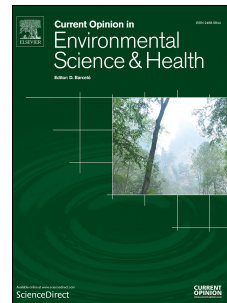# Accepted Manuscript

A 'promising tool'? A critical review of the social and ethico-political effects of wastewater analysis in the context of illicit drug epidemiology and drug policy

Dr Kari Lancaster, Tim Rhodes, Professor, kylie valentine, Associate Professor, Alison Ritter, Professor

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A 'promising tool'? A critical review of the social and ethico-political effects of wastewater analysis in the context of illicit drug epidemiology and drug policy

Dr Kari Lancaster[1], Professor Tim Rhodes[1,2], Associate Professor kylie valentine[3] & Professor Alison Ritter[4]

[1] Centre for Social Research in Health, UNSW Sydney, Australia

[2] London School of Hygiene and Tropical Medicine, UK

[3] Social Policy Research Centre, UNSW Sydney, Australia

[4] Drug Policy Modelling Program, Social Policy Research Centre, UNSW Sydney, Australia

Corresponding author:

Dr Kari Lancaster

Centre for Social Research in Health, UNSW Sydney, Australia

k.lancaster@unsw.edu.au

Abstract:

Wastewater analysis has been taken up with enthusiasm in the illicit drugs field. Through a critical social science lens, we consider claims to what these 'promising' methods might afford in the context of drug epidemiology and policy, recognising that all methods have social effects in their specific contexts of use. We outline several ethico-political issues, highlighting how methods can have different effects as they move from one discipline (environmental science or analytic chemistry) and into another (illicit drugs). Translated into the drugs field, wastewater analysis problematically shifts the focus of drug policy from harm reduction to drug use prevalence and entrenches stigma. Without comprehensive information about the social and contextual aspects of drug harms, effective drug policy is not possible.

A 'promising tool'? A critical review of the social and ethico-political effects of wastewater analysis in the context of illicit drug epidemiology and drug policy

The development of wastewater analysis as a new method is arguably precipitating one of the most significant shifts in illicit drug epidemiology in decades. Also called 'sewage epidemiology' [1, 2] or 'wastewater-based epidemiology' [3, 4], these methods have quickly generated worldwide interest in the illicit drugs field given their potential to provide near "real-time data on geographical and temporal trends" in illicit drug consumption [3, 4]. Wastewater analysis is increasingly regarded as "an important adjunct to established drug monitoring tools" [4], complementing methods such as self-report population or household surveys and analysis of crime statistics and drug seizure data. Unlike established epidemiological methods, wastewater analysis is deemed "non-invasive" [3], "not subject to the biases associated with self-report data" and able to "better identify the true spectrum of drugs being consumed" by a community [4-7] while "preserving the anonymity of the individuals involved" [8]. While self-report survey methods are often expensive, take time to administer and tend to focus on metropolitan centres [2, 4, 5, 7], wastewater analysis is said to offer "prompt identification of changes in trends and habits" [2]. Given that drug use is an illicit and largely hidden practice it has also been suggested that wastewater analysis may provide more "realistic" and "objective" evidence [7] because "self-reporting of socially censured behaviour is likely to be unreliable" [6]. Through the lens of critical social science, in this review we consider claims to what wastewater analysis methods might afford as they are rapidly taken up in the context of illicit drug epidemiology and drug policy. In doing so, we situate current discussions regarding wastewater analysis within a body of literature which has illuminated the need for cross-methodological dialogue between social science and epidemiology if drug-related harms are to be understood and ameliorated [9, 10], recognising that all methods have social and ethico-political effects in their specific contexts of use [10-14].

