Parliament of Victoria

Research Note

Parliamentary Library and Information Service

ISSN: 2204-4779 (Print) | 2204-4787 (Online)

No. 3 | July, 2022

Microplastics in biosolids – definitions and implications

Anwyn Hocking, Data Journalist

Abstract

The use of biosolids as agricultural fertilisers and soil treatments has provided economic benefit and reduced environmental burden across Australia. However, biosolid production and use has been identified as a major source of unintended microplastic dispersion into the environment. In 2021, Australia produced 349,000 tonnes of biosolids, 73% of which was used for agricultural land application (ANZBP, 2022). Recent research has indicated that between 1,241 and 7,170 tonnes of microplastics are applied to Australian farmlands each year through the land application of biosolids (Mohajerani & Karabatak, 2020, p. 256). Although preliminary research suggests significant environmental and health impacts, the consequences of such microplastic dispersion are yet to be fully understood.

What are microplastics?

Microplastics are water insoluble 'synthetic solid particles or polymeric matrices, with regular or irregular shape' ranging from 1 micrometre (µm) to 5 millimetres (mm) in size and of either primary or secondary manufacturing origin (Frias & Nash, 2019, p. 146). Primary microplastics are objects manufactured to be less than 5 mm in size, such as plastic microbeads, which are added to health and beauty products. Secondary microplastics result from the decay of larger plastic items, which may be a result of UV radiation, temperature, microbial degradation, atmospheric pressure, or physical abrasion (Allouzi et al., 2021). Particles smaller than 1 µm are referred to as nanoplastics (Frias & Nash, 2019, p. 146). Microplastics and nanoplastics (MNPs) vary in polymer type, size, shape, colour and are predominantly produced from polyethylene, polypropylene, polystyrene, polyvinylchloride, and polyethylene terephthalate (Mohajerani & Karabatak, 2020, p. 253).

What are biosolids?

Biosolids are treated sewage sludges derived from wastewater processing (Mohajerani & Karabatak, 2020). Sewage sludge is the solid material collected from the wastewater treatment process which has not yet undergone further treatment. Through such treatment and the reduction of disease-causing pathogens and volatile organic matter, the resulting biosolids contain:

- Macronutrients: nitrogen, phosphorus, potassium, and sulphur
- Micronutrients: copper, zinc, calcium, magnesium, iron, boron, molybdenum and manganese (ANZBP, n.d.)
- Potential pollutants: microplastics, micropollutants, chemicals and pathogens (Mohajerani & Karabatak, 2020, p. 253).

In Australia, biosolids are primarily used for fertilising agricultural land (see Figure 1), followed by stockpiling, landscape composting, landfill, land rehabilitation, forestry, and other uses, such as power production, creating road bases, and manufacturing construction materials (ANZBP, n.d.; Mohajerani & Karabatak, 2020).

