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Features

A CRITICAL REVIEW OF THE U.S. EPA'S RISK ASSESSMENT FOR THE LAND APPLICATION OF SEWAGE SLUDGE

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ABSTRACT

Sewage sludge is a complex mixture of inorganic and organic materials and pathogens generated by the treatment of domestic sewage. Section 40 of the Code of Federal Regulations Part 503 regulates the land application of sewage sludge based on pathogen content and sets standards for nine inorganic chemicals. It is believed that the Part 503 standards are protective of human health and the environment and that sewage sludge applied to land poses little risk. A critical inspection of the pertinent literature, however, reveals that the standards were based on outdated methods, outdated data, inaccurate data, and flawed assumptions, leading to underestimation of risk. The standards are not sufficiently protective, and even if changes were made, sewage sludge is so complex that it is very unlikely it could be monitored to ensure the protection of human health and the environment. For these reasons, the practice of land application of sewage sludge must be discontinued.

Sewage sludge is defined by the U.S. Environmental Protection Agency (EPA) as the "solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works" [1]. Sewage from homes, industries, medical facilities, agriculture, street runoff, and businesses is collected at wastewater treatment facilities where it undergoes treatment processes to remove contaminants. Sewage sludge is the byproduct generated by the processes that remove contaminants from the wastewater so that the treated wastewater can be

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discharged back into waterways. Sludge is generated mainly during primary treatment, where solids settle out, and also during secondary treatment, where microorganisms are added to degrade the biological content of the sewage and the solids settle out. Further treatment can also generate sludge [1].

Many of the contaminants that were in the wastewater concentrate in the sludge, resulting in a mixture with an unknown composition of inorganic and organic materials and human pathogens [1]. Sludge itself can be treated by a variety of processes including aerobic digestion, anaerobic digestion, composting, heat drying, air drying, lime stabilization, and chemical fixation. Sewage sludge that has undergone treatment and meets federal and state standards for land application is called biosolids by EPA. Treated sludge can be applied to land—such as agricultural land, forests, parks and gardens, and home gardens and lawns. Sludge that is untreated or not treated enough to meet land application standards can be disposed of in landfills or incinerated [1-3].

The EPA and other agencies have widely promoted the use of sewage sludge for land application as a safe, beneficial, and economical way to recycle the massive amounts of sludge generated. They claim it is a fertilizer that contains beneficial plant nutrients and has other soil-conditioning properties [2, 3]. Approximately 5.6 million tons of dry sewage sludge are used or disposed of annually in the United States, of which 60 percent is used for land application or public distribution [1]. There are federal standards governing the use and disposal of all sewage sludge in Section 40 of the Code of Federal Regulations Part 503. The land application of sewage sludge has been a hotly debated topic since its inception. The EPA maintains that the standards for land application of sewage sludge are protective of human health and the environment [3]. Numerous reviews of the risk assessment used to establish the standards, however, have found serious flaws with the way EPA conducted the risk assessment. These reports critically assessed the methods used in the risk assessment, the data used, and current scientific data on sewage sludge to determine if the standards were adequate. The review presented here examined these papers and other current literature to determine if there was significant evidence to support the concern over the land application of sewage sludge and found that the literature clearly demonstrates that the current policies and regulations do not adequately protect human health and the environment. Based on the available data, the application of sewage sludge to land must be stopped because the current standards are based on inaccurate and outdated science. If the practice of land application is not stopped, the consequences to humans and the environment will be severe and long-lasting.

HISTORY AND CURRENT STANDARDS

Human excreta have been applied as fertilizer for hundreds of years, and this practice was generally safe because the excreta did not contain industrial waste. As populations grew, the old methods used to remove waste became inadequate and resulted in numerous disease outbreaks. Sewers were invented to deal with the problem by removing the wastewater from the city and town centers. Domestic and industrial sewage was dumped into waterways until they became so polluted that a new method was needed to deal with waste.

