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Thursday, 1 April 2004
www.etcgroup.org

Nano's Troubled Waters:

Latest toxic warning shows nanoparticles cause brain damage in aquatic species and highlights need for a moratorium on the release of new nanomaterials

A new study revealing that engineered carbon molecules known as “buckyballs” cause brain damage in fish is one more brick in the wall of evidence suggesting that manufactured nanoparticles are harmful to the environment and to health. The results of the study highlight the urgency to heed ETC Group’s 2002 call for a moratorium on manufactured nanoparticles in commercial products and they back up last month’s recommendation by the Institut für ökologische Wirtschaftsforschung – in a report commissioned by the European Parliament – that nanoparticles should not be released into the environment.¹ Recent scientific studies have raised serious concerns about the toxicity of nanoparticles (see “Ten Toxic Warnings,” below). This latest study, which has yet to be published, is the first to simulate what could happen when nanoparticles are released into the environment.

How many warnings do government regulators require before they take action to ensure that uses of nanoparticles are safe before workers in production facilities are harmed and before consumers are further exposed?

At the American Chemical Society’s national meeting last week in Anaheim, California, environmental toxicologist Dr. Eva Oberdörster described what happened when she exposed nine largemouth bass to water containing buckyballs at concentrations of 500 parts per billion. (The concentration level is comparable to pollutant levels commonly found in port waters.) After only 48 hours, the researchers found “severe” damage to brain tissue in the form of “lipid peroxidation,” a condition leading to the destruction of cell membranes, which has been linked, in humans, to illnesses such as Alzheimer’s disease. Researchers also found chemical markers in the liver indicating inflammation, which suggested a full-body response to the buckyball exposure.²

Manufactured nanoparticles, measuring a few billionths of a meter, are already used in commercial products ranging from anti-aging creams to sunblocks to car bodies to tennis racquets. Buckyballs – the soccer-ball shaped molecules of carbon touted as “miracle molecules” because of their unusual chemical properties – are considered especially promising for applications in drug delivery and cosmetics as well as fuel cells

and solar cells. Buckyballs have not yet been incorporated into commercial products. The high cost of their manufacture has been considered the biggest barrier to commercialization, but the price of a gram of buckyballs is dropping precipitously – from several hundred (US) dollars to \$20 dollars and manufacturers predict the price will drop even further to 50 cents per gram.³ It is hard to know how many buckyballs have been manufactured since their discovery in 1985, but one company in Japan called Frontier Carbon (a joint venture of Mitsubishi Corporation and Mitsubishi Chemical) is operating a facility with a production capacity of 40 metric tons per year. The company says it has 300 buyers for its fullerenes (the chemical family name of buckyballs).⁴

Regarding the results of her buckyball toxicity study, Dr. Oberdörster warns, “Given the rapid onset of brain damage, it is important to further test and assess the risks and benefits of this new technology before use becomes even more widespread.” Though it is known that nanoparticles can cross the blood/brain barrier in humans, it is not yet known whether they will cause the kind of damage found in Oberdörster’s fish.

In a separate experiment, Oberdörster found that buckyballs are also toxic to “water fleas” – in buckyball-tainted water, half the water flea population was dead in two days. (According to Oberdörster, that means buckyballs are “moderately toxic” to water fleas, more toxic than nickel, but less toxic than copper.⁵) Because water fleas (crustaceans a few millimeters long) are a food source for other aquatic species, Oberdörster expressed concern that nanoparticles could begin to accumulate throughout the food chain, affecting not just fish, but plants and other animals, including people.⁶ Both largemouth bass and water fleas are standard test species for aquatic toxicity.

Though the market for nanoparticles will approach one billion dollars next year, neither government regulations nor labeling requirements exist in any country. Because nanoparticles are composed of elements and compounds whose toxicity is well-studied at larger scales, they have been assumed safe even though they can exhibit wildly different properties from their larger siblings.

With regard to her findings, Dr. Oberdörster said that “this is a yellow light, not a red one.”⁷ Presumably, she believes that the potential for safe applications of nanoparticles still exists, but that commercialization should proceed cautiously until scientific toxicological data catch up to the technology. ETC Group agrees that a yellow light is in order and, once more, urges regulators and international policymakers to move swiftly and responsibly to place a moratorium on the release of new nanoparticles into the environment until lab protocols can be established and until toxicology studies can be undertaken and their results verified. Many nano-proponents insist that modifications can be made to the particles – such as coating them – to ensure that they are safely biocompatible. While this is theoretically possible, there is no independent body to assess the modifications nor any regulations to prevent manufacturers from using unmodified nanoparticles. The situation is made more complicated by most manufacturers’ unwillingness to share their own safety studies with the public or with competitors.

