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BIOSOLIDS AND OTHER WASTEWATER-DERIVED SOURCES

From 503 to infinity

From disposal to beneficial use—10 years of sustainable biosolids management at the Greater Lawrence Sanitary District

Two-phased anaerobic digestion makes New England debut in Vermont

Beneficial use of brown grease—a green source of petroleum-derived hydrocarbons

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From 503 to infinity

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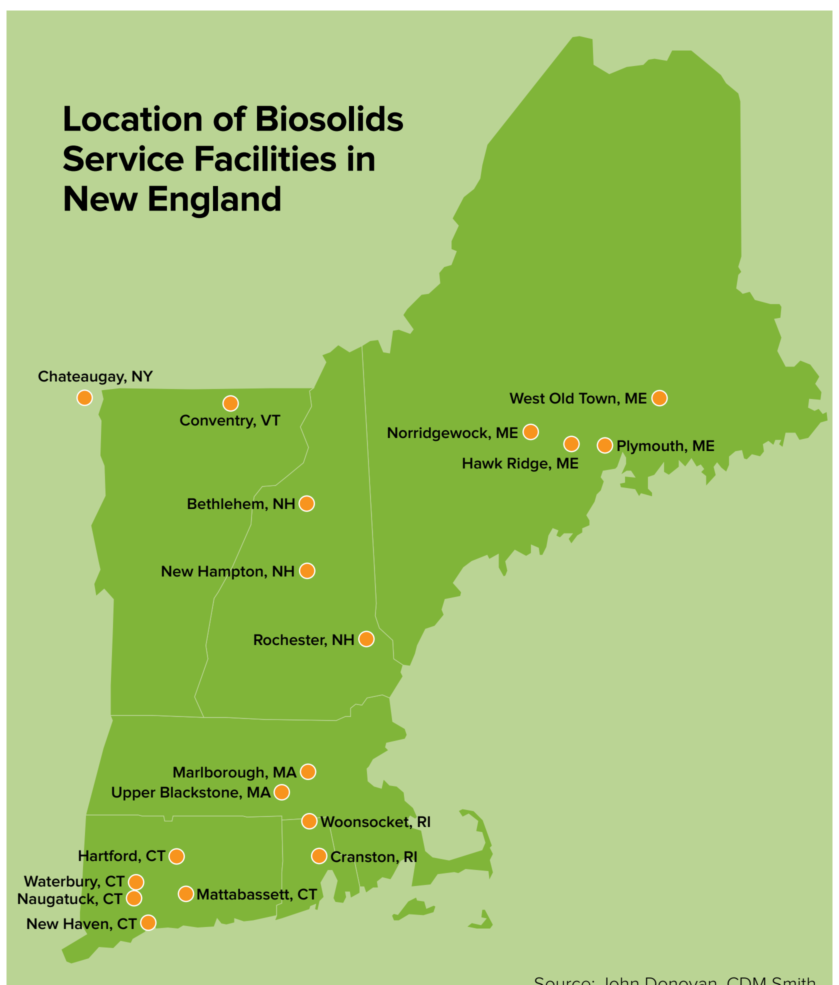
ABSTRACT | The U. S. federal regulations at 40 CFR Part 503 were 20 years old in 2013. This article provides perspective on the history and impacts of the Part 503 rule on biosolids management over the past two decades, from the perspective of three scientists—Dr. Alan Rubin (U. S. EPA, retired), Dr. Rufus Chaney (U. S. Department of Agriculture), and Dr. James Smith (U. S. EPA, retired)—who contributed significantly to its development, as presented at the Northeast Residuals and Biosolids Conference on October 29, 2013. In addition to recounting some history of Part 503, the three scientists provided insights into the future of the rule and biosolids recycling to soils.

KEYWORDS | Biosolids, sewage sludge, wastewater solids, recycling, 40 CRF Part 503, regulation



Source: John Donovan, CDM Smith

Last year was the 20th anniversary of 40 CFR Part 503, the U. S. Environmental Protection Agency (EPA) biosolids rule. This event was marked at last fall's Northeast Residuals and Biosolids Conference, "From 503 to Infinity," co-sponsored by NEWEA and the North East Biosolids and Residuals Association (NEBRA).

Over two decades—and even before it became effective on March 22, 1993—Part 503 has seen controversy. But none of the challenges to the final rule, which have come from all sides, have done more than erode some minor details. Ten years after it became effective, a National Research Council expert peer review concluded, "There is no documented scientific evidence that the Part 503 rule has failed to protect public health," even as it noted that "additional scientific work is needed to reduce persistent uncertainty." Now, after another decade, Part 503 is widely regarded as a robust example of a risk-assessment-based regulation that has created a safe environment in which innovative resource recovery from biosolids can thrive. Despite continued public scrutiny, biosolids utilization has become the norm throughout much of North America, including much of New England. Biosolids products are diversifying and becoming more sophisticated (e.g. see loopforyoursoil.com). They are valued by farms, horticulture, and landscaping. They produce energy. They are tools that solve environmental problems. There are "unprecedented opportunities that now exist and are emerging for the organics, energy, and nutrients in biosolids" (National Biosolids Partnership, WERF, WEF, 2013: "Enabling the Future: Advancing Resource Recovery from Biosolids").

At last fall's conference three scientists—Dr. Alan Rubin, Dr. Rufus Chaney, and Dr. James Smith—central to the development of Part 503 reflected on its history and impacts and the future of biosolids management that it has catalyzed. Drs. Rubin, Chaney, and Smith were a few of the hundreds of scientists who, over decades, have created the body of science and policy that underpins Part 503, especially the standards for use of biosolids on land. However, in their positions in federal agencies, they played central, leading roles in ensuring the best available science was integrated into the regulations.

HISTORY

"In 1987, Congress amended section 405 (of the Clean Water Act) and for the first time set forth a comprehensive program for reducing the potential environmental risks and maximizing the beneficial use of sludge." (Federal Register, 58 FR 9248 | Rules and Regulations | Environmental Protection Agency 40 CFR Parts 257, 403, 503 Standards for Use or Disposal of Sewage Sludge | February 19, 1993). The rule was "to protect public health and the environment from any reasonably anticipated adverse effects of certain pollutants that may be present in sewage sludge."

