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RCRA Regulation of Wastes from the Production, Use, and Disposal of Nanomaterials

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RCRA Regulation of Wastes from the Production, Use, and Disposal of Nanomaterials[1]

EXECUTIVE SUMMARY

The booming growth of nanotechnology in the U.S. economy has already begun to create an expanding universe of wastes from the manufacture, use, and disposal of products containing nanomaterials.[2] Just as nanomaterial products offer useful novel properties, nanomaterial wastes may present regulators with unexpected and unique questions. Researchers are trying to assess how nanomaterials and nanoparticles released into the environment will migrate through groundwater, adhere to soil, move through air/water and water/sediment partitions, and become available for bio-uptake. For example, some scientists have raised concerns that the relatively large surface area presented by small amounts of nanoparticles may make such nanomaterials comparatively more toxic than similar amounts of larger-scaled versions of the same materials.[3]

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1 This paper was prepared by Tracy Hester, Bracewell & Giuliani LLP, who gratefully acknowledges the valuable contributions of Christopher Bell, Sidley Austin Brown & Wood LLP and Joseph Guida, Guida, Slavich & Flores, P.C. The author also acknowledges with gratitude the suggestions from members of the RCRA Nano Team of the American Bar Association (ABA) Section of Environment, Energy, and Resources (SEER), which include Christopher McCormack, Pullman & Comley, LLC; David Meezan, Alston & Bird LLP; George Curran, Hopkins, Curran & Smith P.C.; Linda Breggin, Environmental Law Institute; Patrick Paul, Snell & Wilmer L.L.P.; Richard Fil, Robinson & Cole LLP; Robert Rhodes, Holland & Knight; Scott Mitchell, Gunster Yoakley; Tana Vollendorf, Phelps Dunbar LLP; Elliot Eder, Eder, LLC; David Flynn, Phillips Lytle LLP; John Pendergrass, Environmental Law Institute; and John Kyle, III, Barnes & Thornburg.

2 The Woodrow Wilson Institute's Project on Emerging Nanotechnology has assembled a database listing over 200 consumer products that claim to include nanomaterial components. This database can be accessed at http://www.nanotechproject. consumerproducts (June 2, 2006). The projected market for single-walled carbon nanotube products alone is projected to approach $5 billion within the next five years, and the National Science Foundation has predicted that nanotechnology will have a $1 trillion impact on the world's economy a decade from now. Nanomaterials will likely become ubiquitous parts of consumer products, chemical and metals manufacturing processes, biomedical services and devices, power sources, and military weaponry and systems.

3 *Getting Nanotechnology Right the First Time*, Statement to the National Research Council, Dr. Richard Denison, Environmental Defense (Mar. 25, 2005) at 2.

Nanomaterials will also offer new opportunities for cleaning up hazardous wastes and contamination. For example, nanoscale iron particles have proven effective at reducing concentrations of persistent chlorinated organic compounds in groundwater.[4] Nanomaterials may also play a vital role in creating environmental detectors and sensors that can quickly identify small concentrations of toxic compounds in the environment. Ironically, the use of these nanomaterials to solve environmental problems may collide with concerns that releasing these same nanomaterials into the environment raises unknown and unacceptable risks.[5]

EPA has the authority under the Resource Conservation and Recovery Act (RCRA) to regulate the generation, transportation, management, and disposal of secondary materials that become solid or hazardous wastes.[6] EPA now shares some of that authority through delegation to states with hazardous waste regulatory programs which meet -- or exceed -- EPA's standards. To date, neither federal nor state waste management programs have offered regulations or guidances that expressly address the management or disposal of nanoscale wastes. EPA has noted, however, that "[n]anomaterials that meet the definition of RCRA hazardous wastes would be subject to these regulations."[7]

This paper assesses the potential application of current RCRA statutory and regulatory requirements to the burgeoning field of nanoscale materials.[8] It discusses whether current federal requirements can adequately address potential environmental concerns posed by nanoscale materials.

We conclude that EPA already has expansive authority under RCRA to regulate discarded wastes that might include nanoscale materials. EPA's current regulations governing the management of hazardous wastes will also likely apply broadly to solid and hazardous wastes containing nanoscale constituents. Despite EPA's sweeping powers to regulate hazardous waste

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4 *See, e.g.*, Zhang. W. (2003). Nanoscale iron particles for environmental remediation: An overview. *J. Nanoparticle Res.* 5**:** 323–332.

