthanum used for night-vision goggles, Neodymium used for communications, Europium used for fluorescent and phosphors for lamps/monitors, Erbium used for amplifiers in fiber-optic data transmission, and Samarium used for permanent magnets, precision-guided samples, and stealth technology [F-35 fighter jets]. Rare earth elements are not really rare and they have an average crustal abundance that is 200 X greater than the crustal abundance of Gold. Presently, the US and Australia are creating environmentally friendly user mining developments that are recyclable and thus becoming less dependent on China for the rare earth mining.

However, rare earth mining must come to grips with the fact that environmental contamination is a serious problem in such places such as China. The under-regulated rare earth mining projects produce wastewater and tailings ponds that leak heavy metals, acids, and radioactive elements in the groundwater. The market pressures can occur for cheap mining and reliable rare earths that may cause mining managers to hold back on cost related to environmental protections. The United States has the stricter Environmental Protection Agency requirements, which regulates the mining industry to prevent hazardous conditions. However, there have been problems with contamination due to heavy metal contamination and our lab investigation will address these challenges in the inquiry-lab related to how to develop a sensor that may detect two heavy metals simultaneously [2-11].

The inquiry-based lab shared involves the use of a working electrode (sonogel carbon electrode) set in a three-electrode compartment cell [working –sonogel material, reference electrode –Ag/AgCl electrode, and auxiliary electrode - platinum wire] to detect the two heavy metals lead and indium simultaneously utilizing Square Wave Anodic Stripping Voltammetry [SWASV]. SWASV is an electrochemistry tool that is quick and inexpensive for determining low levels of toxic metals in the parts-per-billion range. In this inquiry-based lab experiment the Pb(II) and the In (III) are pre-concentrated onto the working electrode via electrochemical reduction for a specified length of time, then the electrochemical stripping of the reduced metal from the working electrode surface results in a faradaic signal which correlates to the analyte's concentration. The current due to the Pb(II) and the In(III) oxidation peaks are displayed as heights proportional to the concentration of the heavy metal present, Figure 1. The SEM utilized by the industry field trip to test the working electrode and illustrated in Figure 2; depicts the morphology of the modified sonogel working electrode surface developed.



In(III) ↑ Pb(II) ↑

Figure 1. SWASV response of 100 ppb of In(III) with 40 ppb Pb(II) in 2% nitric acid; square wave amplitude 25 mV, and square wave frequency 25 Hz with predeposition at -1200 mV for 60 seconds at sonogel working electrode

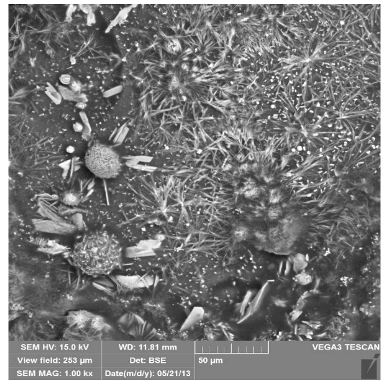


Figure 2. SEM of sonogel modified working electrode.

Conclusion

The purpose of the integrated experiences with industry and academia has the overriding goal of training our future scientist for what is needed to fulfill these career openings in chemistry and geology/ STEM (Science Technology Engineering and Mathematics) fields of study. These research students are engaging in real-world industrial experiences with such prominent companies as Bowser-Morner, Inc. Our pre- and post-test assessments have shown that the integrated field/industrial experiences with the academia together have increased our students content scores significantly as R.R. Hake' notes greater than 0.7 normalized gains as with inquiry-based learning [12].

Acknowledgements

We want to thank Bowser-Morner, Inc; Tom Ryan and Lora Goodpaster and the OAIMA for their industrial collaboration with our students to encourage them learning science and sharing their technology.

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