Wastewater analysis was originally used by environmental scientists for the purposes of monitoring the potential ecological risks of excreted pharmaceutical drugs and personal-care products in aquatic environments [15-17]. Following speculation that this method might also be used to monitor illicit drug use [16], wastewater analysis approaches have subsequently been taken up and adapted purportedly to help estimate population-level consumption of illicit drugs. Early studies experimented with this approach by measuring human metabolic residue of illicit drugs in surface water and wastewater entering sewage treatment plants [6-8, 18, 19] (with the latter sampling method recommended for population studies [2]). Since its first experimental application in Italy in the mid-2000s [6], this approach has been used in numerous studies and integrated into drug monitoring systems around the world including in Australia, China, Canada, South Africa, Switzerland, the United States of America, and across Europe and the Nordic states [e.g. 4, 5-7, 20-34]. Data generated from these studies are also now being used to inform the United Nations Office on Drugs and Crime World Drug Report [35]. In a relatively short period of time, wastewater analysis has established itself as a "promising tool" [7] in the illicit drugs field. Indeed, it has been said that "the advantage of adding another tool to the epidemiological toolkit cannot be overestimated" [4].

In the context of illicit drug epidemiology, wastewater analysis involves collecting samples of raw wastewater which are then analysed to measure particular drug metabolic residues. To translate these data into evidence that can made useable and relevant in this specific policy context, total amounts of drug metabolic residues are converted into "average doses" [4]. To estimate the quantity of illicit drugs consumed in a community, expressed as "daily amounts (or daily doses) per thousand population", a back-calculation is performed which takes into account daily flow rates of sewage (to obtain the daily sewer load of metabolic residue), the size of the population served by the treatment plant, the average excretion rate of each drug target residue and the molecular mass of the parent drug/metabolite, and an assumed mean dose [2-4, 36]. The assumed mean dose is the

area of greatest uncertainty. The rationale underlying the approach is that the "concentrations of the metabolic residues of illicit drugs measured in raw communal wastewater can […] reflect the amount of a particular drug that has been used by a population served by a particular sewer network" [36].

The development of wastewater analysis as a technology of illicit drug epidemiology brings together multiple forms of expertise across disciplines, including between analytic chemists, environmental scientists, illicit drug epidemiologists and policy makers. The first multidisciplinary discussions were hosted by the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) in 2007, and considered how these newly developing approaches might be taken up in drugs monitoring efforts in Europe [2]. More recently, there have been efforts to coordinate and standardise approaches to wastewater analysis studies internationally through the establishment of a European network called the 'Sewage analysis CORe group – Europe' (SCORE) in 2010 [30, 37]. In 2013, the SCORE network published a consensus protocol for sampling, analysis and reporting of wastewater analysis studies, which has provided a foundation for the first comparative wastewater analysis studies across Europe [24, 37, 38]. As well as refining and developing the technical aspects of wastewater analysis methods, these discussions have been aimed at ensuring that data produced in different locations and by different research teams are comparable and therefore useful for drug monitoring and surveillance.

The processes led by the EMCDDA have also sought to raise key ethical and legal questions about the use of wastewater analysis in the context of illicit drug epidemiology given the sociopolitical sensitivities and possible risks associated with these approaches, including issues of privacy, consent and data protection [2]. The EMCDDA has noted that the purpose of wastewater analysis studies

ought to be made clear, in particular "whether the findings are to be used in the interests of public health or as part of law enforcement or political control measures" [2]. How these data are put to use (that is, made useful as evidence [39]) in the specific context of illicit drug policy is key to these ethical considerations. Concerns have been raised that data generated through these measures may "form the basis for potentially controversial decisions" [2] in drug policy and be easily misinterpreted by media if results are not carefully communicated. Sensationalised media reporting can perpetuate "stigmatisation and labelling of vulnerable groups, influencing how they are treated by society and the state" and may "generate political incentives to 'get tough' on drug use and crime" [40] contrary to the aims of evidence-based drug policy.

While it has been suggested that using wastewater analysis approaches in the context of illicit drug epidemiology "merely capitalises on science's existing technical capabilities in analytical chemistry" [16], the ethical questions raised by the EMCDDA and others [41-43] point to the ways in which methodological tools can have different effects as they move from one discipline (environmental science or analytic chemistry) and into another (illicit drugs epidemiology) [13]. An established body of critical social science literature in the drugs field has demonstrated why it is important to consider the specific context in which a method is put to use, the veracity of measures, and the socio-political effects of epidemiological approaches [10, 14]. This work has shown how purportedly more accurate measures of 'risk behaviours' often remain blind to complex relations, power and structural violence at work in the social worlds in which harms occur [9, 10]. What a new and 'promising' method might afford and how it might produce 'better evidence' will always relate to its specific implementation and policy context. What is required is critical consideration of how the method is used in relation to the 'problem' it is purportedly addressing. This requires translation work and multidisciplinary dialogue beyond engagement with methods experts, to explore how evidence generated through these approaches might be made to matter and put to use locally in specific policy contexts.