5 *Nanoscience and Nanotechnologies: Opportunities and Uncertainties*, RS Policy document 20/4, RAEng Policy document R2.19 (July 2004) at 5 ("[s]pecifically, we recommend as a precautionary measure that . . . the use of free nanoparticles in environmental applications such as remediation of groundwater be prohibited").

6 Regulations implementing Subtitle C of RCRA for hazardous waste management appear in 40 C.F.R. Parts 260-279.

7 U.S. Environmental Protection Agency, NANOTECHNOLOGY WHITE PAPER (Initial Draft) (Nov. 2, 2005) at 25.

8 We use the terms "nanomaterials" and "nanoparticles" in a generic sense. The precise definitions of nanoscale materials, however, remains a topic of active open discussion, and several associations (including the International Standards Organization and the ASTM International) are attempting to set standards that will define these materials.

management and its comprehensive regulatory framework, we also identify below several areas of potential interest where EPA may wish to determine whether its current regulations will have unintended consequences when applied to nanoscale waste materials.

I. RCRA OFFERS BROAD STATUTORY AUTHORITY TO EPA TO REGULATE WASTES CONTAINING NANOPARTICLES

RCRA provides EPA with broad statutory and regulatory powers to control the management of hazardous wastes in the United States. For example, RCRA Section 3002 directs EPA to set out comprehensive regulatory standards for generators of hazardous wastes, and other provisions of RCRA empower EPA to set out detailed regulatory standards for all aspects of waste management and disposal.[9] Similar statutory provisions direct EPA to set out expansive regulatory standards for persons who generate or transport hazardous wastes.[10]

If nanomaterials are discarded or are included in other secondary materials managed as wastes, they will almost certainly fall under this sweeping statutory framework. To the extent that nanomaterials in wastes pose novel environmental risks, which EPA's current regulations fail to address, EPA likely has sufficient authority under RCRA to promulgate new regulations to address discarded secondary materials arising from the generation, use, treatment, or disposal of nanomaterials.

EPA's powers to promulgate new regulations to address environmental risks will allow it to respond to novel characteristics or hazards from discarded nanoscale materials. For example, if EPA's current regulatory definitions of hazardous characteristics (ignitability, corrosivity, reactivity, and toxicity) fail to encompass unexpected risks from nanoscale materials, EPA possesses ample statutory authority to promulgate regulations to define new characteristic or listing aimed at certain troubling nanomaterials.

As an intermediate step before promulgating new regulations, EPA can also draw on its emergency authorities to address particular hazards posed by discarded nanomaterials. For example, EPA (and, to a lesser extent, private parties) can seek injunctive relief to address imminent and substantial endangerments posed by the release of hazardous constituents from solid or hazardous wastes.[11] It is likely that the conventionally sized versions of many nanomaterials will fall within the broad array of chemicals that qualify as "hazardous constituents" under EPA guidance,[12] and therefore EPA can rely on its emergency authority to

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9 42 U.S.C. § 6921 *et seq*.

10 *Id*.

11 42 U.S.C. §§ 7002, 7003.

12 *See* 40 C.F.R. Part 261, App. VIII (listing of hazardous constituents); 40 C.F.R. Part 264, Appendix IX (ground water monitoring list of hazardous constituents); 55 Fed. Reg. 30798, 30874 (July 27, 1990) (proposal to define "hazardous waste" or "hazard

address dangerous releases of these nanomaterials. EPA can also rely on other authorities to address releases of nanomaterials that might otherwise fall outside its regulatory ambit, including its permit omnibus authority for facilities that have (or should have had) permits to treat, store, and dispose of hazardous wastes.[13]

II. EPA'S REGULATORY DEFINITIONS OF "SOLID WASTE" AND "HAZARDOUS WASTE" CAN ENCOMPASS MOST SECONDARY MATERIALS CONTAINING NANOMATERIALS

A. Nanomaterials and the Definition of "Solid Waste"

EPA has expansive authority to regulate secondary materials once they are discarded and become "solid waste" within the RCRA universe. EPA has promulgated regulations that broadly interpret the types of discarding activities that can bring secondary materials into the category of "solid waste." As a result, EPA's RCRA regulations should apply to wastes containing nanomaterials that are discarded onto land, burned, or recycled as a means of disposal.[14] These broad categories of "discard" should cover actions that would typically occur with wastes containing nanomaterials.

