An Overview of the Dangers of Sewer Sludge (Biosolids)

by Dr. Thomas Maler, Ph.D.

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Application of Sewage Biosolids on Land

The 2004 National Water Quality Inventory by the US EPA reported that 44 % of surveyed rivers and streams were impaired by pathogens and organic enrichment, and the top source of these impairments was from runoff from agriculture activities. In addition, 30 % of surveyed bays and estuaries were considered impaired by pathogens and organic enrichment, with municipal discharges/sewage listed among the top three sources of the impairment (US EPA, National Water Quality Inventory Report to Congress, 2004 Reporting Cycle, Jan. 2009). Also in 2004 approximately 60 % of total "biosolids" produced in the US were applied to land, (NEBRA, A National Biosolids Regulation, Quality, End use and Disposal Survey—Preliminary Report, April 14, 2007). Since 2004 more stringent effluent discharge requirements and sewage treatment plant upgrades have resulted in significant increases of sludge production and hence the need to dispose of it in an acceptable manner. Public doubts regarding the efficacy and safety of land application have been supported by scientific research that indicates commercial chemicals, pharmaceuticals, personal care products, engineered nanoparticles and innumerable contaminants of emerging concern (COEC) are having a greater impact on the environment and public health than previously assumed (Abstracts of Presentations, "Environmental Protection in a Multi-Stressed World: Challenges for Science, Industry and Regulators," 25th Annual Meeting of SETAC, 2015, Barcelona). Further studies and alternative methods of extracting and processing the components of sewage and disposing of the sludge are required. There is potential for reducing the life cycle costs of sewage treatment plants, recovering energy and destroying or immobilizing harmful components instead of being applied to land, (Biosolids Management Strategies: An Evaluation Of Energy Production As An Alternative To Land Application, Environmental Science and Pollution Research International, Jul 2013).

Composition of sludge/biosolids.

Sewage sludge, when treated in an anaerobic digester or further treated with heat or alkali is now called biosolids in order to make it sound more acceptable for "beneficial" uses such as spreading on farmland. The sludge/biosolids contains nutrients useable for plant growth, however they also contain in addition to human and animal wastes, 30,000 or more different toxic chemicals from pharmaceuticals, hospital, household and industrial waste, bacterial, viral and other parasitic biological pathogens, multi-drug resistant bacterial/Superbugs and prions, heavy metals, micro-plastics and micro-fibres. One class of these thousands of chemicals in sludge/biosolids is called PPCPs or Pharmaceuticals and Personal Care Products and these compounds are taken up by plants in hundreds of micrograms per kg of plant tissue and nothing is known about the effect of this on the plants and on the animals that consume them including humans. The uptake and metabolism of these thousands of different compounds varies greatly with their composition. (M. Bartrons, J. Peñuelas, TRPLSC 1514, 12, 2016, p.10).

Health Effects

Damage to DNA from environmental chemicals is likely a major cause of cancer, birth defects, and this uptake may contribute to heart disease and other health effects. Genetic defects get carried over to future generations; exposure to mutagens is from natural sources but increasingly from synthetic chemicals such as industrial chemicals, pesticides, hair dyes, cosmetics and pharmaceuticals, (Bruce N. Ames, Dept. of Biochemistry, UC Berkley).

When substances have a similar mode of action, their concentrations can be added together to predict their combined effect. This includes concentrations below levels of concern and the toxicity effect is larger than the sum of the components. Although antagonistic and synergistic effects occur, the additive effect of toxicity is generally what occurs (Environmental Toxicology and Chemistry, Dick de Zwart and Leo Posthuma, Vol 24, Issue 10, Pg 2397-2713 – Modeling of single and multiple chemicals in the environment).