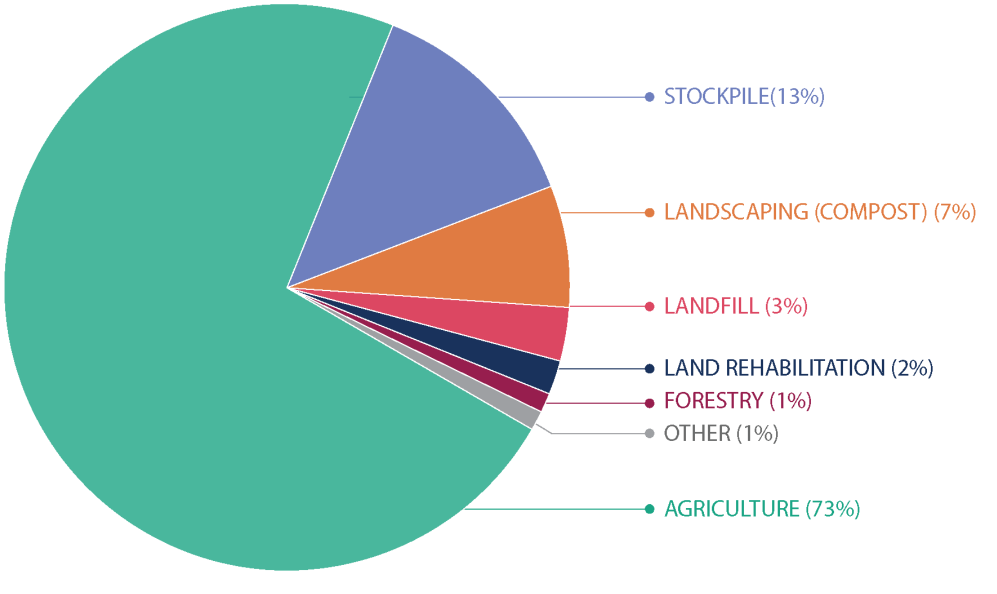

Figure 1: Biosolids end-use in Australia, 2021 | Source: ANZBP, 2022

How do biosolids contribute to microplastic dispersion?

Plastics are ubiquitous in the wastewater that treatment plants receive from household kitchens, laundries, bathrooms, industrial effluents, and storm water. While larger plastic items are removed during wastewater processing, it can be challenging to remove smaller particles (ANZBP, n.d.), meaning MNPs are able to accumulate in the resultant biosolids.

Although the use of biosolids in Australia is contingent upon chemical composition and the level of pathogens remaining after treatment, these emerging and difficult to remove pollutants are yet to be accounted for by regulations. As such, biosolids containing MNPs may be used for agriculture and topsoil rehabilitation. Figure 2 illustrates a typical pathway of MNPs to the environment via biosolid agricultural land application.

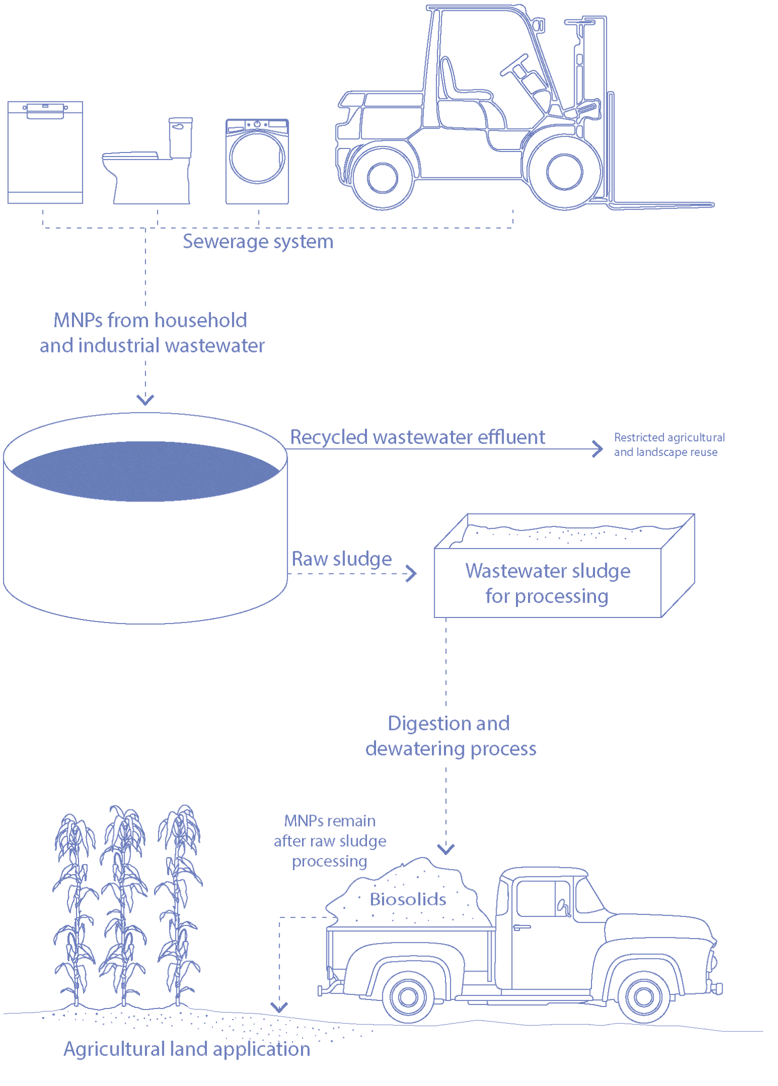

Figure 2: An example of a pathway of MNPs from wastewater to agricultural land via biosolid land application | Adapted from: ANZBP, n.d.; Koutnik et al., 2021; Castan et al., 2021; de Bhowmick & Sarmah, 2022.