EPA's authority to regulate secondary materials containing nanomaterials is less clear, however, when manufacturers attempt to recycle or reuse those nanomaterials. Given the high value of specially manufactured nanomaterials (*e.g.*, nanoscale metals such as platinum used in catalysts or gold in biomedical devices, or highly valuable configurations of single-walled carbon nanotubes), manufacturers and users may have a strong interest in recovering certain nanomaterials for reuse or recharging. While EPA's regulatory authority only extends to discarded secondary materials, it has set out detailed regulations for the management and

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constituent" for corrective action purposes to include items listed in these two Appendices). To the extent that RCRA arguably only grants EPA corrective action authorities over "hazardous wastes" at interim status treatment, storage, and disposal facilities, EPA has interpreted "hazardous waste" under Section 3008(h) of RCRA to encompass any kind of waste within the broad statutory definition of the term. Under this interpretation, EPA can order corrective action for releases of nanomaterials that qualify as "hazardous wastes" under 42 U.S.C. Section 6903(5) even if they do not constitute "hazardous waste" under EPA's current regulatory definition. 55 Fed. Reg. at 30809.

13 42 U.S.C. § 3005(c)(3) (authorizing Administrator to include terms and conditions "necessary to protect human health and the environment" in permits for hazardous waste treatment, storage, and disposal facilities). As discussed below, EPA can also order permit holders to take similar actions to address releases of hazardous constituents from solid waste management units at facilities that manage hazardous wastes. 42 U.S.C. §§ 3004(u)-(v), 3008(h).

14 40 C.F.R. § 240 *et seq*.

handling of recycled materials that may become sufficiently waste-like to trigger RCRA requirements.

To our knowledge, the issues related to recycling of nanomaterials in manufacturing and consumer products have received comparably less attention.[15] It is possible, however, that in the near future EPA may need to investigate potential environmental concerns posed by the continued use of off-specification nanomaterials that fail to meet strict quality requirements but which retain valuable characteristics.[16] To the extent that such off-specification nanomaterials remain in commercial use, they may fall outside EPA's regulatory ambit under RCRA.[17] The long-term accumulation and storage of secondary nanomaterials destined for continuing commercial use also may potentially pose regulatory concerns.[18]

B. Nanomaterials and the Definition of "Hazardous Waste"

EPA regulations currently define solid wastes as "hazardous wastes" if they either display a hazardous characteristic or appear on a list of hazardous wastes from certain industrial activities or certain discarded commercial chemicals.

1. Characteristic Hazardous Wastes and Nanomaterials

If a solid waste containing a nanomaterial exhibits a hazardous characteristic, the nanoscale dimensions of its constituent should not be relevant to the waste's classification as hazardous. For example, a waste that displays the hazardous characteristic of ignitability because it contains powdered aluminum will remain characteristically hazardous regardless of

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15 *See, e.g.*, Letter from David Wagger, Institute of Scrap Recycling Industries, Inc., to William Farland, U.S. EPA (Jan. 24, 2006) (commenting that EPA's draft White Paper on Nanotechnology fails to adequately address issues posed by the prospective recycling of nanoscale materials and products). These comments are available at http://www.isri.org/AM/Template.cfm?Section=Home&CONTENTFILEID=2589&TEMPLATE=/CM/ContentDisplay.cfm.

16 For example, a batch of nanoscale silver may lack a sufficient concentration of a specific size of nanoparticles needed for use as a medical antibacterial salve, but it may nonetheless remain useful as a general antifungal surface coating.

17 Of course, some of these issues may be addressed by EPA's pending proposed revisions to its regulatory definition of solid waste. 71 Fed. Reg. 23361 (Apr. 24, 2006) (Unified Regulatory Agenda).

18 *See* 40 C.F.R. § 261.2(c)(4) (discarding secondary materials through recycling via speculative accumulation). This regulatory provision, however, does not categorize commercial chemicals listed in 40 C.F.R. Section 261.33 as solid wastes even if they are speculatively accumulated. *Id*.

whether the aluminum is nanoscale. While smaller quantities of the nanomaterials may be required to create the characteristic in the solid waste, the characteristic itself (and the regulatory authority over the solid waste) remains unaffected.

