

- Pesticides can be more easily aerosolized as a powder or droplets – therefore inhale-able, and perhaps a greater threat to human health and safety.
- Could pesticides formulated as nanocapsules or nano-scale droplets exhibit different toxicity and enter the body and affect wildlife through new exposure routes, for example, across skin (see box on page 7, Keeping Nanoparticles Out of the Environment).
- Potential for use as a bioweapons delivery vehicle.
- What other external triggers might affect the release of the active ingredient (e.g., chemical binding, heat or break down of the capsule)?
- Microcapsules are similar in size to pollen and may poison bees and/or be taken back to the hives and incorporated in honey. Because of their size, "micro-encapsulated insecticides are considered more toxic to honey bees than any formulation so far developed."<sup>55</sup> Will nanocapsules be more lethal?
- It is not known how 'unexploded' nanocapsules will behave in the human gut if ingested with food.

**Implications of Encapsulation for Nanobioweaponry:**

Nanocapsules and microcapsules make an ideal vehicle for delivering chemical and biological weapons because they can carry substances intended to harm humans as easily as they can carry substances intended to kill weeds and pests. By virtue of their small

size, DNA nanocapsules may be able to enter the body undetected by the immune system and then become activated by the cells' own mechanisms to produce toxic compounds. The increased bioavailability and stability of nano-encapsulated substances in the environment may offer advantages to the Gene Giants, but the same features could make them extremely potent vehicles for biological warfare. In addition, because of their increased bioavailability only a small quantity of the chemical is needed.

When programmed for external triggers such as ultrasound or magnetic frequencies, activation can be controlled remotely, suggesting a number of grim scenarios. Could agrochemical/seed corporations remotely activate triggers to cause crop failure if the farmer infringes the company's patent or fails to follow prescribed production practices? What if nanocapsules containing a potent compound are added to a regional water supply by a foreign aggressor or terrorist group?

According to The Sunshine Project, the "Australia Group" (a group of 24 industrialized nations) recently proposed that microencapsulation technologies be added to a common list of technologies banned from export to 'untrustworthy' governments for fear of use as bioweapons.<sup>57</sup> Documents obtained by Sunshine Project also show that the US military funded the University of New Hampshire in 1999-2000 to develop microcapsules containing corrosive and anaesthetic (that is, to

*“The ultimate expression of this technology would be development of a vector that encapsulates, protects, penetrates, and releases DNA-based BW [biological warfare] agents into target cells but is not recognised by the immune system. Such a ‘stealth’ agent would significantly challenge current medical counter-measure strategies.”*

– Defense Intelligence Agency analysts, US government, Washington, DC.<sup>56</sup>

*Could agrochemical seed corporations remotely activate triggers to cause crop failure if the farmer infringes the company's patent or fails to follow prescribed production practices?*

produce unconsciousness) chemicals. The documents describe how the microcapsules could be fired at a crowd, corrode protective gear and then break open in contact with the moisture on human skin.<sup>58</sup>

### **Precision Agriculture: from Smart Dust to Smart Fields**

#### **Robo-farming with Nanosensors**

"Precision farming," also known as site-specific management, describes a bundle of new information technologies applied to the management of large-scale, commercial agriculture. Precision farming technologies include, for example: personal computers, satellite-positioning systems, geographic information systems, automated machine guidance, remote sensing devices and telecommunications.

"It is 5 a.m. A Midwest farmer sips coffee in front of a computer. Up-to-the-minute satellite images show a weed problem in a field on the northwest corner of the farm. At 6:30 a.m., the farmer drives to the exact location to apply a precise amount of herbicide." - Illinois Laboratory for Agricultural Remote Sensing press release<sup>59</sup>

Precision farming relies upon intensive sensing of environmental conditions and computer processing of the resulting data to inform decision-making and control farm machinery. Precision farming technologies typically connect global positioning systems (GPS) with satellite-imaging of fields to remotely sense crop pests or evidence of drought and then automatically

adjust levels of irrigation or pesticide applications as the tractor moves around the field. Yield monitors fitted to combine harvesters measure the amount and moisture levels of grains as they are harvested on different parts of a field, generating computer models that will guide decisions about application or timing of inputs. Precision agriculture promises higher yields and lower input costs by streamlining agricultural management and thereby reducing waste and labour costs. It also offers the potential to employ less skilled, and therefore cheaper, farm machinery operators since, theoretically, such systems can simplify and centralize decision-making. In the future, precision farming will resemble robotic farming as farm machinery is designed to operate autonomously, continuously adapting to incoming data.

If they function as designed, ubiquitous wireless sensors (see below) will become an essential tool for bringing this vision of precision farming to maturity. When scattered on fields, networked sensors are expected to provide detailed data on crop and soil conditions and relay that information in real time to a remote location so that crop scouting will no longer require the farmer (or agribusiness executive) to get their boots dirty. Since many of the conditions that a farmer may want to monitor (e.g., the presence of plant viruses or the level of soil nutrients) operate at the nano-scale, and because surfaces can be altered at the