Alan Rubin, PhD, entered U. S. EPA when the water program was expanding dramatically because of the Clean Water Act. From 1984 until his retirement from EPA in January 2005, he was the lead staff person to the EPA office of science and technology, health and ecological criteria division, in which he led the development of the Part 503 rule and its implementation. His responsibilities included refinement and implementation of multimedia/multi-pathway chemical risk assessments, development of microbial operational standards for the Part 503 rule, and communication of the Part 503 rule and its technical basis to the states and the general public to accelerate the rule's implementation.

Dr. Rubin was passionate about his work—and remains so in retirement. That passion runs to the very core of the science; for example, he once exclaimed excitedly: "The periodic table! It's so elegant, how it all fits together!" When he speaks about the Part 503 rule, his familiarity with every detail is evident. This was his life work. As Andrew Carpenter, president of NEBRA, noted during the conference, "even in contentious meetings, Alan was always eager to engage on this topic."

Alan Rubin: *I'm a boy from Brooklyn, N.Y. I wouldn't know a cow from a stalk of corn. Fortunately we have people like Dr. Chaney here to tell me a little about soil chemistry and soil analysis and risk assessment. And, of course, on the pathogen side, I had very little experience… and that's where we depended heavily on Dr. James Smith and his colleagues in the Cincinnati laboratories (of U. S. EPA)….I thank them for supporting me at (EPA) headquarters. My job was to develop the regulation…. as required under the Clean Water Act.*

In the early '80s, we began to get a sense of the scope of the rule and how it would work. Before Part 503, sewage sludge was something that was going to be regulated under the Resource Conservation and Recovery Act as a nonhazardous solid waste. You could put it on the land under a not-very-sophisticated rule.

My branch (at EPA) that was developing the rule started in 1984. We did the national sewage sludge survey in '89. We had to get a sense of what pollutants were in biosolids, and it didn't take a genius to figure out it depended on what was going into wastewater. From that we picked out 50 of the most probable compounds that we thought we'd find in biosolids, and, more importantly, those that we thought would have the most potential impact on human health and the environment. And then we did the risk assessment.

We put out the proposed rule in 1989; it was controversial. There were things that were wrong and things that were right.… And that's where Dr. Chaney and Dr. Smith and others came in and really helped guide the final development of the 503 rule, which we finally promulgated in 1993.

That initial effort was "Round one"—numerical standards and management practices for pollutants that we knew about. The Clean Water Act says that every two years EPA is supposed to go back and look at additional pollutants. We did a second round and determined that we were not going to regulate dioxins: There was no need to, based on risk assessment. There is now a third round looking at some additional pollutants.

503 for the first time clearly identified actions that must be followed. And it identifies who is responsible: the generator, (i.e. wastewater treatment plants), to the processor, to the transporter, to further treatment (e.g. compost), to the end use. In theory, a gardener… who uses Milorganite is on the hook for complying with Part 503. The rule covers everybody in the train.

QUANTITATIVE RISK ASSESSMENT—TRACE ELEMENTS

Part 503 regulates the use and disposal of sewage sludge (the legal term used by EPA) via landfill disposal, surface disposal, incineration, or application to land. It includes seven elements—general requirements, management practices, monitoring, record-keeping, reporting, and—most important—numeric limits on pollutants (e.g, potentially harmful elements/heavy metals and chemicals) and operational standards (which control pathogens).

Alan Rubin: *The numeric limits are standards based on risk assessment—maximum values of concentrations of elements that can be applied and the maximum pollutant loading rates. This allows for protection of human health and the environment because it is based on multi-pathway risk assessment. Cumulative pollutant loading rate (CPLR) is the gold standard of all the numerical limits…. The one that helped the industry the most were the "clean" numbers—concentrations of pollutants in biosolids that are low enough that if you place it on the land at 10 metric tons per hectare for 100 years, you would not exceed the CPLR. What that means is that if you get down to that clean number, you do not have to keep track of the accumulation on the land. That was the beginning of treating that kind of material (biosolids) as a regular fertilizer, where there are no requirements to track the CPLR. And that was important. The industry fought for that. Originally, at EPA, we were opposed to that, but eventually it made sense to us: If it is clean enough, why penalize biosolids; why not treat it just like regular fertilizer?*

The original risk assessment done for Part 503 used worst-case point values for every pathway. This was unrealistic; you can't pick out one facility from the 10,000 doing land application. So we used probabilistic (Monte Carlo) analysis looking at conditions (e.g. diets) throughout the United States. When you run these analyses, you get a distribution; the 100-percent number is the most stringent; that is not appropriate to use.

We eventually used the 95th percentile. This was a conservative, but realistic, approach. At one time we were toying with worst-case scenarios. Worst case means that every condition you put in the model is the absolute maximum in terms of giving someone a high exposure. It doesn't exist. I call it "the unicorn." There aren't real people like that in the world. So we chose the 95th percentile in establishing the numerical standards.

The numerical standards, along with the operational standards for pathogens, are what define the quality of biosolids. And, when you have biosolids that meet the EQ (exceptional quality—Class A and low metals) numbers, you now have a material that in effect becomes fertilizer. And a lot of the management practices and general requirements go away— it's treated. You've turned it into a material of sufficient value—have taken the time, effort, and expense—that we don't think you are going to abuse it—you're not going to pile the stuff on the land and create problems.

These standards for pollutants in biosolids and soils have been the driver for much of biosolids management research over the past 45 years, including a major part of Dr. Chaney's award-winning professional career.

Rufus Chaney, PhD, is a senior research agronomist in the environmental management and by-product utilization laboratory of the USDA-Agricultural Research Service at Beltsville, Md.

Rufus Chaney: *The original 1989 proposal would have prohibited biosolids use on land. There would have been none, if we hadn't had a peer review process where the industry and the (USDA) W-170 committee of researchers from the land grant schools did a scientific review and pointed out the problems. EPA withdrew the original 503 proposal. Then we corralled James Ryan at EPA and other experts to develop the pathways for risk assessment and the numerical standards. It was a remarkable process; we spent two to three years of our lives working half-time just on the 503 Rule.*

Some of the pathways that they had originally considered were flat wrong: for instance, the most limiting (standards for) copper and zinc and others were based on soluble salt metals added in pot studies, which we had shown in basic research was absolutely irrelevant. Now, 20 years later, data shows how even more wrong that was. We finally got the rule based on field applications of biosolids….