While EPA clearly can regulate nanoscale materials under its current regulations, it may nonetheless need to examine in the future whether to revise some of the management scenarios it uses for hazardous characteristic definitions to reflect special uses and characteristics of nanomaterials.[19] Given the lack of clear data at present, we do not know of any special concerns raised by EPA's management scenarios or computer modeling for its current hazardous characteristic definitions.

EPA may also need to address concerns about the standard of knowledge required to adequately characterize a waste containing nanoscale materials relying on the generator's process knowledge. EPA's current regulations allow a generator to classify a waste as hazardous by "[a]pplying knowledge of the hazard characteristic of the waste in light of the materials or the processes used."[20] To the extent that manufacturing processes using nanoscale materials pose novel issues with comparatively less process knowledge, EPA may need to offer guidance to generators on the extent to which they may have to sample or test their nanoscale wastes rather than rely solely on process knowledge.

If nanoscale materials ultimately pose new qualities or risks not adequately captured by current hazardous characteristics, EPA may also need to assess whether it should define new hazardous characteristics to reflect these new risks. We are not aware of any particular novel hazard posed by nanomaterials generally that might require the development of such a new characteristic. As discussed above, however, EPA has broad statutory authority to define new hazardous characteristics as needed through the regulatory process if it feels that

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19 For example, the current toxicity characteristic relies on the toxicity characteristic leaching procedures (TCLP) to determine whether a waste is characteristically toxic. EPA originally designed this test to yield extracts from waste samples that would reflect the releases expected to occur if the hazardous wastes were co-managed in an unlined municipal solid waste landfill. EPA then set levels of constituents allowed to leach from the waste so that such releases would not migrate through groundwater in sufficient concentrations to exceed maximum concentration limits for persons relying on the aquifer for drinking water. To the extent that nanoparticles adhere to soils, transport in groundwater, or infiltrate into drinking water in significantly different ways from larger-scale particles, EPA's current assumptions for the toxicity characteristic may not fully assess how characteristically toxic wastes with nanomaterials might affect groundwater. The presence of nanomaterials in a waste sample might arguably also affect the waste's behavior in a Pensky-Martens Closed Cup test for ignitability, the waste's classification as a "liquid" under the paint filter test for purposes of the ignitability characteristic, and the waste's status as "aqueous" for purposes of the corrosivity characteristic.

20 40 C.F.R. § 262.11(c)(2).

current hazardous characteristics fail to properly regulate risks posed by wastes containing nanoscale materials.

2. Listed Hazardous Wastes and Nanomaterials

EPA's listings for hazardous waste encompass wastes generated either by specific industrial activities and uses (F and K wastes) or by the discarding of commercial chemicals (U and P wastes). Neither category of listings expressly addresses wastes containing nanoscale materials or wastes from nanomaterials manufacturing.[21]

F and K listings include categories of industrial activities that will likely use or generate nanoscale materials. For example, K-listed wastes from the organic chemical, inorganic chemical, pesticides, explosives, and ink formulation industries may soon include nanoscale materials as these industries increasingly formulate new nanoscale products or adopt nanoscale materials to produce existing chemicals in more efficient ways.[22] F-listed wastes may also soon include nanomaterials. EPA's regulations will impose hazardous waste management standards on these listed wastes without regard to the use of nanomaterials as an ingredient or production process.

While EPA's ability to regulate listed hazardous wastes that might contain nanomaterials seems broad and sufficient to address potential environmental risks, EPA may wish to assess whether its current framework could yield unintended consequences. For example, a nanoscale formulation of a commercial chemical may lack the hazardous effects that led EPA to list it (despite the presence of the same hazardous constituents).[23] The derived-from rule and the mixture rule might also lead to the designation of a large quantity of mixed wastes as hazardous because it contains extraordinarily small amounts of a listed hazardous nanomaterial waste. Given special efforts to formulate nanoscale versions of commercial chemical products

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21 While these industries are still adapting to nanotechnologies, many potential examples could quickly arise. For example, the use of nanoscale aluminum in high-grade military explosives might yield wastewater treatment sludges that qualify as K044 listed wastes.