Environmental oestrogens in wastewater treatment effluent are well established as the primary cause of reproductive disruption in wild fish populations but their possible role in wider effects of effluents is under study. Filby et al, revealed a clear link between oestrogen in effluent and diverse, adverse and sex-related health impacts on resident fish species, (Environmental Health Perspectives, Vol. 115, No. 12, Health impacts of oestrogen in the environment, considering complex mixture effects, December 2007, Amy L. Filby, Teresa Neupath, et al).

<u>What happens to the contaminants in the sludge/biosolids?</u>

If governments continue to allow the application of 30,000+ chemicals and PPCPs and many countless biological pathogens on the land, they should prove beyond any reasonable doubt that these contaminants are either removed from the sludge/biosolids before land application or will be destroyed when applied on the land. However, the proof is simply not there. This is a herculean task, it will be impossible to measure the concentration and the rate of removal or the decomposition of 30,000+ chemicals applied on the land. The technology does not exist to measure these thousands and thousands of chemicals and the cost of doing so even if it were possible would be prohibitive. Even though endogenous soil bacteria can probably degrade a small number of chemicals in the sludge, the metabolic pathways to degrade and destroy 30,000+ synthetic chemicals that did not exist in the past, do not exist. A certain amount of these thousands of chemicals will be water soluble and with other small particles including microplastics they will get washed away with the rains and will end up in the streams, rivers and the ocean or will contaminate aquifers. Effluent discharges have been expressed as the mode for contamination that is reputed to play a role in the formation of “dead” zones or oxygen depleted “hypoxic” zones in lakes and the near shore oceans around the world (Scientific American, 2008; National Ocean Service, US Dept. of Commerce, 2010). The oceans are exploding with dead zones (Business Insider, June 26, 2013), and the zones appear to be increasing in size over time.

Clearly, there are toxic chemicals in sewage sludge.

We also do not know anything about what other toxins can form from a 30,000+ chemical soup when sludge is being treated/turned into biosolids. Furthermore, nothing is known about what synergistic effects this chemical cocktail will exhibit when applied on the land. Another unknown is what effect the many antibiotics present in the sludge/biosolids will play on the plant microbiota or on the microbiota of the animals that live on the land where the sludge/biosolids getapplied. Both endogenous bacteria as well as mycorrhizal fungi play a crucial role in the growth of plants and trees and altering this microbiome with antibiotics present in the sludge/biosolids can easily negate its nutritional benefits.

<u>Biological Pathogens</u>

Sewage sludge/biosolids also contains largely an unknown number of bacterial and viral pathogenic organisms, protozoan and other parasites and even prions. What is often never discussed in the prosludge and biosolids literature is the fact that ALL sewage treatment plants in the world, including all secondary and tertiary treatment plants breed Superbugs or multi-drug resistant bacteria, (Y. Luo et al, Environmental Sci. Technol. Lett. 2014, 1, 26-30; A. McGlashen, Sci.Am. 2017, 01/18.) The reason is simply the fact that antibiotics end up in sewage and during the treatment process with bacteria, the bacteria that acquire antibiotic resistance will get selected in the presence of antibiotics in the sewage. However,the level of treatment (secondary or tertiary) will affect the degree of ocean protection from the contaminants in the sludge. The sludge is simply settled out in secondary treatment and the effluent which is too dirty to be reused typically gets pumped to a receiving environment, such as, a river, lake or into the ocean. However, in tertiary treatment, the sludge gets filtered from the water with 0.04 micron membranes and this step will remove not only the bacteria, but also the source of the bacterial multi-drug resistance or Superbugs, the plasmids. Plasmids are small circles of DNA which contain the genes for the drug resistance and can confer the resistance not only to same species bacteria, but also to unrelated bacteria such as the endogenous soil bacteria. These small circles of DNA called plasmids can survive outside of the bacteria either in water or can even survive for hundreds or possibly even thousands of years in a completely dry state. Plasmid DNA has even survived on the surface of a rocket shot into space and the heat of re-entry into atmosphere, (D.F. Maron, Sci. Am. Nov. 26, 2014). So it is totally unrealistic to hope that Superbug DNA will somehow magically disappear if we let the sludge sit on the land for a few months. The addition of 5-10 or larger micron size disc filters suggested to improve the quality of the effluent instead of the 0.04 micron membrane filters used in real tertiary sewage systems will do nothing for the environmental protection because it will NOT filter out plasmids or anything else smaller than the pore size of such filters.