Environmental and health impacts

Research into the environmental, social, and economic impacts of widespread MNP accumulation through biosolid use is nascent and, as such, lacks clear consensus. While some studies have found evidence of concerning environmental and human health repercussions, others have challenged whether MNP dispersion poses any real threat. As Bucci et al. (2020, p. 14) contend, there is need for research 'using more ecologically relevant scenarios and teasing apart the effects of different characteristics of microplastics.' Some of the preliminary findings of potential risks are considered below.

Environmental impacts

Biosolids provide a pathway for MNPs to accumulate in soil ecosystems, which can affect the biophysical properties of soils, plants and microbial organisms. MNPs interact with harmful pollutants from the environment and can release toxic plastic additives, serving as sinks and conduits for various toxic compounds into the environment. MNPs may also impact soil fauna, such as earthworms and nematodes, affecting their growth, reproduction, lifespan and survival. In turn, the natural ecological activities of these organisms, such as litter decomposition, nutrient cycling and energy flow will be impacted (Wang et al., 2021). In addition, MNPs can be transferred through the food chain as they accumulate in plant root systems. Consumption of such MNP-contaminated plants by humans and other animals may lead to health deterioration.

To date, there is limited knowledge of how plants respond to MNPs in the soil. As Kumar et al. (2020) have identified, more research is needed to understand:

- The distribution, transport, and degradation of MNPs
- Effect of MNP absorption on flora and animals/humans
- Effect of MNPs on the microbial ecology and microbial activity
- Behavioural responses of plants, animals, and other organisms to MNP pollution in agricultural soils
- MNPs as vectors of environmental pollutants in different terrestrial ecosystems.

Health impacts

Research suggests that MNP exposure may harm humans via physical and chemical pathways, particularly impacting the nervous system, respiratory system, kidney system, digestive and excretory system, placental barrier, and skin (Smith et al., 2018, p. 380; Campanale et al., 2020, p. 16).

Potential physical impacts of MNP exposure

The physical effects of accumulated microplastics are less understood than the impact of the distribution and storage of toxic substances in the human body. Preliminary research has demonstrated several potentially concerning impacts:

- Enhanced inflammatory responses (Gruber et al., 2022)
- Size-related toxicity of plastic particles
- Disruption of gut microbiome (Smith et al., 2018, p. 380).

Potential chemical impacts of MNP exposure

Chemical additives used to create plastics or chemicals absorbed by MNPs in the environment may have toxic effects on the human body. For instance:

- Chemicals, such as BPA, phthalates, and some brominated flame retardants (BFR) that are used to create plastics have been shown to disrupt the endocrine system. Endocrine-disrupting chemicals are associated with various diseases and conditions, such as hormonal cancers, reproductive problems, metabolic disorders, asthma, and neurodevelopmental conditions (Campanale et al., 2020, p. 5).
- Heavy metals may be used in the production of plastics or may be absorbed by MNPs from the environment. Metals such as arsenic, cadmium, chromium, lead, and mercury are classified as 'known' or 'probable' human carcinogens according to the International Agency for Research on Cancer (IARC). Other metals such as Al, Sb, As, Ba, Cd, Cr (II), Co, Cu, Pb, Hg, Ni, Se, Sn and V are metal-estrogens due to their high affinity to estrogen receptors and are considered to be potentially linked with breast cancer (Campanale et al., 2020, p. 9).