22 Given the likely ubiquitous use of nanomaterials and nanotechnology, other K-listed industrial sectors may generate wastes containing nanomaterials. For example, petroleum refineries may look to nanoscale catalysts to increase production efficiency, and many printing operations will likely adapt inking formulations that rely on precise application of inks in nanoscale amounts.

23 This situation may pose EPA with tricky questions of statutory interpretation. For example, petitioners may request that EPA classify nanoscale materials as fundamentally different and consequently a "new chemical" under the Toxic Substances Control Act. At the same time, however, those same petitioners may ask EPA to designate nanoscale versions of currently listed hazardous wastes as the same material within the hazardous waste listing description.

that would offer comparative environmental benefits, retaining nanoscale versions of listed wastes as hazardous without regard to their actual environmental risks may discourage efforts to harness nanotechnology for green chemistry or other environmentally beneficial uses.

Nanoscale materials may also affect the process that EPA uses to list or delist solid wastes as hazardous. EPA currently adds solid wastes to the hazardous waste listings based on whether they (1) exhibit a hazardous characteristic; (2) display acute toxic effects on humans or rats; or (3) pose a substantial present or potential hazard to human health or the environment when improperly managed.[24] EPA uses similar factors to weigh whether to delist a hazardous waste upon a showing the waste does not pose an environmental hazard based on its actual management and disposal. To the extent that wastes containing nanomaterials display unique characteristics that EPA's current regulatory factors or computer models would not accurately predict, the listing process and delisting procedures may inappropriately over- or under-predict environmental risks.

C. Nanomaterials and Exemptions from the Definitions of "Solid Waste" and "Hazardous Waste"

The regulatory definitions of "solid waste" and "hazardous waste" include numerous exemptions for several types of secondary wastes. EPA included these exemptions for a broad array of reasons, including (1) other regulatory programs already address risks posed by the materials (*e.g.*, exemptions for discharges pursuant to National Pollutant Discharge Elimination System permits); (2) the materials pose relatively little environmental risk (*e.g.*, *de minimis* releases to wastewater treatment systems); (3) RCRA includes statutory exemptions for certain activities (*e.g.*, Bevill amendment wastes or wastes resulting from oil and gas exploration and production activities); or (4) a need to provide flexibility for production activities that may include some wastes at an intermediate stage (*e.g.*, exemptions for in-process recycling or product storage tank bottoms prior to removal).

Notably, the exemption from the definition of "hazardous waste" given to household hazardous wastes may pose the most immediate forum for EPA to address these issues.[25] A large array of consumer items purporting to contain nanomaterials have already entered the marketplace.[26] One potential avenue for the uncontrolled release of nanomaterials

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[24] 40 C.F.R. § 261.11(a).

[25] 40 C.F.R. § 261.4(b)(1).

[26] To complicate this issue further, some products marketed as "nanotechnology" may not actually contain nanomaterials. A. von Bubnoff, *Study Shows No Nano in Magic Nano, the German Product Recalled for Breathing Problems*, SMALL TIMES (May 26, 2006) (accessible at http://www.smalltimes.com/document_display.cfm?document_id=11586). EPA may need to wrestle with the accuracy of "nanomarketing" claims if they start to cloud the application of RCRA regulatory requirements.

into the environment will be the discarding of consumer goods that qualify as household hazardous wastes. While EPA can address some of these releases, if necessary, through its emergency authorities under RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act,[27] this approach would only allow mitigation of environmental damages after they occur rather than prevent the release in the first place.

Given the large array of exemptions and the separate policy rationales underlying each of them, EPA may need to revisit how these exemptions apply to specific uses of nanomaterials on a case-by-case basis. Unfortunately, the large variety of nanomaterials and the significant difference in their properties based on small incremental differences in particle size or structure will make it difficult for EPA to craft modifications to these exemptions on broad-based principles.

III. EPA'S CURRENT REGULATORY FRAMEWORK ALLOWS IT TO REGULATE GENERATORS OF SOLID AND HAZARDOUS WASTES CONTAINING NANOSCALE MATERIALS

RCRA regulations set out several requirements for generators of hazardous wastes. Depending on the quantity of hazardous waste produced at its facility, a generator may need to satisfy notification, recordkeeping, storage, and management requirements. Facilities that generate waste containing nanomaterials will face the same requirements regardless of the dimensions of the underlying constituents of their hazardous waste.