Close-to-market applications for nanoparticles are wide-ranging and many involve the release of nanoparticles in water or in soil. One company, Altair Nanotechnologies, currently seeks to market a nanoparticle-based product that will be used to clean water

at industrial fish farms and in swimming pools. Clear Spring Foods, an aquaculture company that farms around a third of US trout production, has been carrying out tests for nanoparticle-based vaccine delivery. The DNA vaccine in nanoparticle form would be added to fish ponds and then activated by ultrasound to inoculate trout. Meanwhile, reports from Kyoto in Japan show that scientists are experimenting with using buckyballs for agricultural fertilizer. Fertilizer runoff is already a major pollutant of water ways.

The international community must formulate a legally-binding mechanism to govern the products of new technologies, based on the Precautionary Principle, one that addresses their health, socio-economic and environmental implications. International assessment should be incorporated under a new International Convention for the Evaluation of New Technologies (ICENT). The issues of nanoparticle toxicity and environmental release should be on the radar screens of civil society and peoples' organizations, as well as intergovernmental agencies. ETC Group has been in touch with the International Collective in Support of Fishworkers (ICSF, Chennai, India), which monitors issues related to the livelihood of small-scale fishworkers around the world. ICSF is already monitoring the issue of nanoparticle toxicity. ETC Group has also contacted the World Fish Center based in Penang, Malaysia, which is part of the international network of research centers known as CGIAR (Consultative Group on International Agricultural Research). The issue of nanoparticle toxicity should be urgently considered by the Oslo Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), whose Hazardous Substances Committee meets next month in Wismar, Germany.

The following list is not exhaustive, but includes some of the biggest, reddest flags on the issue of engineered nanoparticle safety:

Ten Toxic Warnings

- 1 1997 – Titanium dioxide / zinc oxide nanoparticles from sunscreen are found to cause free radicals in skin cells, damaging DNA. (Oxford University and Montreal University) Dunford, Salinaro *et al.*⁸
- 2 March 2002 – Researchers from the Center for Biological and Environmental Nanotechnology (CBEN, Rice University, Houston) report to US EPA that engineered nanoparticles accumulate in the organs of lab animals and are taken up by cells. *"We know that nanomaterials have been taken up by cells. That sets off alarms. If bacteria can take them up then we have an entry point for nanomaterials into the food chain."* – Dr. Mark Wiesner⁹
- 3 March 2003 – Researchers from NASA / Johnson Space Center report that studies on effects of nanotubes on the lungs of rats produced more toxic response than quartz dust. Scientists from DuPont Haskell laboratory present varying but still worrying findings on nanotube toxicity. *"The message is clear. People should take precautions. Nanotubes can be highly toxic."* – Dr. Robert Hunter (NASA researcher)¹⁰
- 4 March 2003 – ETC group publishes first scientific literature survey on nanoparticle toxicity by toxicopathologist Vyvyan Howard. Dr. Howard concludes that the smaller the particle, the higher its likely toxicity and that nanoparticles have various routes into the body and across membranes such as the blood brain barrier. *"Full hazard assessments should be performed to*

establish the safety of species of particle before manufacturing is licensed. We are dealing with a potentially hazardous process.” – Dr. Vyvyan Howard¹¹

5 July 2003 – *Nature* reports on work by CBEN scientist Mason Tomson that shows buckyballs can travel unhindered through the soil. *“Unpublished studies by the team show that the nanoparticles could easily be absorbed by earthworms, possibly allowing them to move up the food-chain and reach humans” – Dr. Vicki Colvin, the Center’s director¹²*

6 January 2004 – Research by Dr. Günter Oberdörster is published showing that nanoparticles are able to move easily from the nasal passageway to the brain. *“The nanotechnology revolution may design particles that are very different chemically from the ones we are exposed to, and they might have very different properties that made them more harmful. We should be vigilant.” – Professor Ken Donaldson, University of Edinburgh¹³*

7 January 2004 – Nanosafety researchers from University of Leuven, Belgium, write in *Nature* that nanoparticles will require new toxicity tests: *“We consider that producers of nanomaterials have a duty to provide relevant toxicity test results for any new material, according to prevailing international guidelines on risk assessment. Even some ‘old’ chemical agents may need to be reassessed if their physical state is substantially different from that which existed when they were assessed initially.” – Peter H. M. Hoet, Abderrahim Nemmar and Benoit Nemery, University of Belgium¹⁴*

8 January 2004 – At the first scientific conference on nanotoxicity, Nanotox 2004, Dr. Vyvyan Howard presents initial findings that gold nanoparticles can move across the placenta from mother to fetus.¹⁵