The PCB work was probably the funniest. One of the EPA contractors had found the highest uptake slope they could find for plant uptake of PCBs. Unfortunately, the compound in the paper they were citing was PCNB, which is a fungicide (intentionally applied to) and taken up by plants to make it work! Using that would not have allowed for any PCBs in land-applied biosolids, and all biosolids have some traces of PCBs. Now, the great reduction in uses of PCBs in society has made that a non-issue. But, at the time, when the original rule was proposed, zero PCB would have been allowed in biosolids.

The most important part of the 503 rule—and why you in the profession need to read the (EPA) *Guide to the Risk Assessment*—is to understand the pathways.

The most important part of the 503 rule—and why you in the profession need to read the (EPA) "Guide to the Risk Assessment"—is to understand the pathways. EPA is now using this kind of pathway approach for most compounds in the general environment, because we look at every known exposure—not just to humans but also to livestock and wildlife, soil organisms, and fish and so on, in receiving waters. We took realistic exposures that were, however, excessive—for instance, for the home garden pathway, we assumed that you are going to consume 60 percent of the garden vegetables that you've grown at home. We don't really find that that happens. People don't grow 100 percent of their vegetables. It was an overestimate. For soil ingestion, we used 200 mg/day, which came from Superfund; further research found that the geometric mean of young children's ingestion of soil is about 35 mgd/day for the median and 90 mg/day for the 95th percentile. So there, again, we were using an overestimate to make the rule. The same on the livestock pathways. We've looked at all the pathways—even earthworms living in those soils that are going to be eaten—they may biomagnify a compound, like cadmium or PCBs or DDT, and they are going to be eaten by shrews, which eat a third of their diet as earthworms. So we protected the shrews, as well as the children, as well as people who live and garden (with biosolids) for 70 years.

One of the points that I made (and everybody has since bought) is that in the natural environment elements are controlled by their chemistry and the chemistry of their soils. An example is the soil-plant barrier: Between binding in the soil and keeping in the roots, most elements never get into the edible part of plants. Insolubility and adsorption are so strong—chromium, lead, mercury—are so insoluble they don't enter plants. The next group of elements can have phytotoxicity under some worst-case conditions. But, when you have visible injury from these, such as at least 25-percent yield reduction due to the toxic element being taken up by the plant, (the plant) is still perfectly safe for 100 percent of the diet of livestock. So built-in phytotoxicity protects the rest of the environment. The exceptions to that protection are from soil ingestion: cadmium and selenium possibly for humans, and molybdenum, selenium, and cobalt possibly for ruminant livestock. Eating soil circumvents (the soil-plant barrier), and therefore iron, lead, arsenic, mercury, and fluoride could conceivably pose risk. But not at the levels of 503—the APL does not allow you to get that kind of issue.

(There) are all the different things that are known to bind metals in soil. We knew these back in 1989. They are the reason we never had toxicity in field trials, even though we were applying metals. In comparison, when you add soluble salts to a pot, it takes years before they reach the equilibrium, steady-state concentration. And, in the case of Ni and Zn, we form new compounds… and these elements become less and less available to plants or animals that would eat soil. It helps us understand why soluble salt studies were so wrong and irresponsible when they were used in the original 503 rule proposal.

In the original 503 proposal, PCB would have been allowed at .019 kg/ha. Copper: 46 kg/ha total, which is one application of an average sludge. Obviously, experience does not support that. Eventually, we abandoned that (original Part 503 risk assessment).

I want to point out the success of pretreatment. For example, Pennsylvania data from Rick Stehouwer over the period of 1978 to 2000 shows a remarkable reduction (in metals concentrations in biosolids). This data shows one city sludge I studied: It had 1,000 ppm (parts per million) cadmium. It was sludge given to farmers and gardeners. They eventually had to go back and take the soil from those gardens and do something to help those farms. But now, pretreatment and regulatory enforcement removes any high cadmium sludges, and now the median is 2 mg/kg (ppm)—in 2000. It is even better today. At Madison, Wis., there was cadmium as high as 30 or so (in the mid-1980s), and it's now down to 2 or 3. Zinc came down too. And the number I care about the most, the cadmium to zinc ratio, if it's above 0.015, theoretically, worst case, I could conceivably find somebody with too much cadmium; otherwise, high zinc kills plants, and zinc inhibits absorption of cadmium (in people and animals). In the newest targeted national sewage sludge survey, the cadmium/zinc ratio is well below 1 percent. So we don't have any in that survey that are failing the overwhelmingly protective goal that I provided….

There are some crazy things toxicologists are doing these days.... Some in EPA want to have soil arsenic standards that are lower than the background level of arsenic in soils in the U.S. California is pushing to regulate chromate in biosolids and soils even though there is no evidence that normal soils, and especially biosolids, are reducing environments (that would create the more toxic form of chromium—Cr(VI)). Iron—the only thing we see there is that ruminant livestock eating a large amount of biosolids could be iron poisoned, and we have high iron biosolids from using iron to remove phosphorus. Otherwise iron is a valuable component in biosolids. We have people who want zero emission of mercury from the soil, and so we're going to have some squabbles about that in the future perhaps.

Alan Rubin: The risk assessment was looking at a modeled individual that I don't think exists. That's the way that EPA does risk assessment. It gives confidence that you are being very conservative. The individual modeled is a lifestyle farmer who is never going to leave the land, he'll eat all the food he raises and drink only the water from under the land, slaughter the animals, be exposed to runoff, eat fish from the farm pond, etc. The farmer is based on a combination of data from conditions throughout the U.S.—profiles of climates and soils, very complex. He's exposed for 365 days a year for 70 years. The 95th percentile data used in the risk assessment is for this person! What does that mean for you and me? We essentially have no exposure.