Wastes containing nanomaterials may nonetheless pose challenges to EPA's current framework to regulate generators. Most notably, RCRA requirements for generators vary based on the amount of hazardous waste that they generate in a calendar year. Large quantity generators of hazardous waste must notify EPA of their activities, establish contingency plans, and store their wastes in certain units generally for 90 days or less.[28] By contrast, small quantity generators (SQGs) and conditionally exempt small quantity generators (CESQGs) need to meet only a subset of these requirements and have more flexible time limits for storing waste on-site. Because nanoscale materials may present novel properties at comparatively small quantities, the current 100 kilogram annual threshold to qualify as a CESQG may allow the on-site storage and management of nanomaterials for extensive periods of time. EPA may review whether to vary

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[27] *See CERCLA Nanotechnology Issues*, American Bar Association, Section of Environment, Energy and Resources (June 2006) at 4-7. As discussed above, EPA can address releases of constituents of solid or hazardous wastes that pose an imminent risk to human health and the environment under RCRA Section 7003. While the household hazardous waste exemption removes such materials from the definition of hazardous wastes, they nonetheless remain solid wastes and therefore releases of hazardous constituents from them should be subject to EPA's emergency order authority.

[28] 40 C.F.R. Part 262 *et seq*.

storage and management quantity thresholds based on the actual hazard posed by the nanomaterials rather than their quantity.[29]

Numerous regulatory exemptions allow generators to stay outside the full panoply of hazardous waste regulatory management standards.[30] While these exemptions also serve numerous policy objectives, they generally assume that larger quantities of hazardous waste stored for a longer period at a generator's facility will pose a larger risk to human health and the environment. To the extent that nanomaterials may change the degree of risk posed by equivalent volumes of waste, or may have qualities that make standard tank and container storage inappropriate for them, EPA may need to confirm the suitability of standard regulatory standards applicable to generators managing hazardous nanomaterials under exemptions from RCRA permitting.

The exemption of on-site storage of nanoscale wastes in certain types of management units may pose one of the most immediate and significant areas for EPA inquiry. It is likely that many nanoscale materials or wastes may be handled under existing exemptions for 90-day storage in tanks and containers, treatment in elementary neutralization units and totally enclosed treatment facilities, in-loop recycling, and other exempt storage and treatment options. To the extent that nanoscale materials display unusual qualities or respond differently to standard treatment technologies, these exemptions may not adequately address those unique aspects. Alternatively, the special qualities of nanoscale materials may make it very difficult for generators to manage their wastes in certain types of units and create regulatory uncertainty and dislocation for existing operations.[31]

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29 EPA has already recognized that wastes which pose a greater toxic risk in relatively smaller doses may merit different classification and treatment. Acute hazardous waste, for example, remains subject to different thresholds for accumulation and temporary storage at generator facilities.

30 Perhaps the most notable exemptions allow generators to store and (in limited circumstances) treat hazardous waste in Subpart J tanks and Subpart I containers for less than 90 days without triggering full permitting requirements under 40 C.F.R. Parts 264 or 265. EPA also exempts satellite accumulation areas from permitting requirements, and as a result facility operators may store and manage nanoscale waste materials for an unlimited time as long as they satisfy labeling and minimal storage requirements and they do not exceed 55 gallons (or 1 quart for acute wastes). 40 C.F.R. § 262.34(c).

31 For example, it may prove problematic for a generator to demonstrate that a totally enclosed treatment facility (TETF) has prevented all possible releases of nanoscale materials treated in the TETF when current monitoring and detection technologies may not reliably detect low-level releases of nanoscale materials. Current regulatory standards require that a TETF be "constructed and operated in a manner which prevents the release of hazardous waste or any constituent thereof into the environment during treatment." 40 C.F.R. §§ 260.10 (definition of TETF), 264.1(g)(5) (exemption from permitting for treatment occurring in a TETF).