Scale of MNP dispersion via biosolid end-use

In 2021, Australia produced 349,000 tonnes of biosolids, of which Victoria contributed around 120,000 tonnes (Figure 3). In Victoria, the majority of these biosolids were used for agriculture (65%), followed by stockpiling (31%) and landscaping (4%).

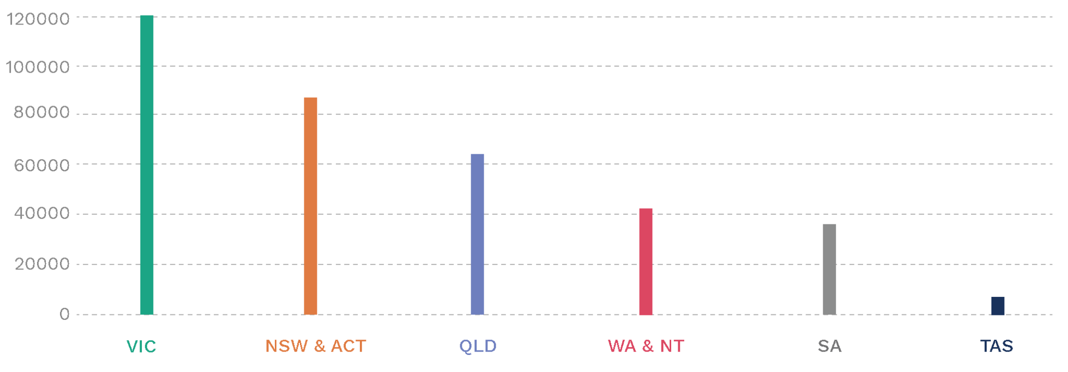

Figure 3: Total production of biosolids by Australian state in 2021 | Source: ANZBP, 2022

In a 2016 study, biosolid samples collected from 82 wastewater treatment plants across Australia were analysed for seven common plastics. Approximately 99% of the samples contained plastics at concentrations between 0.4 and 23.5 mg/g, with polyethylene being the most common material detected (Okoffo et al., 2020). Based on this finding, the per-capita release of the measured plastics was estimated to be approximately 200 g/person/year for each Australian in 2016 (noting that the samples analysed were collected in 2016 during the census week and population data from the 2016 census was used for all estimations). Using this figure, it was estimated that 4,700 tonnes of plastic are released into the Australian environment annually through biosolid end-use, with 3,700 metric tons released to agricultural land and 140 metric tons to landscape topsoil (Okoffo et al., 2020). Extrapolating these findings to consider the Victorian situation, it can be estimated that about 1,200 metric tons of microplastics may be released to Victorian environments through biosolid end-use per year.

- *200 g/person/year x 2016 Victorian population (5,926,624) = 1,185 (~1,200) metric tons* (Okoffo et al., 2020)

In considering such estimates, it must be noted that some authors argue that reliable estimates are challenging to ascertain due to the lack of standardised analysis methodologies for calculating microplastics in biosolids (ANZBP, 2020).

Current policy and regulations

Biosolid production and use varies between states and is regulated by each state's environmental protection agency or equivalent authority. To date, there are no specific national or state-based regulations around MNP concentrations in biosolids. The table below shows relevant legislation and guidelines across Australia:

State	Legislation/Guideline
Federal	Carbon Credits (Carbon Farming Initiative) Regulations 2011
VIC	*Water Act 1989*
	Environment Protection Regulations 2021
	Guidelines for environmental management: Biosolids land application
NSW	*Protection of the Environment Operations Act 1997*
	Local Government (General) Regulation 2021
	Protection of the Environment Operations (General) Regulation 2021
	Waste Management (General) Regulation 2018
	Environmental Guidelines: Use and Disposal of Biosolids Products
	Biosolids Order
	Biosolids Exemption
	Waste Classification Guidelines
QLD	*Waste Reduction and Recycling Act 2011* End of Waste Code Biosolids (ENEW07359617)
	Environmental Protection Regulation 2019
	Waste Reduction and Recycling Regulation 2011
NT	Guidelines for Sewerage Systems Biosolids Management
TAS	Tasmania Biosolids Reuse Guidelines 2020
	Approved Management Method for Biosolids Reuse - July 2020
WA	Western Australian Guidelines for Biosolids Management
ACT	ACT Waste Management Strategy: Towards a sustainable Canberra 2011–2025
SA	Guidelines for the safe handling and reuse of biosolids in South Australia