Although wastewater analysis approaches have been taken up with enthusiasm in the illicit drugs field, there are several ethico-political issues deserving of critical attention when we consider how these methods translate into this arena [13]. Our focus here is not on the technical, chemical or methodological uncertainties of wastewater analysis approaches (for these have been documented elsewhere, and continue to be the focus of ongoing scientific development: [e.g. 2, 3, 4, 44-47]). Rather, we wish to engage with some of the critical questions that arise when considering how wastewater analysis approaches are being mobilised specifically *for* and *within* drug policy [13]. These questions move beyond concerns about technoscientific capabilities or the 'promise' of these approaches, to focus on the implications of their use in the specific circumstances of illicit drug policy.

Illicit drug use remains criminalised in most jurisdictions around the world [48]. However, the local context in which drugs are used confers variable social and physical risks (including stigma and discrimination, social disadvantage, violence, and other harms) [49]. The variability of risk conferred in local environments of drug use complicates the potential and possible effects of evidence generated by particular methods as it is mobilised into policy. Features of the 'risk environment' are "ethically significant considerations" that ought to be taken into account when assessing the appropriateness and usefulness of particular research methods [49]. To date, wastewater analysis studies have had little ethical oversight. Wastewater analysis studies generally do not require approvals by human research ethics committees, or are considered to be 'low-risk' [40]. Ethical concerns have been raised about the use of wastewater analysis approaches in the context of monitoring a largely hidden and illegal practice like drug use, especially given that the informed consent of individuals is not required for this kind of research [2, 3]. These concerns have led to the development of ethical guidelines for undertaking wastewater analysis [3, 40] with the aim of fostering ethical practice across this new and burgeoning field of inquiry. An important ethical

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dimension of wastewater analysis is the potential impact on groups of people, and this is not well captured in conventional frameworks governing ethical research with humans, which focus on individuals. For example, a number of studies have used wastewater analysis in small catchment areas such as schools [50, 51], prisons [52-54], and during short term events such as music festivals [55]. However, the recently published ethical guidelines note that there may be risks associated with conducting site-specific studies in settings such as schools, prisons and workplaces [40]. It has been suggested that site-specific studies can be unethical because data may be used to justify the introduction of punitive anti-drug strategies by prison authorities, unfair working conditions, and increase stigmatisation of targeted groups, inadvertently causing harm to participants who did not provide consent [40]. Indeed, these are not hypothetical concerns. In Australia, it has been suggested that sewage would be tested to identify specific geographic areas of high-drug use in order to implement a targeted strategy of drug testing welfare recipients in Australia [56].

While it has been suggested that wastewater analysis ought not raise ethical concerns when used to monitor illicit drug use in large populations [41], our own research has demonstrated that these methods are not simply neutral ways of describing drug use realities and have a range of potentially deleterious political effects [13]. Claims that wastewater analysis approaches are 'more accurate' than self-report survey methods tend to carry weight because illicit drug use is a largely hidden and stigmatised practice, and because people who use drugs are already regarded as untrustworthy, unreliable and undeserving of a meaningful voice in research and drug policy decision-making [13]. Wastewater analysis approaches tend to foster an image of people who use drugs as lacking in knowledge (unable to 'accurately' report on their own drug use) and reinforces an impression of people who use drugs as criminal and in need of surveillance, thus reproducing the stigma perpetuated in popular discourse about drugs [13]. In the context of illicit drug epidemiology, the

more 'scientific', 'direct' and 'accurate' methods of wastewater analysis operate as a means of truth-detection, revealing 'tell-tale' signs of otherwise hidden and illicit practices and populations [13].

