A NEFARIOUS APPLICATION FOR COMMERCIAL MICROCAPSULES

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This essay identifies the ease of transitioning from legitimate microcapsule manufacturing applications to weaponization and the complex challenges microcapsules pose for current detection and decontamination. Microcapsule engineering is a process where microcapsules are designed for use in many different biological and non-biological systems for many purposes. Commercial cargo microcapsules are pervasive in countless consumer goods like shampoo and medications. They are designed to contain a substance such as liquid fragrance oil until the outer shell desiccates, allowing its release.[1,2] This process began in 1953 with dye encapsulation for copy paper[3] and has progressed extensively over the last 70 years. In this paper, the human body is the biological system referenced, which contains two systems where adsorbed (particle adhesion to a surface) and absorbed (particle transfer into a material) microcapsules are designed to target. Absorbed microcapsules are transported through the body's internal system, while adsorbed microcapsules remain external to the body, typically on the skin or hair. Manufacturers use microcapsules in numerous industrial and consumer applications for legitimate and productive purposes; however, they could be considered dual-use for militarily significant applications, including as a delivery means for chemical or biological agents.

For example, a commercially engineered microcapsule intended for bodily absorption is a drug-filled microcapsule coated in polyethylene glycol that can evade the human immune system, allowing it to maneuver through the body to its designed end location[4] This microcapsule type is an excellent means for drug delivery directly to an organ within the body without the potential of destruction by the immune system. This type of microcapsule coating design continues to be developed and improved significantly in recent years.[5] Virtually no barriers exist to alter the intended course of these microcapsules, even if they are filled with a chemical or biological agent. Commercially, microcapsules are already used for insecticide encapsulation and utilization as a means of delivery within agricultural settings to destroy specific harmful insects.[6] Should one choose to target a human population, it would be an undetectable type of agent that is dramatically more difficult to decontaminate than current delivery systems like aerosolized agents. With the internal absorption of a chemical or biological agent, treatment is only possible if the agent is known. Non-traditional hazards are even more challenging to detect and identify with current sensor designs.[7] It is important to note that the Chemical and Biological Weapons Conventions prohibit these hazard types.[8] Few medical antidotes exist even with proper and rapid detection and identification. Additionally, short treatment timeframes can increase the potential for mass casualty events.

Another example is of an adsorbed commercial microcapsule coated in a cationic copolymer called acrylamide-acrylamidopropyltrimonium copolymer, often used in soaps and shampoos. The cationic copolymer keeps the microcapsule tethered in place under aggressive fluid flow in the presence of a surfactant or soap. This polymer is regularly used as a raw ingredient in today's cosmetics with the intent of a delayed fragrance release. An example would be continuing to smell shampoo fragrance after rinsing in the shower. For clarification, the polymer-attached capsule does not remain on the human body indefinitely but desiccates or dehydrates. This results in the microcapsule rupturing and releasing the cargo, allowing its microscopic pieces to be rinsed off in an upcoming shower. A second microcapsule engineering example is manipulating the capsule surface to achieve this long-lasting effect, like flower pollen attaching to an animal's fur.[9] These long-lasting capsules are a preference for manufacturers but can also be filled with a chemical or biological agent, which is then intended for delayed release with the capsule and polymer desiccation. Adhered and encapsulated microcapsules filled with insecticides carried by insects like bees back to their nest have increased efficacy and induce much higher casualty rates.[10] Unfortunately, transitioning from insects to humans for this delivery system is not difficult as microcapsules can be specifically engineered for this purpose.

As previously mentioned, microcapsules can be engineered with specific diameter, volume, encapsulating material, and deposited amount to ensure the delivered agent would be toxic to humans. Microcapsules can be formulated in many sizes but are anywhere from nanometer range up to 50 microns.[11] The spherical volume of a 20-micrometer diameter microcapsule, for example, is 4,188 cubic micrometers.[12] According to the Center for Disease Control Medical Management Guidelines for Nerve Agents, the general population limit for an eight-hour work shift is 0.000003 milligrams/cubic meter[13] or 3.0×10^{-21} micrograms/cubic micrometer. Although this may seem insignificant, there can be thousands of microcapsules deposited onto a human body at any given time, which can easily exceed the threshold dose. Not only can the microcapsule size and deposited number be manipulated, but the encapsulating material as well. Typically, the material would be a natural protein for internal absorption, whereas adsorbed microcapsules can be made from a plastic polymer.[14,15]

The current military procedure is a thorough decontamination process. The Occupational Safety and Health Administration gives three decontamination methods: removing contaminants by physical or chemical means, physically removing contaminants, or inactivating contaminants.[16] According to the Army Technical Procedures, troop or personnel physical decontamination is conducted with soap and water.[17] This works for traditional agents and delivery methods but is ineffective against microcapsules since they are purposely engineered to remain adhered despite using soap and water. The microcapsules could be engineered to be adsorbed or tethered to human hair and skin even after fluid flow. For human exposure, there are only specific ways decontamination is possible. Decontaminates like bleach and heat treatment would not be applicable. Progress continues to be made in other areas, like inactivating compounds using engineered polymers.[18] This is only useful if the engineered polymer can penetrate the inside of the adhered microcapsule to deactivate the chemical or biological agent. Another possible solution is to increase the water flow pressure to dislodge the adhered polymer and microcapsule attachment. However, commercial microcapsules are designed to adhere despite applying the highest water pressures people can withstand.[19] Another method within the Army Technical Procedure guidelines involves physically removing gross contamination caused by microcapsules. This method is virtually impossible since they are microscopic and cannot be physically removed by brushing them off the body. Without a doubt, microcapsule engineering is a future problem for military decontamination procedures, especially concerning the difficulty of detection. As previously stated, the current detection equipment is not designed for emerging chemical and biological threats, so it would be difficult to determine whether decontamination would be necessary and whether it would even work.

This paper is an adaptation of my graduate thesis, where the copolymer was attached to different material microcapsules to maintain deposition on the human body. Although the research is intended for legitimate commercial applications, creative thinking led to my developing this thought piece. Designing a chemical or biological warfare agent that is delivered to the human body through a microcapsule system is not an extended leap from encapsulating insecticides to producing casualty effects in an operating environment. Although these types of weapons have been technically banned, that does not make them less of a threat, and the current detection and decontamination procedures need to be modernized to mitigate the threat. ■

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