Last, EPA may face novel challenges arising from the application of universal waste management standards to wastes that may now begin to contain nanomaterials. For example, EPA has promulgated universal waste standards that provide reduced management burdens on certain types of large-volume, low-risk wastes such as discarded batteries and lamps. Some of the most promising applications for nanomaterials will likely arise in exactly these areas, and discarded universal wastes in these categories may begin to contain nanoscale components. If universal waste management standards for these items allow their co-disposal into municipal solid waste landfills, EPA may need to review in the near future its current regulatory framework appropriately addresses these wastes if they contain nanomaterials.[32]

IV. EPA'S CURRENT REGULATIONS ALLOW IT TO REGULATE TRANSPORTERS OF SOLID AND HAZARDOUS WASTES THAT CONTAIN NANOMATERIALS

EPA's current regulations provide a comprehensive framework for persons who transport hazardous wastes. These rules require generators to provide manifests to allow tracking of hazardous waste shipments, establish management standards for the transporters themselves, and impose obligations on the ultimate receivers of hazardous waste to report discrepancies between the shipped wastes and the manifest information. These rules do not address any specific risk or management practice that expressly affects nanoscale materials, but EPA's current regulatory scheme should allow it to address effectively environmental risks posed by the transport of solid and hazardous wastes containing nanomaterials.

As generators create increasingly large amounts of hazardous nanomaterial wastes that require shipping for off-site treatment or disposal, they may have to consider how certain EPA requirements for transporters might apply to their waste shipments. For example, the pending uniform hazardous waste manifest provides a block for special handling instructions and additional information. Given that many nanomaterials may not contain clear handling instructions or spill response information in the material safety data sheets that accompany them, generators and transporters may wish to assure that the nanowaste's manifest includes any special measures needed to respond to a release or spill. To the extent that transporters may also temporarily store hazardous wastes containing nanomaterials during transport for periods up to ten days, some of the same concerns outlined below for on-site accumulation by generators may also apply to transporters operating or using transfer facilities.

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[32] We also note that generators must certify on the Uniform Hazardous Waste manifest that they have a waste minimization program in place, and (for large generators) that they selected the "practicable method of treatment, storage, or disposal currently available" that "minimizes the present and future threat to human health and the environment." 40 C.F.R. Part 262 Appendix (uniform hazardous waste manifest). All off-site shipments of hazardous waste after September 2006 will have to use the new uniform manifest.

V. EPA'S CURRENT RULES FOR TREATMENT, STORAGE AND DISPOSAL FACILITIES ALLOW IT TO REGULATE THESE FACILITY'S MANAGEMENT AND DISPOSAL OF NANOSCALE WASTES

RCRA bestows EPA with broad authority to regulate facilities that treat, store, and dispose of hazardous wastes (TSDFs), and the statute sets out numerous specific requirements that EPA must implement for certain types of waste disposal methods (*e.g.*, minimum technology standards for certain land-based units used to store or treat hazardous wastes).[33] This sweeping statutory grant of authority appears unaffected by the nanoscale dimensions of wastes that might be managed at the TSDF, and EPA should have the ability to promulgate regulations as needed to address novel environmental risks posed by the disposal of hazardous wastes containing nanoscale materials.

While EPA has extensive statutory authority to address hazardous wastes containing nanoscale materials, it may wish to re-examine some of its existing TSDF regulatory standards to assess their adequacy for nanomaterials. One notable area of potential review would be whether land disposal restriction (LDR) treatment standards for certain waste codes will -- when applied to wastes containing nanoscale materials -- meet the statutory standard of substantially reducing the underlying hazardous constituents in the waste so as to minimize any risk it poses to human health and the environment.[34]

EPA may also wish to assure that facilities that treat, store, or dispose of nanoscale waste materials have adequate plans in place for closure and post-closure activities. To the extent that nanoscale materials exhibit unexpected or qualitatively different properties in groundwater, soils, or waste waters, current standards for corrective action may also need to expressly account for these factors when selecting an appropriate response action. For example, to the extent that EPA or delegated states rely on conservative default values to select a response action threshold, those default values will almost certainly not include any adjustments for potentially different risks posed by nanomaterials.

Several aspects of nanomaterial management remain relatively unexplored. We are unaware, for example, of tests on the efficacy of incineration or combustion as a control strategy for nanoscale versions of either hazardous constituents or wastes typically handled in incinerators, boilers, or industrial furnaces. While we do not know of any anticipated chemical

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33 42 U.S.C. § 6924(o) (minimum technological requirements).