It has been suggested that having access to the kind of 'objective' and 'accurate' data generated by wastewater analysis will make a difference to drug policy decision-making and planning, and allow governments to be more responsive to changing needs [3, 4, 29]. However, such a view relies on a range of problematic assumptions about how drugs are understood as a policy problem and how evidence is mobilised in policy decision-making [13]. While other epidemiological methods can provide information about patterns of use, routes of administration, and demographic characteristics of people who use drugs, wastewater analysis approaches cannot provide data about specific drug use practices or harms [13]. Reporting of wastewater analysis necessarily emphasises drug use *per se* (and not drug related harms) as a measure of a 'drug problem' in a community and homogenises drug consumption within that specific geographic location [13]. The erasure of the contextual aspects of drug use is a weakness of any evidence provided by wastewater analysis, as it cannot include any information on the specific, socially situated and contingent practices associated with drug-related risk and harm [57, 58]. Mobilising evidence generated through wastewater analysis approaches shifts the focus of drug policy discussion from harm reduction (where the overarching goal is to reduce the harms associated with drug use without necessarily reducing use per se) to a more narrow and punitive goal of reducing population drug use per se, primarily informing demand reduction and supply reduction strategies. The persistent focus on drug use prevalence as the primary outcome measure used to assess drug policy has been called into question by leading drug policy scholars, as it belies the complexity of patterns of use (not all drug consumption is associated with harm; and even as prevalence decreases, drug-related harms may increase amongst some groups or in some places) [59-61]. Amidst calls to revise the range of indicators used to assess drug policy and more meaningfully evaluate "so-called real-world

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outcomes of relevance to communities" by using measures which better discriminate between "problematic and non-problematic forms of drug use" [62], the narrow focus of wastewater analysis on measuring prevalence is arguably antiquated. While wastewater analysis might be a useful tool for providing information about the size or nature of drug markets in particular spatial locations over time, used as a measure of per capita population consumption these data have the potential to skew the kinds of policy questions which can be asked and the range of responses deemed appropriate by shifting the focus from drug-related harms to the mere use of drugs as evidenced by metabolic residues [13, 62].

So long as the emphasis remains on generating evidence of illicit drug use per se, and not patterns of use or harms, the extent to which data generated via wastewater analysis can meaningfully inform harm reduction, treatment or health service planning is marginal. Even in early discussions about the potential of wastewater analysis approaches for illicit drug epidemiology it was acknowledged that "no single measure provides a full picture of the drug situation" [2]. However, the promise of technoscientific innovation, claims to 'accuracy' and 'objectivity', flexibility, timeliness and cost-savings might mean that wastewater analysis measures are increasingly privileged (and funded) over and above other established epidemiological methods. Ensuring that wastewater analysis approaches are ethically and carefully integrated to complement established methods of drug epidemiology, rather than simply replacing them, is important. While "research in this field is progressing very fast" [4], staying alert to both the potential promise and pitfalls of these approaches as they are mobilised in drug policy discussions and decision-making will be crucial in the coming years. Without comprehensive information about the social, relational and contextual aspects of drug harms, effective drug policy will not be possible.

Acknowledgements

References

1. Castiglioni, S., E. Zuccato, and R. Fanelli, eds. *Illicit drugs in the environment: occurrence, analysis, and fate using mass spectrometry.* 2011, John Wiley & Sons: Hoboken.
2. EMCDDA, *Assessing Illicit Drugs in Wastewater: Potential and Limitations of a New Monitoring Approach*, in *EMCDDA Insights*. 2008, European Monitoring Centre for Drugs and Drug Addiction: Lisbon, Portugal.
3. EMCDDA. *Frequently asked questions (FAQ): wastewater-based epidemiology and drugs*. 2019 [cited 2019 2 April]; Available from: http://www.emcdda.europa.eu/publications/topic-overviews/content/wastewater-faq_en.
** 4. EMCDDA, *Assessing illicit drugs in wastewater: Advances in wastewater-based drug epidemiology*, in *Insights 22*. 2016, European Monitoring Centre for Drugs and Drug Addiction, Publications Office of the European Union: Luxembourg.

The European Monitoring Centre for Drugs and Drug Addiction have led co-ordinated approaches to wastewater analysis studies throughout Europe. This report provides an updated summary of developments in the field.