Wastewater treatment became the new technique to deal with the problem and with wastewater treatment came sewage sludge. The passage of the Clean Water Act in 1972 more than doubled the amount of sludge generated as the treatment processes that create it became mandatory and all water had to be treated. The use of sludge for land application became widespread with the 1988 Ocean Dumping Ban, which eliminated dumping of sludge in the ocean and forced EPA to invest in land application. In 1990 the term "biosolids" was coined for sewage sludge that was treated and acceptable for land application in order to increase its appeal. Biosolids were classified as a fertilizer, and EPA pushed this use [4, 5].

In 1993 the Part 503 standards established pollution limits, operational standards, and management practices to "protect public health and the environment from any reasonably anticipated adverse effects from chemical pollutants and pathogenic organisms" in sewage sludge [1]. Minimum standards regarding ceiling concentration (mg/kg), pollutant concentration (mg/kg), cumulative pollutant loading rate limits (kg/ha), and annual pollutant loading rate (kg/ha/yr) for contaminants in sludge were established that had to be met for the sludge to be approved for land application. Originally 10 inorganic chemicals were regulated: arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Chromium was dropped in 1995 and molybdenum has only a ceiling concentration [1]. Since sewage sludge can contain bacteria, viruses, protozoa, parasites, and other microorganisms, Part 503 mandates that sewage sludge undergo specific treatment processes to reduce pathogens before it can be applied to land. Based on the treatment processes and the amount of pathogens still present, treated sludge can be classified as Class A or B biosolids. Class A biosolids are treated to reduce pathogens to below detectable levels and can be used without any application restrictions. Class B biosolids are also treated to reduce pathogens, but pathogens remain at measurable levels, so there are restrictions regarding the application of Class B biosolids and the use of the land receiving the biosolids to minimize human contact until natural processes can further reduce pathogen content [3].

Using available data on chemicals and data from the 1988 National Sewage Sludge Survey (NSSS), EPA conducted an extensive risk assessment to establish the Part 503 standards. To support the safety of land application of sludge, proponents often quote a 1996 National Research Council (NRC) report that reviewed the use of wastewater and biosolids for agricultural purposes: the use of biosolids "presents negligible risks to the consumer, to crop production, and to the environment . . . existing regulation and guidelines governing the use of reclaimed wastewater and sludge in crop production are adequate to protect human health and the environment" [1]. What proponents fail to mention is that the report also highlighted limitations and inconsistencies in the risk assessment approach and NSSS data used by EPA and made recommendations for further research [1, 6].

In fact, EPA did not follow through on any of the recommendations and made no changes to the standards. A 2002 National Research Council (NRC) report re-evaluated the standards and again focused on the inconsistencies and problems identified earlier, as well as on EPA's failure to make any adjustments [1]. The 2002 report found "no substantial reassessment has been done to determine whether the chemical or pathogen standards promulgated in 1993 are supported by current scientific data and risk-assessment methods" [1]. It is because of the inconsistencies, flawed methods, and outdated data used to create the Part 503 standards documented in the NRC reports and other reviews that strongly support the end to the land application of sewage sludge. There are fundamental errors in the science on which the standards are based because of inaccurate and outdated data, outdated methods, and questionable assumptions. Part 503 cannot be counted on to be truly protective of human health and the environment.

Inaccurate Data

A major problem with Part 503 is the way in which EPA determined which chemicals to regulate. Two rounds of hazard assessment and chemical selection were conducted. Round 1 identified an initial set of pollutants using hazard screening and risk assessment. Using information from studies from 1984, 200 potential chemicals of concern were initially identified, of which 50 were chosen for evaluation. These were further screened by data on toxicity, occurrence, fate, and pathway-specific hazards, and 22 chemicals were selected for potential regulation. Based on available data, a hazard index was calculated for each chemical via each of the 14 exposure pathways decided on by EPA to determine if a full risk assessment was needed for the chemical via the most limiting exposure pathway. Background exposure was eliminated from the assessment, and if the hazard index was greater than 1.0, a full risk assessment was done for the specific pathway [1]. Not including background levels is questionable because there are chemicals, like metals, for which background exposure in soil is high due to geologic properties of the area, so an additional source of exposure to the chemical could potentially elevate one's risk. Including all relevant sources of exposure would have been a better way to generate the hazard index to ensure all possible sources of exposure were assessed and included [1].

