

## **The Paradigm Shift of Nanotechnology: Consequences of Status Quo Lab Attitudes**

*by Stephanie Vasko and Billy Butler*

Alex and Ben are grad students who work in a lab which focuses on nanoparticle development at College X. Recently they have been working on a project with exotically doped quantum dots. Quantum dots have opened a new realm of science, one where the nanoscale properties of a material differ greatly from that of the bulk material. In a bulk semiconductor, most electrons exist in the valence band, while only a few exist in the conduction band. In order for an electron to move from the valence band to the conduction band, an outside stimulus, such as heat, voltage, or light, must be applied. In bulk conducting material, there are continuous energy levels, but in a semiconductor, these energy levels are not continuous, there is a gap between the valence (filled) electron levels and the conducting electron levels. Only a small fraction of the electrons cross the gap. In insulators, the gap is so large that not even an outside stimulus can provide enough energy for the electron to move from the valence band to the conduction band. Quantum dots get their name from the fact that they are governed by the Heisenberg uncertainty principle, an important relationship from quantum mechanics, which states that you cannot know the location and energy of the electron at the same time. While quantum dots show promise in industries like solar power, in vivo imaging of cancer and optoelectronic devices, some are made of extremely toxic materials, including Cadmium, Selenium, Tellurium, and Lead.

Ben has worked in the lab for five years and is the safety officer. Alex began working in the lab about two months ago, and received his general safety training from a university class and his lab-specific safety training from Ben. Typical waste labeling in labs at College X include chemical composition, percent, and check boxes which are labeled with common associated hazards, including corrosive, oxidizer, and “other”. There is no space listed for identification of the material type. In their lab, nanoparticle waste is labeled the same as a bulk waste. When Alex questions Ben about waste processing, Ben tells him this is standard procedure and that they just need to list the chemical composition. Alex is concerned about the safety conditions of Ben’s fume hood, where there is build up from previous reactions and chemicals which are unidentifiable. Alex and Ben share lab space and Alex is not comfortable with Ben’s lab habits. Alex voices his concerns at a group meeting, and his professor tells Ben to clean his space. Ben promises to clean his space, but over the course of a few weeks, nothing is done to remedy the situation.

At this point, Alex feels conflicted. His lab has been creating and characterizing these particles for several years and should have a detailed disposal method for it. As the new member of the lab, Alex

is torn between discussing the situation with the lab safety director in his department and keeping the problem to himself. He is being financially supported by his adviser, and is concerned that if he blows the whistle his graduate and professional careers might be ruined.

During Alex's first year, the Environmental Protection Agency (EPA) performs spot checks on the labs at College X. The EPA does not examine all labs at the college, but Alex's lab is chosen for the inspection. During the spot check, Alex privately voices his concerns about Ben's hood to the EPA agent. The EPA agent then does a preliminary inspection of the hood and decides that the conditions warrant further investigation. Alex asks the EPA agent what will happen next, and the agent says that the EPA will begin a thorough review of the lab's background. The EPA will gather information about the lab's status as a waste generator, applicable permits the lab may already have, potential violations, and the lab's compliance history (if any). Alex is also told that there may be other inspectors, depending on whether the EPA contacts the Occupational Safety and Health Administration (OSHA) and if results of the preliminary inspection necessitate contacting other departments.

As this is happening, a Resource Conservation and Recovery Act (RCRA) inspector from the EPA is assigned to review the lab's information and prepare for the inspection. Given a concern for hazardous materials storage, the inspector determines that a protective material is necessary. The inspector learns that the lab is using a contractor to dispose of waste and identifies pathways that the waste takes according to the contractor's records. The RCRA inspector determines that one or two more inspectors are necessary because of the size of the facility and contacts OSHA to conduct a joint inspection. This takes a few days as OSHA is informed of the situation and agrees that there is a probable cause for inspection. OSHA and the RCRA inspector decide to make an unannounced inspection of the lab based on Alex's concerns.

Two weeks pass and Alex continues to ponder whether he made the right decision. Then, that morning as Alex is working in the lab Ben arrives and asks him if he knows anything about an inspection being done. Alex doesn't say anything about talking to the EPA agent. While Alex and Ben are talking two inspectors come by with another grad student and the lab safety director. They introduce themselves, and Alex realizes that it is an OSHA and a RCRA inspector. They ask to speak to Alex privately and the OSHA inspector requests to see Ben's hood. The RCRA inspector asks for details on labeling of the specific chemicals in the hood. Normally the RCRA does not take samples during a compliance inspection, but the inspector decides to after seeing the condition of Ben's hood. Both inspectors leave the hood and continue around the facility photographing other hoods and containers of material. They continue through the lab and the OSHA inspector asks about safety and employee working conditions while the RCRA inspector inquires about environmental concerns and human health outside of the lab.