5. Mastroianni, N., et al., *Five-year monitoring of 19 illicit and legal substances of abuse at the inlet of a wastewater treatment plant in Barcelona (NE Spain) and estimation of drug consumption patterns and trends.* Science of the Total Environment, 2017. **609**: p. 916-926.
* 6. Zuccato, E., et al., *Cocaine in surface waters: a new evidence-based tool to monitor community drug abuse.* Environmental Health, 2005. **4**(1): p. 14.

This was the first experimental study to explore the potential for wastewater analysis approaches to be used to estimate population level consumption of illicit drugs.

* 7. van Nuijs, A.L.N., et al., *Illicit drug consumption estimations derived from wastewater analysis: A critical review.* Science of The Total Environment, 2011. **409**(19): p. 3564-3577.

This critical review was published at a key point in the early development of wastewater analysis approaches in the drug field, and provides a summary of the literature internationally as these techniques were being taken up.

8. Castiglioni, S., et al., *Identification and Measurement of Illicit Drugs and Their Metabolites in Urban Wastewater by Liquid Chromatography–Tandem Mass Spectrometry.* Analytical Chemistry, 2006. **78**(24): p. 8421-8429.
9. Bourgois, P., B. Prince, and A. Moss, *The Everyday Violence of Hepatitis C Among Young Women Who Inject Drugs in San Francisco.* Human organization, 2004. **63**(3): p. 253-264.

10. Bourgois, P., *Anthropology and epidemiology on drugs: the challenges of cross-methodological and theoretical dialogue.* International Journal of Drug Policy, 2002. **13**(4): p. 259-269.

11. Law, J. and J. Urry, *Enacting the social.* Economy and Society, 2004. **33**(3): p. 390-410.

12. Law, J., *Seeing Like a Survey.* Cultural Sociology, 2009. **3**(2): p. 239-256.

* 13. Lancaster, K., et al., *"A more accurate understanding of drug use": A critical analysis of wastewater analysis technology for drug policy.* International Journal of Drug Policy, 2019. **63**(1): p. 47-55.

This was the first paper in the drug policy literature to critically analyse the ontopolitical effects of wastewater analysis, applying poststructural theory.

14. Rhodes, T., et al., *Structural Violence and Structural Vulnerability Within the Risk Environment: Theoretical and Methodological Perspectives for a Social Epidemiology of HIV Risk Among Injection Drug Users and Sex Workers*, in *Rethinking Social Epidemiology: Towards a Science of Change*, P. O'Campo and J.R. Dunn, Editors. 2012, Springer Netherlands: Dordrecht. p. 205-230.

15. Daughton, C.G., *Pharmaceuticals and Personal Care Products in the Environment: Overarching Issues and Overview*, in *Pharmaceuticals and Care Products in the Environment*, C.G. Daughton and T. Jones-Lepp, Editors. 2001, American Chemical Society: Washington, DC. p. 2-38.

16. Daughton, C.G., *Illicit Drugs in Municipal Sewage*, in *Pharmaceuticals and Care Products in the Environment*, C.G. Daughton and T. Jones-Lepp, Editors. 2001, American Chemical Society: Washington, DC. p. 348-364.

17. Calamari, D., et al., *Strategic Survey of Therapeutic Drugs in the Rivers Po and Lambro in Northern Italy.* Environmental Science & Technology, 2003. **37**(7): p. 1241-1248.

18. Zuccato, E., et al., *Estimating Community Drug Abuse by Wastewater Analysis.* Environmental Health Perspectives, 2008. **116**(8): p. 1027-1032.

19. Castiglioni, S., et al., *Mass spectrometric analysis of illicit drugs in wastewater and surface water.* Mass Spectrometry Reviews, 2008. **27**(4): p. 378-394.

20. Bramness, J.G., et al., *Recent trends in the availability and use of amphetamine and methamphetamine in Norway.* Forensic Science International, 2015. **246**: p. 92-97.

21. Been, F., P. Esseiva, and O. Delémont, *Analysis of illicit drugs in wastewater – Is there an added value for law enforcement?* Forensic Science International, 2016. **266**: p. 215-221.