In 1988, the NSSS was conducted; it collected information on 400 pollutants from 180 sewage plants throughout the country. The EPA used this information to further screen out chemicals not at concentrations deemed to pose a risk. Chemicals were eliminated if they were banned from use, had restricted use, were no longer manufactured in the United States, had a detection frequency of less than 5 percent in the NSSS, and/or the concentrations reported in the NSSS were so low that the estimated annual amount applied to cropland would fall below the standard annual pollution loading rate [1]. For example, even if the chemical was detected in more than 5 percent of the samples, it was not considered for further evaluation if it was no longer being manufactured.

The result of this first round of selection was regulation of 10 inorganic contaminants, and because of the criteria, all organic chemicals under consideration for regulation were eliminated. These criteria do not adequately address the adverse health effects of organic chemicals. Ignoring them does not make them or their toxic effects go away. As an example of the impact of these criteria, the selection process eliminated polychlorinated biphenyls (PCBs) because they were no longer used or manufactured, even though they were detected in more than 5 percent of samples and the concentrations would have resulted in an annual pollutant loading rate over allowable risk-based levels [1]. PCBs have not been manufactured in the United States since the 1970s but they continue to contaminate the environment and are found in sludge. Slow to degrade, they are persistent organic pollutants found all over the world and are classified as "probably carcinogenic." PCBs can bioaccumulate in animal fat, making ingestion of animal meat and milk of animals that grazed on sludge-covered land a significant concern [7]. Thus, PCB contamination is still a problem even though they have not been manufactured in almost 30 years. It is a matter of great concern that out of 200 chemicals from one study and 400 found in the NSSS, only 10 were deemed problematic, and all were metals. This is a very limited number of contaminants, and the fact that no organic chemicals were chosen raises serious questions about the validity of the methods EPA used.

A second round of evaluations was done using the 411 pollutants analyzed in the NSSS. This time chemicals were eliminated if they were not detected (254) or were detected in less than 10 percent of samples (69). Chemicals for which there was insufficient data to adequately complete the risk assessment (15) were also dropped from consideration. Of the 31 chemicals left, only dioxins, furans, and coplanar PCBs were evaluated in a risk assessment [1]. In 2003, EPA decided not to regulate these chemicals, believing they posed little risk. Yet dioxins are highly toxic and known to cause cancer and neurologic and immunologic problems. Since approximately 90 percent of dioxins in wastewater are likely to end up in sludge—and according to David Carpenter, director of the Institute for Health and the Environment at the State University of New York at Albany, "sewage sludge is the second greatest source" of exposure to dioxins for the general U.S. population—it is unclear how EPA arrived at this decision [7, 8].

The criteria that were used to eliminate chemicals in the second round of evaluations potentially missed many chemicals of concern. The 2002 NRC report found "no adequate justification for EPA's decision to eliminate from regulation all chemicals detected at less than 5% frequency in the NSSS" [1]. The NSSS reported data on a national level, which may not be representative of sludge in different locations. The contents of sludge are likely to be site-specific, reflecting the homes and industries in the area that are discharging to local wastewater plants. Thus, for a particular type of industry that releases large amounts of certain chemicals, nationwide concentrations and frequencies appear low, but high concentrations in sludge from a specific site would be of a concern for the people receiving the sewage sludge from that treatment plant. Thus eliminating a chemical because it was detected at a low frequency in a national survey could be putting an area that does have high concentrations at risk [7]. Furthermore, eliminating a chemical because there is not enough data to do a risk assessment is irresponsible and not good science. Lack of data is a serious limitation, but "ignorance is not a solution to uncertainty" [7]. The EPA disregarded the chemicals on which there was not a lot of information as though this indicated there was not a problem with these chemicals. Lack of data is not equal to lack of risk. It means there are data gaps that need to be addressed by additional research. There might not have been enough information at the time, but these chemicals should not have been disregarded completely.