Future directions

Given the limitations of existing research and lack of clear consensus on the implications of widespread MNP accumulation, more research is needed to understand the complexities of MNP degradation and environmental application via biosolids (Gruber et al., 2022; Mohajerani & Karabatak, 2020, p. 263; de Bhowmick & Sarmah, 2022). As Amobonye et al. (2021) argue, in addition to further research, there is also a need to develop standardised methodologies for analysing MNP contamination in biosolids, and more comprehensive regulations around MNP concentrations in biosolids for land-application. Alternatively, as Mohajerani and Karabatak (2020) contend, using biosolids for other uses, such as in the production of fired clay bricks, may offer a more sustainable end-use option to offset the detrimental environmental and health effects of biosolid land-application.

References

Abel De Souza Machado, A., C. W. Lau, W. Kloas, J. Bergmann, J. B. Bachelier, E. Faltin, R. Becker, A. S. Görlich & M. C. Rillig. (2019). Microplastics Can Change Soil Properties and Affect Plant Performance. *Environmental Science & Technology, 53* (10), 6044-6052. https://doi.org/10.1021/acs.est.9b01339

Allouzi, M. M. A., D. Y. Y. Tang, K. W. Chew, J. Rinklebe, N. Bolan, S. M. A. Allouzi, P. L. Show. (2021). Micro (nano) plastic pollution: The ecological influence on soil-plant system and human health. *Science of The Total Environment, 78*8, 147815. https://doi.org/10.1016/J.SCITOTENV.2021.147815

Amobonye, A., P. Bhagwat, S. Raveendran, S. Singh & S. Pillai. (2021). Environmental Impacts of Microplastics and Nanoplastics: A Current Overview. *Frontiers in Microbiology, 12*, 3728. https://doi.org/10.3389/FMICB.2021.768297/BIBTEX

Australian & New Zealand Biosolids Partnership (ANZBP). (n.d.). What are Biosolids? Fact Sheet. https://www.biosolids.com.au/info/what-are-biosolids/

Australian & New Zealand Biosolids Partnership (ANZBP). (2019). *Australian biosolids statistics.* https://www.biosolids.com.au/guidelines/australian-biosolids-statistics/

Australian & New Zealand Biosolids Partnership (ANZBP). (2020). *ANZBP preliminary report on microplastics risk for the Australian and New Zealand biosolids industry.* https://www.biosolids.com.au/wp-content/uploads/ANZBP-Factsheet-on-Microplastics.pdf

Australian & New Zealand Biosolids Partnership (ANZBP). (2022). *Biosolid production in Australia 2021.* From the ANZBP 2022 survey, access via admin@biosolids.com.au.

Bucci, K., M. Tulio, & C. M. Rochman. (2020). What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. *Ecological Applications, 30* (2). https://doi.org/10.1002/eap.2044

Campanale, C., C. Massarelli, I. Savino, V. Locaputo, & V. F. Uricchio. (2020). A Detailed Review Study on Potential Effects of Microplastics and Additives of Concern on Human Health. *International Journal of Environmental Research and Public Health.* https://doi.org/10.3390/ijerph17041212

Castan, S., C. Henkel, T. Hüffer, & T. Hofmann. (2021). Microplastics and nanoplastics barely enhance contaminant mobility in agricultural soils. *Communications Earth & Environment 2021 2:1,* 2(1), 1–9. https://doi.org/10.1038/s43247-021-00267-8

Ebere, E. C., V. A. Wirnkor, & V. E. Ngozi. (2019). Uptake of Microplastics by Plant: a Reason to Worry or to be Happy? *World Scientific News*. www.worldscientificnews.com

de Bhowmick, G., & A. K. Sarmah. (2022). Microplastics contamination associated with land-application of biosolids: A perspective. *Current Opinion in Environmental Science & Health,* 26, 100342. https://doi.org/10.1016/J.COESH.2022.100342