22. Du, P., et al., *Methamphetamine and ketamine use in major Chinese cities, a nationwide reconnaissance through sewage-based epidemiology.* Water Research, 2015. **84**: p. 76-84.

23. van Nuijs, A.L.N., et al., *A one year investigation of the occurrence of illicit drugs in wastewater from Brussels, Belgium.* Journal of Environmental Monitoring, 2011. **13**(4): p. 1008-1016.

24. Thomas, K.V., et al., *Comparing illicit drug use in 19 European cities through sewage analysis.* Science of The Total Environment, 2012. **432**: p. 432-439.

25. Ort, C., et al., *Spatial differences and temporal changes in illicit drug use in Europe quantified by wastewater analysis.* Addiction, 2014. **109**(8): p. 1338-1352.

26. Löve, A.S.C., et al., *Analysis of stimulant drugs in the wastewater of five Nordic capitals.* Science of the Total Environment, 2018. **627**: p. 1039-1047.

27. Archer, E., et al., *Wastewater-based epidemiology and enantiomeric profiling for drugs of abuse in South African wastewaters.* Science of the Total Environment, 2018. **625**: p. 792-800.

28. Bruno, R., et al., *Association between purity of drug seizures and illicit drug loads measured in wastewater in a South East Queensland catchment over a six year period.* Science of The Total Environment, 2018. **635**: p. 779-783.

29. Australian Criminal Intelligence Commission, *National Wastewater Drug Monitoring Program Report 1, March 2017*. 2017, Commonwealth of Australia: Canberra.

** 30. EMCDDA, *Wastewater analysis and drugs: a European multi-city study*, in *Perspectives on Drugs*. 2019, European Monitoring Centre for Drugs and Drug Addiction: Lisbon.

This report documents the largest European study to date using wastewater analysis approaches in a multi-city study.

31. Irvine, R.J., et al., *Population drug use in Australia: A wastewater analysis.* Forensic Science International, 2011. **210**(1): p. 69-73.

32. Banta-Green, C.J., et al., *The spatial epidemiology of cocaine, methamphetamine and 3,4-methylenedioxymethamphetamine (MDMA) use: a demonstration using a population measure of community drug load derived from municipal wastewater.* Addiction, 2009. **104**(11): p. 1874-1880.

33. Metcalfe, C., et al., *Illicit drugs in Canadian municipal wastewater and estimates of community drug use.* Environmental Pollution, 2010. **158**(10): p. 3179-3185.

34. Karolak, S., et al., *Estimation of illicit drugs consumption by wastewater analysis in Paris area (France).* Forensic Science International, 2010. **200**(1): p. 153-160.

35. Research and Trend Analysis Branch UNODC, *World Drug Report 2018 Methodology Report*. 2018, United Nations Office on Drugs and Crime: Vienna.

36. Castiglioni, S., et al., *Testing wastewater to detect illicit drugs: State of the art, potential and research needs.* Science of The Total Environment, 2014. **487**(July): p. 613-620.

37. Sewage analysis CORe group - Europe, *Common protocol of action for monitoring illicit drugs in wastewater* 2013, European Monitoring Centre for Drugs and Drug Addiction: Lisbon.

38. van Nuijs, A.L.N., et al., *Multi-year inter-laboratory exercises for the analysis of illicit drugs and metabolites in wastewater: Development of a quality control system.* TrAC Trends in Analytical Chemistry, 2018. **103**(June): p. 34-43.

39. Lancaster, K., *Performing the evidence-based drug policy paradigm.* Contemporary Drug Problems, 2016. **43**(2): p. 142-153.

** 40. Sewage analysis CORe group - Europe, *Ethical research guidelines for wastewater-based epidemiology and related fields*. 2016, European Monitoring Centre for Drugs and Drug Addiction: Lisbon.

As wastewater analysis approaches have developed, questions about the ethical oversight of these methods have also been raised. This report outlines one of the first co-ordinated attempts to develop ethical guidelines for wastewater analysis studies.

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41. Hall, W., et al., *An analysis of ethical issues in using wastewater analysis to monitor illicit drug use.* Addiction, 2012. **107**(10): p. 1767-1773.