The EPA also relied on concentration data in the NSSS in the selection of chemicals to potentially regulate. The accuracy and reliability of the NSSS data have been called into question by two NRC reports [1]. Accurate concentration data is essential in assessing whether a chemical poses a risk. Errors in measurements can lead to over- or underestimation of concentrations, which in turn affect the risk estimates. The methods used by the NSSS were flawed and led to chemicals of concern being eliminated erroneously. Analytical problems and high detection limits prevented accurate measurements of chemicals. Some of the detection limits exceeded several hundred parts per million [1].

Many chemicals in the NSSS had levels of detection that were greater than EPA soil screening levels (SSLs) [1]. SSLs are soil concentrations used to determine if a risk assessment is required at a Superfund site, and they are risk-based conservative assumptions. The 2002 NRC report re-assessed eight organic chemicals and found that five of them had limits of detection higher than their respective SSLs [1, 9]. Thus the NSSS results were "not sensitive enough to detect pollutant concentrations that, if present in soil at a Superfund site, would have triggered a risk assessment" [9]. Hexachlorobenzene, a persistent organic pollutant considered a probable human carcinogen, is an example of a chemical that was eliminated because it was not detected in any of the samples. However, the limits of detection ranged from 5 to 100 mg/kg, while the SSL is 0.1 to 2 mg/kg, depending on the route of exposure [9]. Analysis of recent data on chemicals in sludge showed that the majority of reported hexachlorobenzene levels exceeded the lowest SSL [9]. Thus, the NSSS failed to achieve low enough detection levels to adequately determine if the concentrations present required further action.

The NSSS concentrations were used to calculate the hazard indexes to determine if a full risk assessment for a specific chemical via the most limiting exposure pathway should be done. Even if the hazard index for a chemical was greater than 1, if the chemical was detected infrequently, it was eliminated [1]. Given that the detection limits were so high, it is unclear how many of these chemicals were incorrectly identified as having low frequencies and/or concentrations. If more sensitive detection limits had been used, many more chemicals of concern would have been selected to be evaluated further and possibly regulated. The NSSS data lack credibility, given that the limits of detection were so high that chemicals were missed but would have warranted assessment under different conditions. Every analytical method has a limit of detection, but the goal is to have consistent and low detection limits. One wants to be able to detect the lowest concentration present with the greatest accuracy possible. The fact that NSSS had unreliable data undermines all the standards in Part 503 [1, 7, 9]. How can these standards adequately protect human health and the environment given that chemicals were erroneously eliminated and never assessed because of poor science?

Outdated Exposure Assessment Methods and Flawed Assumptions

After choosing the chemicals to be included in the risk assessment, human exposure to sewage sludge by various exposure routes was assessed to calculate risks. For 14 exposure pathways, the risk associated with each pathway for each contaminant was assessed separately; risks from multiple pathways or from exposure to multiple chemicals were not examined. Current practice is to perform a risk assessment after aggregating all the pathways to which a single individual is likely to be exposed to in order to have the most complete exposure assessment. Part 503 assessed exposure assuming one would be exposed via only one pathway, which is not realistic. This method severely underestimates risks because it is highly unlikely one will be exposed to a chemical in the soil via only one route. It is much more likely that a child playing in the soil will have incidental ingestion of the soil, ingestion of plants that grew in the soil, ingestion of animals that grazed on grass that grew in the soil, and dermal contact with the soil, all contributing to the child's exposure to the chemicals. Exposure to a single pathway might not pose a significant risk but once all the pathways are combined, there could be a very different outcome [1, 7].

The EPA also used limited exposure pathways, assessing inhalation only for sludge applicators, not residents. The EPA also assessed only chronic exposure, but there is a risk of short-term exposure to volatile compounds. Volatile organic compounds were eliminated because EPA believed release occurred during the wastewater processing that produced the sludge. However, when sludge is applied, it can release volatile organic compounds (VOCs) such as sulfur- or nitrogen-containing compounds, acids, aldehydes, and ketones [1, 7]. There was also inadequate assessment of pathogen risk. Movement of pathogens to groundwater was not addressed completely, nor was exposure to pathogens in dust and aerosols after land application of sludge. Exposure to radioactive chemicals was not addressed at all [7].