The closest we ever got to an issue in the U.S. was back in the Wild West days before Part 503 when, for example, Chicago was putting out sewage sludge on farmland with 200 ppm cadmium. Even so, I don't think we wound up with any kidney issues from that, which would not be legal now because of Part 503.

Modern biosolids are hard to abuse with respect to metals. They can be abused based on nutrients if over-applied (nitrate in groundwater, as can happen with other fertilizers), or you can make someone sick (because of pathogens) if you put out raw sewage sludge (which is not legal because of Part 503). But the low levels of trace chemicals are not going to cause any issue.

QUANTITATIVE RISK ASSESSMENT—TRACE CHEMICALS

Besides containing elements of potential concern, biosolids also contain synthetic chemicals, including organic chemicals, of potential concern. These were also evaluated as part of the original multi-pathway risk assessment. And, in the second round of evaluation for Part 503 in the 2000s, EPA evaluated dioxins, furans, and co-planar PCBs. Dioxins are some of the most toxic chemical contaminants known, and they are ubiquitous in small amounts in various media. They are, therefore, excellent sentinel chemicals for understanding risks to human health and the environment from traces of persistent organic chemicals found in biosolids.

Alan Rubin: (When it comes to risks from trace chemicals) the question is what level is ecologically or toxicologically relevant? About 80 percent (of a typical biosolids) is water. Contaminants of concern make up just micrograms that could potentially create any issue.

For dioxins, we could not find a significant incremental increase in cancer or non-cancer risk from biosolids. The Office of Management and Budget said "you're not going to regulate this just to feel good." We couldn't show any benefits of regulating dioxin in biosolids, so we didn't. We also looked at PCBs and couldn't find risk there either. I'm confident that the trace organics are just not in biosolids at levels that pose any risk. If anything, we come in greater contact with many of these compounds in using the products that contain them.

Rufus Chaney: The science behind the 503 standards applies also to PPCPs (pharmaceuticals and personal care products). Lipophilic compounds are concentrated in biosolids. Hydrophilic compounds mostly end up in the effluent. Applying the 503 risk assessment to these chemical compounds shows that the most sensitive pathways are likely direct biosolids or soil ingestion. But, if they were soluble, they stay with the effluent, and if they are not, they are bound to the organic matter and biosolids, so they are not taken up. People who have done tests on plant uptake have used artificial test systems that promote maximum plant uptake. The aging of these residues also makes them less available. We don't have any evidence of a problem with these in biosolids.

And direct exposure in other ways is more significant. Colgate Total has 3,000 ppm triclosan; here we go worrying about what is in biosolids and we use soap with 1 percent triclosan. Human exposure from biosolids triclosan is trivial—beyond trivial.

However, POTWs need to know what's in your influent. If you know, then you can know what you need to do to protect the environment. Industrial pretreatment can protect most things. The Decatur, Ala. situation (in which perflourinated compounds (PFCs) were found in high levels in a land-applied biosolids) could have been prevented by industrial pretreatment. PFCs are slow to degrade; they are water soluble—a leaching risk. But they are not a risk to plants and animals. The research about organics applies to PFCs. Decatur is an extraordinary case.

ADDRESSING PATHOGENS AND STABILITY

In addition to potentially harmful levels of elements and chemicals, pathogens in wastewater solids present the other major concern for risk to human health and the environment. It is in this realm—microbiology—that James Smith, PhD, has spent his professional career.

Dr. Smith has worked in the environmental field since 1963 and has more than 140 presentations/ publications in the areas of residuals management, water and wastewater treatment, and hazardous waste management.

Jim Smith: From the earliest times, fecal material has been beneficially used on land, and, perhaps surprisingly, so has the link between human health and what humans ingest, inhale, or come in contact with by some other means. We read in the Bible that people can get sick from drinking some waters and applying fecal material to agricultural land. Thus it suggests that water destined for drinking first either be exposed to the sunlight or boiled. For fecal material to be beneficially used and disease potential reduced, we see in ancient Egyptian records the suggestion that lime be added and in Roman records that composting be utilized.

The early (EPA wastewater) regulations served to keep residuals out of waterways. As far as any kind of sludge/wastewater solids treatment, early 1900s texts simply noted that while stabilization by processes like aerobic or anaerobic digestion might be considered as a way to reduce sludge's odor, they mainly should be looked at as a way to reduce the mass and volume for any further solids processing.

Federal residuals management research earnestly began in the mid 1960s in the EPA Cincinnati laboratory with Bob Dean as chief. He quickly enhanced his staff with individuals like me, Joe Farrell, Ken Dotson, Mary Beth Kirkham, and Jim Ryan. Joe Farrell was concerned with incineration; I was responsible for stabilization research; and Ken Dotson, Mary Beth Kirkham, and Jim Ryan did land application research. Two early reports of the group pulled together what was then known about sludge management and presented information needed for process design. These documents were: "A Study of Sludge Handling and Disposal" (1968) and "Process Design Manual for Sludge Treatment and Disposal (1974)." These reports established the fact that residuals management was something that needed to be considered in planning the design of a wastewater treatment facility, and it was not just an arrow on a flow diagram going nowhere.

In the late 1970s, EPA's offices of solid waste and research and development cooperated in writing regulations for the landfilling of sewage sludge with solid wastes (40 CFR Part 258) and the management of sewage sludge by other means (40 CFR Part 257) including land application. Research work over the years clearly showed that wastewater, and thus sludges, very likely contained pathogenic bacteria, viruses, parasites, nematodes, etc. So it was no surprise that the 40 CFR Part 257 regulation contained requirements for control of pathogens and vectors; it was the origin of requiring the use of a process to significantly reduce pathogens (PSRP) or a process to further reduce pathogens (PFRP). The intent of the PSRP processes like aerobic digestion, anaerobic digestion, and lime stabilization was to reduce the pathogenic organisms like viruses, helminth ova, and Salmonella by one log and indicator organisms like fecal coliforms by 2 logs. In contrast, the intent of the PFRP processes like pasteurization, heat drying, and composting was to reduce pathogenic organisms to below the detection limits of available analytical processes. Since pathogens are likely to still be present with the employment of PSRP processes, it is essential that time be allowed for land-applied sludge to undergo further pathogen reduction by natural attenuation. Thus public access, crop harvesting, and grazing restrictions are applied.