Frias, J. P. G. L., & R. Nash. (2019). Microplastics: Finding a consensus on the definition. *Marine Pollution Bulletin*, 138, 145–147. https://doi.org/10.1016/J.MARPOLBUL.2018.11.022

Gruber, E. S., V. Stadlbauer, V. Pichler, K. Resch-Fauster, A. Todorovic, T. C. Meisel, S. Trawoeger, O. Hollóczki, S. D. Turner, W. Wadzak, A. D. Vethaak, & L. Kenner. (2022). To Waste or Not to Waste: Questioning Potential Health Risks of Micro- and Nanoplastics with a Focus on Their Ingestion and Potential Carcinogenicity. *Exposure and Health*. https://doi.org/10.1007/S12403-022-00470-8

Koutnik, V. S., S. Alkidim, J. Leonard, F. DePrima, S. Cao, E. M. V. Hoek, & S. K. Mohanty. (2021). Unaccounted Microplastics in Wastewater Sludge: Where Do They Go? *ACS ES&T Water*, 1(5), 1086–1097. https://doi.org/10.1021/ACSESTWATER.0C00267

Kumar, M., X. Xiong, M. He, D. C. W. Tsang, J. Gupta, E. Khan, S. Harrad, D. Hou, Y. S. Ok, & N. S. Bolan. (2020). Microplastics as pollutants in agricultural soils. *Environmental Pollution,* 265, 114980. https://doi.org/10.1016/J.ENVPOL.2020.114980

Mohajerani, A., & B. Karabatak. (2020). Microplastics and pollutants in biosolids have contaminated agricultural soils: An analytical study and a proposal to cease the use of biosolids in farmlands and utilise them in sustainable bricks. In *Waste Management* (Vol. 107, pp. 252–265). Elsevier Ltd. https://doi.org/10.1016/j.wasman.2020.04.021

Okoffo, E. D., B. J. Tscharke, J. W. O'Brien, S. O'Brien, F. Ribeiro, S. D. Burrows, P. M. Choi, X. Wang, J. F. Mueller, & K. V. Thomas. (2020). Release of Plastics to Australian Land from Biosolids End-Use. *Environmental Science and Technology*, 54(23), 15132–15141. https://doi.org/10.1021/acs.est.0c05867

Rochman, C. M. (2018). Microplastics research-from sink to source. *Science*, 360(6384), 28–29. https://doi.org/10.1126/SCIENCE.AAR7734

Smith, M., D. C. Love, C. M. Rochman, & R. A. Neff. (2018). Microplastics in Seafood and the Implications for Human Health. *Current Environmental Health Reports*, 5(3), 375–386. https://doi.org/10.1007/S40572-018-0206-Z/TABLES/4

Wang, Q., C. A. Adams, F. Wang, Y. Sun, & S. Zhang. (2022). Interactions between microplastics and soil fauna: A critical review. *Critical reviews in environmental science and technology,* 52, 18, 3211-3243. Https://Doi.Org/10.1080/10643389.2021.1915035.

Suggested citation

Hocking, A. (2022). *Microplastics in biosolids – definitions and implications*. Parliamentary Library & Information Service. Melbourne, Parliament of Victoria.

Acknowledgments

The Parliament of Victoria Library acknowledges the Traditional Owners of the lands across Australia on which we work and live. We pay our respects to Aboriginal and Torres Strait Islander Elders past and present; and we value Aboriginal and Torres Strait Islander history, culture and knowledge.

The author would like to thank and acknowledge Dr. Elvis Okoffo for his clarification and detailed explanation of microplastic dispersion estimates in Victoria, as well as Dr Ben Reid, Caleb Triscari and Debra Reeves for their help with the preparation of this publication.

Enquiries

Victorian Parliamentary Library & Information Service
Parliament House Spring Street, Melbourne
Telephone (03) 9651 8640
http://www.parliament.vic.gov.au