In generating risk calculations, EPA had to make many assumptions. A number of "untenable assumptions" were made and probably led to underestimation of risk [7]. A very limited risk assessment for groundwater contamination was conducted in Part 503, and contamination of waterways was not adequately assessed. The EPA assumed metals cannot leach into groundwater, but recent data has shown that metals exhibit facilitated transport, by which they attach to organic chemicals and travel to groundwater; metals can also move through flow paths created by worm holes or root channels [7, 10]. Also, the rate of contaminant movement in soil that was calculated was much slower than what actually occurs. The rate was not based on actual field data but on data from a single paper based on test tube motility tests from a single soil type [10]. Contamination of surface and groundwater is an area of great concern. Runoff or leachates from land that received biosolids is a significant source of exposure, and it is likely that important water resources could become contaminated, exposing people to the chemicals in drinking water that originated in sludge [10]. Not considering this exposure severely underestimates risk.

When determining cancer risk resulting from sludge application, EPA decided to use the less restrictive value of 1 in 10,000 as an acceptable level of cancer risk compared to what is used in most other regulations to determine cancer risk and influence regulations, including the drinking water standards, of between 1 in 10,000 and 1 in 1,000,000 [7]. When questioned on why this value was used, the EPA acknowledged it was a less restrictive number and was chosen as a policy decision because the agency considered the overall risk from sewage sludge was "especially low" and the more restrictive value would have an economic impact, and it was "difficult to justify such an expense for little or no actual difference in risk" [11]. For soil ingestion, only ingestion as a child was calculated even though incidental ingestion can occur throughout adulthood, especially for home gardeners [1]. Dietary intake of sewage sludge is a critical pathway, and EPA based its recommendations on dietary intakes from the late 1970s. American diets are very different now with regard to vegetable and fruit consumption, meat intake, and water consumption. Comparing the dietary assumptions EPA used with the current food pyramid guidelines shows that the current dietary recommendations specify 16 times the amount of fruits and vegetables that was assumed in developing the Part 503 standards. This is significant: for example, for cadmium, changing only the dietary assumptions, the standard drops from 39 ppm to 15 ppm [1, 7].

The EPA also assumed that the degradation products of organic chemicals were less toxic than the original chemical, but this is not always the case. Surfactants are a group of chemicals found in sludge, and the degradation products of the surfactant alkyl phenol ethoxylate are significantly more toxic than the original compound. The anaerobic digestion process at treatment plants actually promotes this transformation, resulting in a much more toxic compound in the sludge [10]. Uptake by plants and animals is critical to assessing exposure to and risk from sewage sludge, and EPA used very low plant uptake coefficients and low ingestion rates for grazing animals. Many of the soil uptake coefficients are based on plants grown in greenhouses, but these conditions have been shown not to reflect how metals behave in biosolids [1, 7]. The EPA assumed its uptake coefficients would be applicable to all plants under all soil conditions, but uptake differs greatly across plants and soil conditions, so the numbers used were not highly protective [7]. The EPA also assumed that metals would be bound to the sludge, limiting the uptake by plants, but they did not assess if this was reversible due to soil changes or if continual application of sludge changed these parameters [1].

When doing a standard risk assessment, one accounts for the assumptions made and the uncertainties still present by incorporating safety or uncertainty factors. This was not done by EPA for the Part 503 standards [7]. Taken together, the incomplete exposure assessments and flawed assumptions probably lead to an underestimation of exposure to sewage sludge, indicating that the standards are not adequately protective.