9 February 2004 – Scientists at University of California, San Diego discover that cadmium selenide nanoparticles (quantum dots) can break down in the human body potentially causing cadmium poisoning. *“This is probably something the [research] community doesn’t want to hear.” – Mike Sailor, UC San Diego.¹⁶*

10 March 2004 – Dr. Eva Oberdörster reports to American Chemical Society meeting that buckyballs cause brain damage in juvenile fish along with changes in gene function. They also are toxic to small crustaceans (water fleas). *“Given the rapid onset of brain damage, it is important to further test and assess the risks and benefits of this new technology before use becomes even more widespread.” – Dr. Eva Oberdörster.¹⁷*

¹ Haum, Petschow, Steinfeldt, *Nanotechnology and Regulation within the framework of the Precautionary Principle. Final Report for ITRE Committee of the European Parliament.* Institut für ökologische Wirtschaftsforschung (IÖW) gGmbH, Berlin, 11 February 2004. ETC Group’s call for a moratorium on nanotechnology consists of a temporary cessation of lab research and commercialization of new products until national governments, in conjunction with their scientific community, can establish a reviewable “best practices” protocol.

² Mark T. Sampson, “Type of buckyball shown to cause brain damage in fish,” *Eurekalert*, March 28, 2004. Available on the Internet, www.eurekalert.org

³ Scott Kirsner, “Nanotech, biotech at key juncture,” *The Boston Globe*, March 22, 2004.

⁴ Matt Kelly, “Fullerenes Flourish, and Nano-C can make them by the ton,” *Small Times*, 27 October 2003. Available on the Internet, www.smalltimes.com

⁵ Rick Weiss, “Nanoparticles Toxic in Aquatic Habitat, Study Finds,” *The Washington Post*, March 29, 2004.

⁶ Mark T. Sampson, “Type of buckyball shown to cause brain damage in fish,” *Eurekalert*, March 28, 2004. Available on the Internet, www.eurekalert.org

⁷ Barnaby J. Feder, “Health Concerns in Nanotechnology,” *The New York Times*, March 29, 2004.

⁸ Dunford, Salinaro *et al.* “Chemical oxidation and DNA damage catalysed by inorganic sunscreen ingredients,” *FEBS Letters*, volume 418, no. 1-2, 24 November 1997, pp. 87-90.

⁹ Doug Brown, "Nano litterbugs? Experts See Potential Pollution Problems," *Small Times* March 15, 2002. Available on the Internet, www.smalltimes.com

¹⁰ Jenny Hogan, "How safe is nanotech?" Special Report on Nano Pollution, *New Scientist*, Vol. 177, No. 2388, 29 March 2003, p. 14.

¹¹ ETC Group, "Size Matters! The Case for a Global Moratorium," Occasional Paper Series, Volume 7, no. 1, April 2003. Available on the Internet, www.etcgroup.org

¹² Geoff Brumfiel, "A Little Knowledge...," *Nature*, Vol. 424, no. 6946, 17 July 2003, p. 246.

¹³ Alex Kirby, "Tiny Particles Threaten Brain," *BBC News Online*, 8 January, 2004. Available on the Internet, <http://news.bbc.co.uk/1/hi/sci/tech/3379759.stm>

¹⁴ Peter Hoet, Abderrahim Nemmar and Benoit Nemery, "Health Impact of Nanomaterials?" *Nature Biotechnology*, Vol. 22, no.1, January 2004, p. 19.

¹⁵ Ben Wootliff, "British Scientist: Nanoparticles Might Move from Mom to Fetus," *Small Times*, 14 January 2004. Available on the Internet, www.smalltimes.com

¹⁶ Justin Mullins, "Safety concerns over injectable quantum dots," *New Scientist*, Vol. 181, No. 2436, 28 February 2004, p. 10.

¹⁷ Mark T. Sampson, "Type of buckyball shown to cause brain damage in fish," *Eurekalert*, March 28, 2004. Available on the Internet, www.eurekalert.org

The Action Group on Erosion, Technology and Concentration, formerly RAFI, is an international civil society organization headquartered in Canada. The ETC group is dedicated to the advancement of cultural and ecological diversity and human rights. www.etcgroup.org. The ETC group is also a member of the Community Biodiversity Development and Conservation Programme (CBDC). The CBDC is a collaborative experimental initiative involving civil society organizations and public research institutions in 14 countries. The CBDC is dedicated to the exploration of community-directed programmes to strengthen the conservation and enhancement of agricultural biodiversity. The CBDC website is www.cbdcprogram.org