42. Hering, C., *Flushing the fourth amendment down the toilet: How community urinalysis threatens individuals privacy.* Arizona Law Review, 2009. **51**(3): p. 741-776.

43. Prichard, J., et al., *Sewage epidemiology and illicit drug research: The development of ethical research guidelines.* Science of The Total Environment, 2014. **472**: p. 550-555.

44. Castiglioni, S., et al., *Evaluation of Uncertainties Associated with the Determination of Community Drug Use through the Measurement of Sewage Drug Biomarkers.* Environmental Science & Technology, 2013. **47**(3): p. 1452-1460.

45. Lai, F.Y., et al., *Refining the estimation of illicit drug consumptions from wastewater analysis: Co-analysis of prescription pharmaceuticals and uncertainty assessment.* Water Research, 2011. **45**(15): p. 4437-4448.

46. Jones, H.E., N. Goulding, and M. Hickman, *Commentary on Lai et al. (2018): Potential and limitations of wastewater-based epidemiology in monitoring substance use.* Addiction, 2018. **113**(6): p. 1137-1138.

47. Jones, H.E., et al., *Illicit and pharmaceutical drug consumption estimated via wastewater analysis. Part B: Placing back-calculations in a formal statistical framework.* Science of The Total Environment, 2014. **487**: p. 642-650.

48. Bewley-Taylor, D., *International drug control: Consensus fractured*. 2012, Cambridge: Cambridge University Press.

49. McGowan, C.R., et al., *Risk Environments and the Ethics of Reducing Drug-Related Harms.* The American Journal of Bioethics, 2017. **17**(12): p. 46-48.

50. Zuccato, E., et al., *Illicit drug consumption in school populations measured by wastewater analysis.* Drug and Alcohol Dependence, 2017. **178**(September): p. 285-290.

51. Panawennage, D., et al., *Measurement of illicit drug consumption in small populations: prognosis for noninvasive drug testing of student populations*, in *Illicit drugs in the environment: occurrence, analysis, and fate using mass spectrometry*, S. Castiglioni, E. Zuccato, and R. Fanelli, Editors. 2011, John Wiley & Sons: Hoboken. p. 321-31.

52. Postigo, C., M.L. de Alda, and D. Barceló, *Evaluation of drugs of abuse use and trends in a prison through wastewater analysis.* Environment International, 2011. **37**(1): p. 49-55.

53. Brewer, A.J., et al., *Wastewater testing compared with random urinalyses for the surveillance of illicit drug use in prisons.* Drug and Alcohol Review, 2016. **35**(2): p. 133-137.

54. van Dyken, E., et al., *Challenges and opportunities in using wastewater analysis to measure drug use in a small prison facility.* Drug and Alcohol Review, 2016. **35**(2): p. 138-147.

55. Mackuľak, T., et al., *Music festivals and drugs: Wastewater analysis.* Science of The Total Environment, 2019. **659**(April): p. 326-334.

56. Karp, P., *Scott Morrison says sewage will be tested to find areas of high drug use for welfare trial*, in *The Guardian*. 2017: The Guardian News & Media Limited.

57. Rhodes, T., *Risk environments and drug harms: A social science for harm reduction approach.* International Journal of Drug Policy, 2009. **20**(3): p. 193-201.

58.　Duff, C., *The social life of drugs.* International Journal of Drug Policy, 2013. **24**(3): p. 167-172.

59.　Burns, R., et al., *Statistics on Cannabis Users Skew Perceptions of Cannabis Use.* Frontiers in Psychiatry, 2013. **4**(138).

60.　Bewley-Taylor, D., *Refocusing metrics: can the sustainable development goals help break the "metrics trap" and modernise international drug control policy?* Drugs and Alcohol Today, 2017. **17**(2): p. 98-112.

61.　Kilmer, B., P. Reuter, and L. Giommoni, *What Can Be Learned from Cross-National Comparisons of Data on Illegal Drugs?* Crime and Justice, 2015. **44**(1): p. 227-296.

62.　Werb, D., et al., *A call to reprioritise metrics to evaluate illicit drug policy.* The Lancet, 2016. **387**(10026): p. 1371.

Conflict of interest statement

The authors report no conflicts of interest.

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