Between the time the 40 CFR Part 257 and 40 CFR 503 regulations were issued, several activities occurred to bring together national experts and review the state of the art (what was known about the control of pathogens and vectors in sludge) and decide what research work was needed to resolve questions concerning: engineering, health effects due to chemical and microbial contaminants, analytical methodologies, and risk assessment. A 1983 conference in Denver pretty much confirmed the soundness of the approach taken by 40 CFR Part 257.

EPA's health effects laboratory in Cincinnati issued in 1985 a "reference" document on the health effects of the land application of municipal sludge, which discussed the various pathogenic organisms that may be found in sludge, the disinfectant processes available to control them, and their survivability on plants and on and in the soil. Numerous attempts were made in the 1980s and early 1990s to do a quantitative microbial risk assessment. All failed due to a lack of data, particularly with respect to humans and wastewater/sludge. Today, some successful attempts have been made by the British and the Water Environment Research Foundation at doing risk assessments for pathogens like Salmonella. In 1989, EPA's pathogen equivalency committee (PEC) put out the document "Control of Pathogens in Municipal Wastewater Sludge" (the "White House document"), which formally introduced the PEC and discussed how to get approval for using disinfection processes not listed in 40 CFR Part 257.

To get a better understanding of the public health concerns, it is helpful to look at what happens to fecal material from the time wastewater leaves your house and enters a treatment plant. At the plant the wastewater is treated, solids are settled out and given treatment, and the treated solids/biosolids may be land applied. Land application may occur in an area near where people live. What we see, in a situation like this and from a regulatory sense, is the need for some kind of barrier to be put in place. We have to ask the question, what can be done to prevent the movement of pathogens from fecal material to a human host? The answer is to apply some form of disinfection treatment such as pasteurization, heat drying, or thermophilic digestion. Or, in the case of using a PSRP process, combining the disinfection treatment with access restrictions.

Like Part 257, the Part 503 regulations contain the PSRP and PFRP disinfection processes. The public access and harvesting restrictions were only slightly changed.

Vector attraction reduction (VAR) was always viewed as a necessity. The methodologies for achieving it (reducing volatile solids, reducing oxygen uptake, desiccation, and employing injection or incorporation to place a barrier between the treated material and people) were initially more or less included in the PSRP and PFRP process descriptions. However, the options available for VAR implementation were not clearly identified and spelled out in regulatory language until 40 CFR Part 503 was adopted. This 1993 rule added alternatives for achieving disinfection and divided all the alternatives into Class A or Class B; separated out from the PSRP and PFRP descriptions the parts dealing with vector attractiveness; and established acceptable levels of pathogenic and/or indicator organisms for treated sludge intended for beneficial use (biosolids).

We, EPA, are often asked where we got the PSRP and PFRP processes and their definitions from (how they are supposed to work). I will now endeavor to answer that question with the kind of thinking we were doing in the 1970s. Aerobic digestion was best described by Jaworski as recorded in the Water Pollution Control Federation (WPCF) 1977 "Manual of Practice." Later work by Jewell and Kabrick at Cornell and Matsch and Drnevich at Union Carbide helped to formulate the best way to operate a thermophilic aerobic digestion process. Again we turned to the WPCF 1977 manual to come up with the best way to operate an anaerobic digester. This approach was confirmed by the work of Fair and Moore and by EPA (Farrell and Stern) research findings. Both methods of digestion had no difficulty in achieving a 38 percent reduction in volatile solids, and so that is what was expected. How to do lime stabilization of sludge was based on EPA's research work in the Cincinnati laboratory, at the Lebanon pilot plant, and in contract work with Burgess and Niple. Liquid sludge was treated with calcium hydroxide to produce a pH of 12 for up to two hours after the lime is added. This treatment gave a 1 log reduction of Salmonella, a 2 log reduction of fecal coliforms, and a 1 log reduction of viruses. The process was not effective in eliminating Helminth ova. The approach to air drying came out of work in Chicago by Baxter and some work by Joe Farrell in Cincinnati.

The PFRPs, which appeared in the 1979 regulations, addressed pasteurization, composting, heat drying, and thermophilic digestion. Pasteurization—heating the sludge to 70°C (158 F°) for 30 minutes—is based on research by Roediger in Germany and work by EPA's Laboratory in Cincinnati (Ward and Brandon). Requirements for within-vessel and windrow composting processes are largely the work of researchers at USDA's Beltsville research laboratory (Willson, Epstein, Parr, Horvath, Burge, etc.) in the 1970s. Some information was also gained from the composting efforts in Los Angeles.

A proper description for heat drying was easy to come by because of the work of Milwaukee, which had begun making heat dried solids in the 1920s. They had lots of performance data with their rotary kiln system. Samples of their product showed it to be largely sterile.

An area that has not had as much progress as we would like is that of developing improved analytical methods for the microorganisms in sludges and which are cited in the regulations. While we now do have much better methods for fecal coliforms and Salmonella, we still have some distance to go in getting them for enteric viruses and Helminth ova. In performing our analyses we can follow the lead of other countries like Canada and Australia and look at (analyze) larger quantities of sludge mass and thus improve upon a method's sensitivity. Obviously, this approach requires greater labor.

Alan Rubin: *We had a list—not that many—of approved technologies, and people asking if they could demonstrate meeting the performance standards with variations or with new technologies. EPA said, yes, they could, and the pathogen equivalency committee (PEC) was formed, and it's still active. It probably did more than anything else to free up the profession to go out and be innovative and create and hopefully save some money and land apply with a much greater degree of flexibility.*

MANAGING NUTRIENTS

Alan Rubin: *The only nutrient that Part 503 mentions is nitrogen (N). You must meet agronomic requirements of the crop and no more, to avoid nitrate leaching. Guidance documents provide support on making these calculations. There's not a requirement for maintaining soil pH.*

Phosphorus (P) is not included. But, today, phosphorus is often the limiting nutrient, and states—not EPA—are requiring nutrient management plans that focus on phosphorus. The phosphorus index and other requirements are coming for manure and biosolids both. It is unlikely there will be a federal rule controlling P in biosolids or animal manures. When we did the 503 rule—we knew we could prevent nitrogen leaching by using the agronomic rate—it was quantitative. But we did not know how to do that with phosphorus, because it is so site specific. Phosphorus is being regulated through nutrient management. Manure contains the most soluble form of phosphorus; biosolids much less so. But biosolids appliers are having to slow down application rates (in some states).