Next, the RCRA inspector documents waste flow procedures and compliance with procedures based on the nature of waste generation in the lab. The OSHA inspector investigates compliance with lab safety practices and verifies that appropriate guidance and regulations are posted. Both inspectors request facility documentation; waste manifests (RCRA) and incident/illness/fatalities reports (OSHA). The RCRA inspector finds all waste management units, documents their condition, checks for appropriate labeling and examines them for any signs of release. A red flag is raised when the inspector notices that the nanoparticle waste is labeled as bulk. As the generators, students in the lab bear the ultimate responsibility for the life cycle of the nanoparticles after they are discarded. Unfortunately, there are no material safety data sheets that describe the health risk and disposal differences in materials between bulk and nano cadmium and selenium.

The RCRA and OSHA inspectors examine the hazardous and solid waste manifests, inspection logs, training documentation, contingency plans, and the lab's Spill Prevention Control and Countermeasures (SPCC) Plan. After the inspection they meet privately and with the lab director and discuss the results. They noted several concerns outside their scope of work that they may need to report to other offices for inspection. For instance, the contractor uses a state-operated landfill to dispose of the waste. The EPA believes that a site inspection of the landfill and contractor's facility is necessary to ensure that the heavy metals involved in the quantum dot process have not leached into groundwater. The lab is informed that, because of their generator status, they will bear the ultimate responsibility for any infractions which can be directly traced back to their products. Alex finds this bittersweet, while the lab will be required to take responsibility for its waste; there are currently no diagnostic tests for quantum dots. He knows that this means there is little chance that the waste products will be traced directly back to his lab. The EPA and OSHA meet again with the lab director and have a formal discussion about lab violations. Several infractions should be fixed immediately to avoid health issues such as the cleanup of Ben's hood and relabeling of all containers in the lab that are yellowed, faded, illegible, or otherwise incorrect. EPA and OSHA also mention that findings are all preliminary and need to be verified before any final conclusions can be made. As they leave, Alex wonders if anything will change...

## Questions

1. Is it the university's responsibility to provide nanotech disposal training?
2. What are the implications of labeling potentially hazardous nano-size waste as their "bulk" counterparts?  
Does the gender/ethnicity role of each character affect the moral responsibility or the views of the respondent?
3. Did the lab have an ethical responsibility to "anticipate" rather than "alert"? (McGinn, P.113)
4. What role should the EPA play? OSHA? The federal government in general?
5. What resources does Alex have at your university?
6. Should lab safety also include potential accidents outside of the lab, such as releases from a contractor or other entity that endangers people?
7. What is the order of authority for safety incidents at your laboratory?
8. For the scientists in the audience, how would you develop a nanoparticle test that could be implemented in waste disposal situations?

## Further Reading

### Quantum Dots

Alivisatos, A. P., Perspectives on the Physical Chemistry of Semiconductor Nanocrystals. *Journal of Physical Chemistry* **1996**, 100, 13226-13239.

Michalet, X.; Pinaud, F. F.; Bentolila, L. A., Quantum dots for live cells, in vivo imaging, and diagnostics. *Science* 307, 538-544.

Schaller, R. D.; Klimov, V. I., High Efficiency Carrier Multiplication in PbSe Nanocrystals: Implications for Solar Energy Conversion. *Phys Rev Lett* **2004**, 92, 186601.

### Nanotech Ethics

Bainbridge, W. S., Sociocultural meanings of Nanotechnology: Research Methodologies. *Journal of Nanoparticle Research* **2004**, 6, 285-299.

McGinn, R., Ethics and Nanotechnology: Views of Nanotechnology Researchers. *Nanoethics* **2008**, 2, 101-131.

### Resource Conservation and Recovery Act

What is a hazardous waste?

[http://waste.custhelp.com/cgiin/waste.cfg/php/enduser/std\\_adp.php?p\\_faqid=235](http://waste.custhelp.com/cgiin/waste.cfg/php/enduser/std_adp.php?p_faqid=235)

RCRA Online, a resource for RCRA questions and answers: [http://waste.custhelp.com/cgi-bin/waste.cfg/php/enduser/std\\_alp.php](http://waste.custhelp.com/cgi-bin/waste.cfg/php/enduser/std_alp.php)

### Environmental Safety & Policy

<http://www.dtsc.ca.gov/TechnologyDevelopment/Nanotechnology/index.cfm>

<http://epa.gov/oppt/nano/stewardship.htm>

[http://www.frtr.gov/nano/pdf/day2/dreher\\_kevin.pdf](http://www.frtr.gov/nano/pdf/day2/dreher_kevin.pdf)

[http://www.nanotechproject.org/file\\_download/files/PEN3\\_Risk.pdf](http://www.nanotechproject.org/file_download/files/PEN3_Risk.pdf)

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