Fraser Health has repeatedly found cases of the deadly CRE (Carbapenem Resistant Enterococci) in BC Hospitals, however CBC has reported (CBC News, Jan. 30, 2017) that many other hospitals in other provinces are silent on these outbreaks and that there were apparently 160 cases of CRE outbreaks between 2010 and 2012 (Public Health Agency of Canada). These and other Superbugs make their way into the sewage treatment Plants from the hospitals, homes and industrial facilities and so it makes sense that we should not spread them or plasmids containing the genes for this resistance on the land where they can further contaminate and multiply their resistance genes.

Micro-plastic and micro-fibres

Sewage contains micro-plastics from a variety of cosmetic products and micro-fibres that are released into waste water from laundry and industrial processes. These microscopic plastics will remain on the land or be washed from the land into streams, rivers and into lakes and the ocean where they will do their environmental damage. A recent study by the International Maritime Organization, the UN Organization responsible for preventing marine pollution, and carried in

Science and Technology Journal and also reported by CBC, posted to their web site on January 17, 2017 indicates that microplastics are now found in supermarket fish and shellfish. They have infiltrated every level of the food chain in both the marine and fresh water habitats and now we are seeing them come back to us on our dinner plates, (Chelsea Rochman, University of Toronto, 2017). These materials not only enter the gut but also their tissue says Peter Wells, senior research fellow at International Ocean Institute, Dalhousie University. He goes on to say, it’s not only the micro-plastics but the myriad of chemicals that come with them, chemicals such as PCB’s, pesticides, flame retardants and hormone disrupting compounds of many kinds. Although micro-plastics come from many sources and are known to carry chemicals of emerging concern, it behooves us to eliminate sources where possible, including the land application of sewage biosolids.

Micro-plastics are found at an alarming level in Canadian Lakes, Science and Technology Journal, and also reported by CBC, January 2017. They are a concern in lakes worldwide and they are often found at alarming levels says Anthony Ricciardi, professor at McGill School of the Environment. Their source is often municipal coming from the washing of clothes but also from industrial sources and are found at 43,000 plastic particles per square kilometer which jumps to 466,000 near cities around the Great Lakes.

No one wants to eat fish that contains non biodegradable plastics including the many toxins absorbed to these plastics, so it makes sense not to spread them onto land in sludge/biosolids in order to stop further contamination of both the land and the waters.

Micro-plastics are synthetic polymers and cannot be broken down by microorganism no matter how long they will sit on the land or in the ocean. They will survive for many hundreds of years without any noticeable degradation and are eaten by fish, plankton and other marine and fresh water animals, (M.L. Taylor et al, Scientific Reports 6, Article number: 33997 (2016). As noted, the actual toxicity of the micro-plastics themselves is also increased by absorption of toxic chemicals onto their surface. These polymers can't be broken down/metabolized by any creature that ingests them and so if they are loaded by absorbed toxins, they become even more lethal, (M.A.Browne et al. *Current Biology*, 2013; 23 (23): 2388).

The indefinite Problem

Tens of thousands of these components will contaminate the land for decades and perhaps hundreds if not thousands of years once they are applied on the land and there simply is nothing one can do to decontaminate such land. Furthermore, the tests that would determine the extend to which these toxins will be taken up by the plants or animals we consume simply do not exist, with 30,000 different synthetic, man-made chemicals it is unrealistic and impossible to measure the fate of these chemicals once they are applied on the land. The same goes for the vast majority of biological pathogens like Superbugs that will be spread on the land with the sludge. Once micro plastics from sludge are applied on the land, they will contaminate the land for hundreds of years or waterways if they get washed away by rain. Once it's applied on the land, it will either stay there or will end up in the rivers, lakes or the ocean - the genie cannot be put back into the bottle once it gets out so the best solution is not to apply this toxic mixture on the land in the first place.