Rufus Chaney: *In some states, if you have a very high test of phosphorus, you can't apply. But what counts is not the amount you apply, but the amount that is soluble after you apply it…. We should regulate based on the water-soluble phosphorus. Most states are not yet doing that.*

(We asked the question): Is that non-available phosphorus available to plants? We did some experiments on 20- to 25-year plots, growing wheat. Total phosphorus measured up to 5,600 ppm in the soil. The water extractable phosphorus is down in the level of regulations. Is it plant available? The plants show comparably good growth. Because the plant roots change the environment around them, they can get all the phosphorus they want, even if it's bound to iron or aluminum.

TODAY

Alan Rubin: *The rule is self-implementing. EPA, even back then, when we were rich, didn't have enough people in the regions to go around and look at every site. So the rule was written to be self-implementing. So that means—don't expect to see EPA out here to check on you; but you have the responsibility to read the rule, understand it, and follow it. If you ever mess up… you're under regulatory and enforcement liability and maybe legal liability.*


Land application
Essex Junction, Vt

Part 503 is a base rule, which means that if you follow 503, no matter where you are, you will be protective of public health and the environment. For other reasons, states have become more stringent. Why? Sometimes they have a set of pollutants they're obsessing with, sometimes there's political pressure to put more in there, some want greater setbacks. EPA applied limited management practices—how you place it on the land; you can't place it on floodplain or on snow;… you can't put it within 10 meters (33-ft) of U.S. waters.

That's all okay—under federal standards, what the U. S. does not do is reserved to the states, and they have the ability to make something as stringent as they like. EPA has tried to have states take on responsibility for Part 503 through delegation. Several states have been given the authority to administer Part 503 as well as their own rules—delegation.

We originally had chromium (in the Part 503 rule), but it should never have been there. Fortunately biosolids is a great reducing medium; any hexavalent chromium that's originally present eventually winds up as trivalent chromium, which is relatively non-toxic. For molybdenum, we probably over-reached; the last number we had was 18 ppm. We withdrew all but the maximum

number, which is 75. EPA is on the hook to revise these numbers.

Land application of sewage sludge was fairly safe to begin with, but Part 503 has made it safer.... You're home free with respect to potential impact on public health and the environment.

As Dr. Rubin recounts Part 503 history, he emphasizes that how to manage wastewater solids is the choice of the local water resource recovery facility and the community it serves. *What this means has nothing to do with the receiving community: It does not apply to the host site where you are bringing the biosolids. This choice of use or disposal is for the generator only. Citizens cannot use this clause to stop a land application program.*

LOOKING FORWARD…

Drs. Rubin, Chaney, and Smith suggested the following on what they expect may happen with the rule and biosolids management in the coming years.

- Elimination of pathogen reduction Alternative 3 for Class A—testing for pathogens. Jim Smith: *If anyone asks my or the PEC's or some states' opinion, there would be no Class A Alternative 3 or 4. Why? What sense does it make to hunt for enteric virus or Helminth ova when you're unlikely to find any (in today's wastewater and solids)? It's Class A on arrival at the plant. That's the dilemma. If you're really concerned about public health, everything needs to be treated by a demonstrated process. Looking at Class B, it has a similar dilemma. I can't tell you how many sludges we have coming in that have less than 2 million fecal coliform. So they are Class B on arrival. Everything we have should be treated in some way.*
- Elimination of Alternative 4 for Class A—the one-time testing option. Dr. Smith makes the same argument about this as for Alternative 3. However, Dr. Rubin notes: *I don't know how else you deal with a pile of material that you want to manage unless you can test it for pathogens. Not sure I would take that out.*
- Adoption of a numerical standard for molybdenum. Alan Rubin: Forty *(ppm) is the recommended molybdenum number for concentration and cumulative loading rate (based on research); it is still not official.*
- Odor as an aesthetic and human health impact: Alan Rubin: *This is the only issue that can stop this industry.... EPA can't set an odor or aesthetic standard.... (Some states are trying to.) Public acceptance goes along with odors—the only thing that can stop you is enraging the citizenry out there.* Rufus Chaney: *Compost (or further stabilize in some other way), incorporate, or inject the biosolids (to avoid odor impacts).*

Rufus Chaney: *A problem I still point out: We used to have bad sludges that were given to farmers and gardeners. City 13 (one of the cities in one study) was pushing 100 ppm Cd. I went to biosolids fields, some were acid—5.7, some limed to 6.4. We grew crops and got cadmium concentrations in the plants grown on the acid soils of 70 ppm, compared to 0.5 ppm in the control. We really need to do something on these lands. There aren't many of these in the northeastern states, but Pennsylvania has a lot. I think we ought to do something. But I don't have any power to make it happen.*

Despite considerations of what *could* be addressed in changes and follow-up actions regarding the Part 503 rule, Dr. Rubin and others noted that EPA priorities and funding were unlikely to support many—if any—changes in the near future. The EPA office of water is completing the multi-year evaluation of nine elements, nutrients, and organic compounds as part of the required biennial evaluation of additional pollutants. This evaluation is being reviewed by a USDA committee.

Alan Rubin: *The reason round two (the dioxin risk assessment) was completed was because we had lawsuits. Today, there is no more pressure. The golden age of biosolids—where they gave us the resources—is gone, maybe forever. Add to that the new political climate. The agencies are trying to keep programs alive that they know are important, such as climate change. The good news on biosolids: it is now considered a "mature program..." which means, "We're outta here. We're outta here on enforcement, we're outta here on compliance... But don't screw up!"*

I would be surprised to see any changes in 503—even knowing these nine pollutants of round three are out there—it will be a very long time before we see any rule change. And they may find with those nine pollutants that it is not worth regulating them. In this required evaluation of new pollutants every two years, we see we don't have enough information to do the risk assessment.