34 While some treatment methods will likely address any likely novel characteristics of nanoscale materials within their waste code (*e.g.*, thermal retorting for solid wastes containing nanoscale metals), other technologies that rely on fixation or chemical bonding may need review.

aspect of these nanomaterials that would affect the suitability of combustion or other control strategies, EPA may wish to monitor or sponsor research on these issues.[35]

VI. DELEGATED STATE WASTE PROGRAMS MAY ALSO SET OUT THEIR OWN MANAGEMENT REQUIREMENTS FOR NANOMATERIAL WASTES, BUT NONE HAVE YET DONE SO

Pursuant to RCRA's provisions that allow states to assume primary responsibility to administer their own hazardous waste programs that are at least as stringent as federal requirements, EPA has delegated authority to 45 states to implement their own hazardous waste programs. To our knowledge, none of these state programs have any regulations, guidances, or policies that expressly address any special risks posed by solid or hazardous wastes that contain nanomaterials. While several states are investigating nanomaterials, none of them have announced plans to proceed with any regulatory initiatives at this time.[36]

States, however, also have the ability to impose more stringent hazardous waste management requirements within their delegated programs under certain circumstances.[37] Some states may choose at a future date to regulate nanoscale waste materials expressly under standards that differ from EPA's regulatory framework. For example, some states may wish to designate certain nanoscale wastes as listed hazardous wastes even if EPA has chosen not to impose such a listing. Alternatively, other states may wish to allow the use of nanoscale materials in a dispersive fashion into the environment (for example, as an environmental remediation technology) even if EPA might consider the placement of larger-scale versions of the same material as disposal onto land. If EPA wishes to foster a uniform regulatory policy for the regulation of nanoscale waste materials, it may need to offer guidance or regulations to guide state regulations in a consistent manner.

VII. RCRA REQUIREMENTS SHOULD NOT DISCOURAGE THE ENVIRONMENTALLY BENEFICIAL USE OF NANOMATERIALS

This paper has focused on the ramifications of applying RCRA regulatory standards to the wastes that contain nanomaterials. EPA should note, however, that RCRA may also affect the use of nanotechnology in environmentally beneficial ways. For example, nanomaterials may offer innovative means to treat intractable soil and groundwater

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35 EPA, of course, has already actively and expansively supported research into the environmental uses and aspects of nanomaterials, and some of its research may already encompass these issues.

36 California, for example, might act to regulate nanostructures before EPA. L. Bergeson, *Nanotechnology: Opportunities and Challenges for EPA*, EPA Millennium Lecture Series, Frontiers in Nanotechnology (May 9, 2005).

37 40 C.F.R. § 270.1 *et seq*.

contamination.[38] It is unclear, however, how RCRA regulations will deal with the intentional placement of these nanoscale materials onto land in a manner that arguably constitutes disposal. EPA may need to clarify its policy in regard to these uses through guidance similar to its policies for the application to land of agricultural chemicals or military munitions in their intended use.[39]

At the least, current EPA regulations may need to provide a clear path for TSDFs that wish to use innovative nanotechnology in corrective actions to address groundwater or soil contamination. Other potential nanotechnologies that may apply to RCRA waste management options might include the use of nanoscale filters for groundwater remediation and environmental sensors that use nanomaterials for inexpensive and speedy sample analysis or release detection.

CONCLUSION

We conclude that EPA already has expansive authority under RCRA to regulate discarded wastes that might include nanoscale materials. EPA's current regulations governing the management of hazardous wastes will also likely apply broadly to solid and hazardous wastes containing nanoscale constituents. Despite EPA's sweeping powers to regulate hazardous waste management and its comprehensive regulatory framework, we also identify below several areas of potential interest where EPA may wish to determine whether its current regulations will have unintended consequences when applied to nanoscale waste materials.

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[38] Zhang (2003), *supra* note 4; Gavaskar, A., Tatar, L. and Condit, W, *Cost and Performance Report – Nanoscale Zero-Valent Iron Technologies for Source Remediation*, Presentation to Naval Facilities Engineering Command (Sept. 2005); PARS Environmental, Inc., *In situ Groundwater Treatment Using Nanoiron: A Case Study* (2005).

[39] 40 C.F.R. § 261.2(c)(1)(ii).