What do we do with it these sludge toxins? How do we safely dispose of this sludge/biosolids?

The wastewater industry currently has a preference to treat sewage sludge and turn it into a material called "biosolids," a marketing term developed to make it more appealing to farmers to encourage spreading it on the land. It represents a relatively inexpensive way to dispose of the sewage biosolids. Sewage sludge treated in an anaerobic digester converts approximately half of its carbon into biomethane, however, the problem remains what to do with the remaining 50% of the solid residuals. There are risks associated with anaerobic digesters, they are known to explode, thus the reason they are not installed in built-up residential areas.

Thermal conversion is also an option for sewage biosolids disposal, with a remaining issue on how to safely dispose of the ash should it contain potential heavy metal issues. There are two types of thermal conversion, firstly, incineration which has been rejected in many jurisdictions because of the large volumes of air pollutants released during the process; and secondly, gasification which reforms (or manufactures) the sewage biosolids into synthesis gas (syngas) and does not have the massive air pollution issues of an incinerator. In advanced gasifier systems there are no direct air emissions at all. Small gasification systems, suitable for the disposal of sewage biosolids, have only recently been developed having started in Europe in the mid 1990's. These first generation systems have given way to further development into second and third generation systems which are much more reliable, stable and efficient than the earlier systems. The Advanced gasifiers can handle either dewatered raw sewage sludge or dewatered treated biosolids from a digester, the only difference being higher syngas production from the raw sludge. Due to their size compared to anaerobic digesters and municipal incinerators they are much more cost effective and require far lower operating costs as well.

Lessons learned

K. Noguera-Oviedo and D. S. Aga (J. of Hazardous Materials, 316 (2016) 242-251) reported on the lessons learned from more than two decades of research on emerging contaminants in the environment. Just like the exponential growth of research papers published on the topic of Emerging Contaminants (ECs) in the period of 1995-2015, detection techniques have been vastly improved and the amount of data has also grown exponentially. Noguera-Oviedo and Aga identified five (5) lessons learned from research of the past 20 years and reported that these lesson matter now more than ever before.

Lesson 1: Emerging Contaminants have emerged worldwide in Waste Water Treatment Plants effluents and in surface water, drinking water and groundwater. The precautionary principle should be used in dealing with management options for this material.

Lesson 2: Treatment does not mean complete removal and application of the sludge on the land only exacerbates this problem.

Lesson 3: Metabolites and transformational products matter, meaning that during the treatment or after it, the mixing of thousands of these chemicals often forms new compounds that are more dangerous than those that they originated from. That's the nature of chemical processes and unless we actually destroy the mix, new toxins will continue to emerge from the old ones, whether it is on the land or in streams, rivers, lakes or the ocean.

Lesson 4: Unconventional testing of the effects of toxicity are needed, because of the complex mixture of chemicals in the effluents and in the sludge. The simple testing done by the pharmaceutical industry while developing new drugs does not apply in this new world of toxic waste chemicals.

Lesson 5: Even the most advanced tools can miss the target. The exponential growth of scientific literature in detecting these compounds will not negate the need to prevent even further contamination of the environment by persistent ECs.

In conclusion, it seems obvious that application of sewage sludge/biosolids on the land is not the answer to dispose of these toxins and pathogens. Disposal of the sludge mixed with municipal solids waste or with wood chips in a gasifier is the only safe way to go because it completely destroys the toxic chemicals and pathogens. Not putting this toxic soup on the land is the only way of protecting our environment and that's the primary reason for treating our sewage in the first place.