Dr. Chaney says that for the current list of pollutants being evaluated, they shouldn't be wasting money on even looking at them. They do not present a risk. *However, EPA never did anything about iron, which could be a risk, when iron-rich biosolids are surface applied and ruminants directly ingest it. There are sludges with up to 14 percent iron.*

Surface application of biosolids remains a concern of Dr. Chaney. *Surface application of biosolids is a threat to the industry. The British government decided to prohibit surface application.*

Dr. Smith notes that there continue to be many developments in the science of pathogen reduction and stabilization:

- *I'm sure you've been monitoring work done at Bucknell by Matt Higgins and others, indicating that if you anaerobically digest the sludge and high-speed centrifuge it, you may have problems with what appears to be inadequate kill of fecal coliforms.*
- *Work by Sudhir Murthy and others—limited work—suggests we may need to do more than 70°C (158°F) for 30 minutes for lime stabilization. Mark Meckes and others in Cincinnati have also done work on this, and the jury's out.*
- *We've had problems with thermophilic AD because engineers and operators like to operate them continuously. The microbiologists go crazy with continuous systems because you're taking something out and then adding in something that hasn't been there very long. They want to see a batch system.*
- *We've done work on quantitative microbial risk assessment with WERF. We'd like to bring these methodologies together with (the EPA) office of water. You could certainly finish up the Helminth ova pretty fast. We've been doing some work on extraction of viruses from sludge.*
- *What about "emerging" pathogens? Work by Suresh Pillai and Mark Meckes and Chicago has been looking at what is in raw sludge in terms of indicators and pathogens. Work that Pat Millner and I have done concluded that our present PFRP Class A treatment methods are adequate to eliminate all of the newly identified emerging pathogens.*

We have to demonstrate that we're achieving pathogen reduction. And what is stability? Have we done the best job we can? What can we do to make sure there is no odor?

We have the information we need to do a risk assessment for Salmonella and enteric viruses. The difficulty is getting EPA to do that. We did it with WERF successfully; we had EPA office of water (Rick Stevens) participating and people from the environmental assessment staff in Cincinnati.... For a long time, we've had our parasitologist in Cincinnati and others in agreement on methodology. What's needed is for the EPA Office of Water to follow up on this work. Virus risk assessment is farther away. We've done work on extraction of virus from sludge. Pretty good agreement on methodology. May need to do more DNA work on that.

It's important to note that, even as we look more and are able to detect more, it doesn't change the risk. The risk stays the same. The organisms are there and have been there.

Is 503 protective with regards to pathogens? Absolutely. And that came out of a workshop that we had (BioCycle published the findings of that workshop).

TO INFINITY…

Today, 20 years after Part 503, biosolids have become widely accepted tools in agriculture, turfgrass production, landscaping, horticulture, gardening, forestry, and land reclamation. By creating standards for making safe products, Part 503 has allowed for increasingly innovative and helpful uses of biosolids. Reclamation of damaged sites and disturbed soils may be the most environmentally significant way in which biosolids and other organic residuals are used today.

Rufus Chaney: *It's not that we have things about biosolids that we have to fix; we now have biosolids that can fix societal problems. We all know the benefits of growing with biosolids: improve the fertility and organic matter and soil microbes and you get better crops. And when it goes into a period of drought, the control field will wilt and the sludge-treated field will thrive.*

I took that knowledge and worked with EPA at Superfund sites. Since 1989, we have known that we can use combinations of iron and phosphate to bind metals and form lead pyromorphite, which ends up making lead not bioavailable to organisms that eat the soil or plants (grown on the soil).

So, with today's biosolids, if we have mine waste that is pH 2.5, we have to add enough limestone to bring it up to a reasonable pH. And then I prefer to use biosolids or biosolids compost. I've done this in numerous locations in the western U.S. We've even shown that there is leaching of limestone equivalence down into the soil in a way that doesn't happen if you just apply calcium carbonate without applying organic matter. Lots of these mine wastes have been so toxic that there has been no microbial population (before reclamation happened). We can do this one shot, tailor-made biosolids or compost mixture in remediation..... Use the biosolids to solve the toxicity.

For example, look at Palmerton, Pa. We studied it starting in 1979. Just before the smelter closed, the 800-acre (324-hectare) parcel adjacent, owned by the company, was dead. Logs that had fallen 30 years before were not degrading, because there were no organisms *in the soil. A colleague from the NRCS worked out a mixture of fly ash, limestone and digested sludge and seeded it with somewhat metal-tolerant little bluestem and lespedeza. There was a dramatic difference between the biosolids-treated and untreated areas which persists over 20 years later..*

A picture showing the re-vegetated site is charming (a barren area bordering lush green new vegetation on the remediated site). That barren area is the Appalachian trail. They (the land reclamation project) weren't allowed to apply biosolids within 100 yards (91.5 meters) of the trail. So we have a perfect control—the barren land along the trail!

Actually, those kinds of (barren) sites are getting worse, because naturally acidic rainfall is acidifying the part that wasn't killed; higher zinc uptake results and the number of seedlings declines. Palmerton was built around the smelters: Some of the soils had 1.5-percent zinc. (There was) 160 ppm cadmium in the typical vegetable garden in the area. People gardened all kinds of crops, using manure and limestone. It shows how contaminated they were, yet with compost addition they were okay. Soil amendment alkalinity and organic matter knocked the cadmium bioavailability down.

The goal of this kind of reclamation project is to raise the pH and increase metal adsorption. Higher iron and phosphate in biosolids or manures is critical. Leaf compost doesn't do as well, because it doesn't have these. We want to increase metal sorption. In the long term, remediated soils must support legumes. By giving organic nitrogen to get it started, and making it so diverse vegetation can grow on the treated soil, we end up with legumes maintaining the diverse plant cover (by fixing nitrogen). With biosolids compost, (we found that) pH change reached a depth of a meter; without it, the deep acidity restricts rooting depth.