PROBLEMS WITH REGULATED CHEMICALS

There are also problems with the chemicals for which there are standards. Arsenic is regulated in Part 503 as a noncarcinogen. However, arsenic is an established cause of skin cancer via ingestion of drinking water, and there is evidence that it also causes lung and urinary bladder cancer. There are no data to suggest that arsenic ingested in soil behaves differently from arsenic ingested in drinking water [1]. With cadmium, ingestion is a significant route of exposure. The EPA looked at ingestion of soil only for a child even though the reference dose is based on ingestion over a lifetime. Exposure as a child and as an adult should have been assessed. Furthermore, cadmium is well taken up by plants so exposure via multiple pathways of ingestion should have been analyzed to better assess risk. Recent studies also suggest that cadmium is an endocrine disruptor, an endpoint not assessed in Part 503 [1, 10]. The mercury assumed to be in the sludge was considered to be similar in toxicity to the inorganic form mercuric chloride. However, mercury can appear in many forms and the speciation is critical to its fate and transport. The organic form methylmercury has been found in sludge. This is of great concern because it can bioaccumulate in fish. Inhalation exposure to nickel is the most toxic pathway, but this was not thoroughly assessed. Molybdenum has no standard, just a ceiling concentration, but it is well known that molybdenum is toxic to ruminant animals, which are exposed by ingesting legumes, grasses, soybeans, and other crops [1, 10].

NEW CHEMICALS AND PATHOGENS

Another significant problem with Part 503 repeatedly discussed in the literature is that thousands of new chemicals have been produced, used, and released since 1990, and there are new pathogens of concern that have not been considered since the initial standards went into place. The Toxics Release Inventory tracks releases of over 600 toxic chemicals, of which only nine are currently being regulated in sludge; thus very few of these 600 chemicals have been assessed. Brominated flame retardants, antibacterials, pharmaceuticals, fragrance chemicals, surfactants, personal care products, and organotins are just a few of the new chemicals of growing concern. Kinney et al. (2006) analyzed organic wastewater contaminants in nine different sewage sludge products [12]. The most commonly detected chemicals were pharmaceuticals, detergent metabolites, steroids, fragrances, polycyclic aromatic hydrocarbons (PAHs), fire retardants, plasticizers, and disinfectants. Nonylphenol and octylphenol detergent metabolites, known or suspected endocrine disruptors, were detected in greater concentrations than most of the other chemicals measured. Polar compounds were also found at concentrations higher than previously thought possible. Harrison et al. (2006) examined peer-reviewed literature and official government reports to assess the presence and concentrations of organic chemicals in sewage sludge [9]. Data were found for 516 chemicals. There were SSLs for 15 percent of the chemicals, and for 86 percent of these, the reported maximum concentration exceeded the SSL. In 2006–2007, EPA conducted a new analysis of 145 chemicals in sewage sludge, including anions, metals, polycyclic aromatic hydrocarbons, semi-volatiles, flame retardants, pharmaceuticals, and steroids/hormones [13]. Twenty-seven metals were found in virtually every sample; four VOCs were in 72 samples; three pharmaceuticals were in all samples, and nine were in at least 80 samples; three steroids were in all samples, and six were in at least 80 samples; and all flame retardants except one were in every sample. The EPA states that it plans to evaluate the pollutants identified in the survey, first focusing on the nine they had previously determined to be of concern, but if EPA conducts the risk assessment in the same manner as was done for Part 503, the results will again have little credibility.

HEALTH EFFECTS

Occupational exposure to Class B biosolids is considered a concern by the U.S. Centers for Disease Control and Prevention (CDC) and the National Institute for Occupational Safety and Health (NIOSH) due to the pathogens still present in biosolids. Health effects after occupational exposure have been reported in numerous studies [1, 14]. There is little data regarding health effects in the general population exposed to sewage sludge. Two recent studies assessing health effects from exposure to aerosols after sewage sludge application to nearby lands suggest increased risk for certain respiratory, gastrointestinal, and other diseases as well as irritation of the eyes, throat, and lungs and prevalence of *Staphylococcus aureus* infections [10]. The highly publicized case of Andy McElmurray and his dairy farm ruined by the application of sewage sludge further highlights the fact that there are health concerns associated with the application of sewage sludge. One of the chemicals found in Andy McElmurray's sludge was thallium, a metal not regulated under Part 503 [15]. The bacterium *Listeria monocytogenes* has been detected frequently in treated sewage sludge, and crop contamination has been observed when sludge containing this pathogen has been applied [1]. Even these few cases raise significant doubt regarding how protective the standards in Part 503 really are.