At Belvidere Mountain, Vt., (there is a) potential Superfund site, where asbestos mining wastes were piled up. There are 300 acres (121.4 hectares) of serpentinite rock tailings that they washed and blew the asbestos out of. Wind and water erosion were very significant. EPA took emergency action to stop the water erosion. To an agronomist, we know that it will take centuries for this to grow anything. It hasn't happened since 1950. Serpentinite rock is magnesium silicate, so it's severally deficient in phosphorus and calcium. It also contains 2,000 ppm nickel and about that much chromium, but its pH is 8, so none of that is toxic; it's just intensely infertile. We tested different plants, we used compost, and fertilizers. We made a mixture of gypsum (because we need calcium), limestone (to prevent it from becoming acidified in the surface-applied layer), and manure-yard debris compost manufactured nearby. We installed replicated plots. The second year into the study, in 2011, showed diverse grasses and legume with roots going down nine inches. Calcium was migrating down (into the soil) too. The rooting zone and fertility were right for this part of Vermont, and the plants thrived. We had left over compost and gypsum, so we applied it to a steep slope. (That slope) still has highly effective vegetative cover and no movement, even with rainfalls they have in northern Vermont.

What's the logic? First, we did the agronomic evaluation of the soil. We knew what we had to address calcium, phosphorus, infertility, nitrogen, potassium, and even boron. We did greenhouse tests to demonstrate to EPA that it would work. And then we installed test plots at the site. The reason we applied the limestone is that, over time, legume growth generates acidity. You don't want the surface to become acid. It may not have mattered, but the limestone was some insurance. I put in gypsum (fluidized bed gypsum). This site was unusual in needing calcium to achieve revitalization..

CONCLUSIONS

Rufus Chaney: *I'd like to stress that 503 is a highly defensible rule. The pathways, the highly exposed individual basis for it, and this incredible "worst case" loading of 1,000 tons per hectare (406 tons per acre).... We couldn't say 200 tons per hectare (81 tons per acre). We had to be very conservative. That's what you have to do with a regulation like this. But, on the other side, we put in 1,000; that's a big number. We can hardly get there. You're talking about hundreds of years. So even if we have something wrong, we have 100, 200, 300 years at fertilizer application rates to figure it out. We felt we were being overwhelmingly protective.*

The more we look at phytotoxicity, and the experience around the country, we almost have never had toxicity problems after we had 503.

If we look long enough, we may find something of potential danger. But I don't know of anything yet. Lot of money being spent, lot of philosophically important things to ask, but I don't see any great risk. EPA is focusing on arsenic below background levels. I've been working on arsenic in rice. In normal soils, you can't have rice grown that doesn't have arsenic in it. Do you stop eating rice? Or do you decide that it was never toxic at these levels in native soil and rice in the first place?

503 works because it is based on a quantitative risk assessment. The soil-plant barrier is real. Phytoavailability was measured for field-applied biosolids to give the correct constants for determining regulations. We have found important ways to use biosolids for remediation and other important environmental problems that society faces. And I think we can be proud that biosolids does this. You can solve problems using biosolids and limestone and whatever other amendments are needed. Consider the value....not only were biosolids not a problem, they fixed a problem. One million dollars an acre (0.4 hectare) to carry away a polluted soil versus a few thousand dollars to apply biosolids—seems like a pretty obvious choice....

After all those painful years of fighting with Alan (Rubin) in 1989 to 1993 with a team of highly respected biosolids and agronomy scientists... I think we did the right thing. It provides the tools that states need, that regulators need, and that users need.

Jim Smith: The bottom line seems to rest on public acceptance. They need to understand what's being done for pathogen reduction, what's being done for stabilization. And we have to have a low odor potential in our products! Maybe something like north of the border; in Quebec, they have an odor scale.... If you have odors, you know that can kill a program. In the U.K., they have eliminated surface application.

The take-home message: Keep the public satisfied, happy. Not a technical issue. We can't put something out that stinks or attracts vectors. We have to have high-quality products that look nice.

POSTSCRIPT

In New England, many biosolids management programs have been routine for years. Some have shifted from disposal to beneficial use or vice-versa. Many wastewater solids are managed by private contractors. John Donovan (CDM Smith) presented an overview of current biosolids management in New England at the NEWEA spring conference in June, reviewing the current "network" of biosolids management facilities around the region. He suggests that likely changes in New England biosolids management in this region in the next decade will be improvements in Class A biosolids processes and products. "But there is no silver bullet technology," Donovan noted.

Resource recovery will continue to be a focus—with more digestion and co-digestion with food waste and other organic residuals and improved fertilizer products. Meanwhile, Class B land application is likely to continue its decline. Many New England wastewater facilities will continue to have their solids processed by "the network," while MWRA and some northern New England facilities continue to manage their own solids via in-house or contracted recycling programs. "Biosolids management decisions are still based on costs, not sustainability," Donovan says. But with more private-public partnerships, there continues to be more flexibility in how the costs are allocated.

Where wastewater solids management is today is due to the foundation laid by the Part 503 Rule. The 20th anniversary of that rule has refreshed memories about the extensive research and history behind it and a chance to honor those who were instrumental in its creation, including Drs. Rubin, Chaney, and Smith.

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- Dr. Alan Rubin received four EPA Bronze Medals, including two for his work on the Part 503 rule. He has been a presenter at many state, regional, national, and international conferences and meetings on biosolids. Prior to 1984 at EPA, Dr. Rubin worked on the development of the Clean Water Act Section 307 ambient water quality criteria, water quality standards, and regulations for the incineration of chemical wastes at sea.
- Dr. Rufus Chaney conducts research on the fate, food-chain transfer, and potential effects of soil microelements at the USDA—Agricultural Research Service at Beltsville, Md. Since beginning his career in 1969, Dr. Chaney has 450 published papers (300 peer reviewed) and 285 published abstracts on related topics.
- Dr. James Smith's career has included managing a research laboratory in the investigation of improved methods for wastewater solids disinfection, stabilization and dewatering; chairing EPA's pathogen equivalency committee; and working for the World Health Organization's division of environmental health in Geneva, Switzerland, where he directed marine and fresh water quality, drinking water and wastewater treatment studies.

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Ned Beecher is executive director of NEBRA, tracking research, legislation, and regulations and providing information to members and the public. He edits and contributes to NEBRA's email newsletter, NEBRAMail, and NEBRA Highlights in the *NEWEA Journal*, and has been the lead author on various biosolids documents.