TOO COMPLEX TO REGULATE PROPERLY

The recent studies on the composition of chemicals in biosolids show the fundamental problem with sewage sludge: it is a complex, always-changing mixture. Even if major changes were made to the standards, there are too many unknowns regarding the amounts, behaviors, and toxicity of thousands of chemicals that are found in sewage sludge to regularly ensure the protection of human health. Sewage sludge is too complex to properly monitor and regulate. In a 2006 study examining reported organic compounds in sludge, of the 516 organic chemicals that had available data, 83 percent of the chemicals were not on the priority pollutant list and 80 percent were not on the target compound list of chemicals that must be detected and quantified in analyses of soil from Superfund sites, leading the authors to conclude that even if monitoring were expanded to include chemicals on these lists, it "will not capture the vast majority of chemicals that may be present" [9]. It is significant that this study found data on only 516 chemicals even though thousands are in use.

There are too many variables and too many unknowns to properly regulate the land application of sewage sludge in a way that adequately protects human health and the environment. The EPA assumes "that models approximating the reality of a ranch in west Texas are also appropriate for a vegetable farm in New York" [7]. This could not be further from the truth. The components of the wastewater, type of treatment process, application rates, climate, and soil characteristics vary greatly from location to location, and these are just a few of the numerous factors that impact the fate, transport, bioavailability, and toxicity of the chemicals in sewage sludge. People are not exposed to just one chemical. It is difficult enough to assess risk for one chemical, and adding multiple chemicals makes the assessment infinitely more difficult. Evaluating risk posed by individual chemicals requires multiple assumptions; adding in mixtures means more assumptions have to be made and this can lead to unacceptably high levels of uncertainty [1, 5, 7].

The 2002 NRC report concluded that it was "not possible to conduct a risk assessment for biosolids at this time (or perhaps ever) that will lead to risk management strategies that will provide adequate health protection without some form of ongoing monitoring and surveillance," because sewage sludge is a complex mixture that can change unexpectedly over time and place [1]. It is impractical and financially impossible to continually monitor sewage sludge for every type of chemical that could be in it. For many of the chemicals, much is unknown: how they interact with other chemicals, the form that is found in sludge, how bioavailable they are, and how toxic. How can sewage sludge be properly regulated if there is not complete information on all the chemicals present in it and the variables that govern their fate in the environment? Ignoring the unknowns is not the answer.

Inadequate enforcement of rules and practice adds to the problem. The EPA itself says the Part 503 regulations are "self-implementing" [7]. Periodic reporting is required, but no permits are needed for land application and no record-keeping regarding application rates is required. After application of Class B biosolids, there are waiting periods from 30 days to one year. However, the rules for enforcement are vague, and there is no testing required after the time limit to ensure that natural processes have reduced the pathogens to safe levels [7]. A recent example exhibits the consequences of inadequate enforcement. In a county in Alabama, the blood of 200 residents is being tested for the presence of perfluorinated chemicals in drinking water. The chemicals were released from nearby industries and concentrated in sewage sludge, which was distributed as free fertilizer for 12 years. The EPA knew the chemicals were in the sludge but did not know the sludge was being applied to agricultural land until finding out by accident in 2008 [16].

The federal Clean Water Act defines sewage sludge as a pollutant, and it needs to be treated as one. It is not a fertilizer with soil-conditioning properties. Sludge is a complex mixture that contains organic, inorganic, and biological pollutants from wastewater coming from a variety of sources [5, 6]. Basically, anything flushed down the drain or toilet can make its way into sludge. The point of a wastewater treatment plant is to make the effluent as clean as possible. In doing so, the sludge becomes more toxic as it concentrates the pollutants that were in the liquid sewage [5]. Although EPA believes the standards in Part 503 are keeping the public safe, the "data gaps and non-protective policy choices result in regulations that are not adequately protective of human health and the environment" [7]. There are other methods to manage sludge that are more environmentally friendly and safer that need to be investigated [6]. Until the Part 503 standards are reevaluated using more current and reliable data and methods, the practice of land application must be discontinued because that is the only way to protect human health and the environment. The data strongly support that applying sewage sludge to land is not safe, and if things continue as they are, the long-term consequences to human health and the environment have yet to be felt.

NOTES

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