Independent Expert Panel Review of a Publication on Polymer Biodegradation and Emissions

Prepared by:

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1. Introduction

SciPinion was retained by a confidential client to conduct an independent peer review of a publication on the modeling of polymer biodegradation and potential emission from wastewater treatment plants (Roslky and Kelkar, 2021). In this study, the authors estimated the US nationwide emissions of polyvinyl alcohol (PVA) resulting from domestic use of laundry and dish detergent pods, corroborated by a nationwide, online consumer survey and a literature review of its fate within conventional wastewater treatment plants. Based on their literature search, consumer survey, and modeling efforts, the authors estimated that approximately 17,200 ± 5000 metric ton units per year of PVA are used, with 10,500 ± 3000 mtu/yr reaching wastewater treatment plants. The authors further estimated that ~61% of PVA ends up in the environment via sludge, and ~15.7% via the aqueous phase. The study authors concluded that PVA presence in the environment, regardless of its matrix, is a threat to the ecosystem due to the potential mobilization of heavy metals and other hydrophilic contaminants.

The goal of this review is to: (1) identify the strengths and weaknesses of this study; (2) put the results of this study into context given newer information (Menzies et al., 2022) and the existing decision-making framework used by regulatory agencies for the biodegradation of chemicals.

2. Methods

2.1. Process Overview

Expert panels and peer reviews performed by SciPinion are conducted using the process summarized in **Figure 1**. The peer review is implemented through the use of a SciPi™ (pronounced sī-pī), a series of questions soliciting the experts' ***Sci***entific o***Pi***nions. The peer review process includes the following defined roles:

- ***Sponsor*** – The role of the Sponsor in the review is depicted in red in **Figure 1**. Specifically, the Sponsor can provide the following items: (1) data package (e.g., report, manuscript, data summary, raw data) to be reviewed; (2) minimum and desired expertise criteria for the Peer Reviewers; and (3) draft questions for the reviewers that form the basis of the panel review process (SciPi™). The Sponsor may be the author of the data package, a public or private entity seeking to use the data package to support a decision, or a combination of multiple stakeholders or other entities who seek to use the data package to support a decision. The Sponsor may choose to remain anonymous, known only to SciPinion.
- ***SciPinion*** – The role of SciPinion in the review is depicted in blue in **Figure 1**. As manager of the peer review process, the role of SciPinion is defined by the following tasks: (1) coordinate all other roles; (2) finalize questions included in the SciPi to be asked of the Reviewers; (3) identify and assemble the panel of Reviewers; (4) implement the SciPi™; (4) prepare and finalize a report that summarizes the methods and results of the peer review; and (5) as an

option and at the Sponsor's discretion, SciPinion may post the results of public SciPis to their website (www.scipinion.com).

- ***Peer Reviewers (Expert Panelists)*** – The role of the Reviewer is depicted in grey in **Figure 1**. Peer reviewers are tasked with: (1) reviewing the data package; and (2) participating in the SciPi™ by providing their expert opinions in the answers to the questions. An important aspect of the peer review process at the heart of the SciPi™ is that Peer Reviewers work independently. The one exception to this independence occurs in SciPis with multiple rounds in which peer reviewers interact in later rounds (e.g., Delphi format). The other equally important aspect is the anonymity of the Peer Reviewers—to ensure they are free to offer their unbiased opinion, Peer Reviewers remain anonymous to the Sponsor and to any recipients of the report. Only SciPinion and the Auditor know the identities of the Peer Reviewers.
- ***Auditor (Optional)*** – The role of the Auditor in the peer review is depicted in green in **Figure 1**. An Auditor is retained by SciPinion to independently verify that: (1) Peer Reviewers meet the minimum expertise requirements as defined for the SciPi™; and (2) the submitted responses can be attributed to the SciPinion user accounts belonging to the Peer Reviewers. The Auditor conducts the verification review through an independent audit process not under control of SciPinion or the Sponsor. The Auditor prepares a brief report containing the conclusions of their review. An Auditor was not used for this project.
- ***Editor (Optional)*** – An independent Editor is retained by SciPinion to ensure that the questions in the SciPi™: (1) focus on the science issues associated with the data package; (2) are clearly written; and (3) are not leading or biased. The Editor prepares a brief report containing the conclusions of his/her review. An Editor was not used for this project.

Importance of Anonymity

SciPinion advocates for the use of blinding for its peer reviews, in which the identities of the Sponsor and the Peer Reviewers are withheld. The benefits of anonymity are three-fold: (1) scientists tend to be thoughtful and often introverted and by their very nature may not be willing participants to controversy and conflict; (2) scientists may be reluctant to offer opinions about controversial topics that might make them targets of public and private attacks; and, (3) increased participation by scientists to inform the most important societal decisions that involve influential and often controversial scientific information used to support regulatory decisions. By withholding the Sponsor's identity from the Peer Reviewers, any potential bias towards the Sponsor can be minimized. By providing anonymity to the Peer Reviewers, the Sponsor can expect to receive a minimally biased opinion from the individual Peer Reviewers. For this review the identities of the Sponsor was withheld from the reviewers. The identities of the reviewers were withheld during the panel recruitment and engagement, and were revealed to the Sponsor after the engagement upon delivery of this report. All experts also remained anonymous to each other during online deliberations.

Importance of Independence

SciPinion advocates for the collection of opinions from its Expert Panel Members using a process that ensures their independence. While it is recognized there are many benefits to allowing experts to deliberate in face-to-face settings, this also introduces some potential pitfalls.

Specifically, it introduces social influences that can result in conformity rather than consensus of its members (e.g., groupthink). Some examples of these types of influences include:

- domination of deliberations by an outspoken member;
- magnification of bias (e.g., deliberating panels can adopt more extreme views when influenced by like-minded members);
- reluctance of members to confront or contradict an expert perceived as having higher status;
- domination of deliberations of information commonly shared by members regardless of its importance, at the expense of important information known by few or one member; and
- undue influence of order by which opinions are expressed (e.g., views expressed first are more likely to be repeated and confirmed).

By ensuring the independence of its Expert Panel Members, SciPinion seeks to minimize these influences so that focus can be appropriately placed on the science issues associated with the data package. The goal of the peer review is to improve confidence in the validity of the input received from the Expert Panel Members to support decision-making by the Sponsor or those receiving this peer review report. A follow-up round was included that involved; 1) providing answers to all questions from Round 1 from all experts to each of the experts for their review, and 2) a follow-up round of questions to further elucidate the opinions of the experts. This facilitated the opportunity for the experts to learn from each other.

Compensation

It is recognized that the majority of scientific journals rely upon a peer review process in which peer reviewers are not compensated. Instead, peer reviewers volunteer their time (typically a few hours) for this important service. This is the review model with which most scientists are familiar. However, as scientific manuscripts and their underlying data become increasingly large and complex, a few hours may not be sufficient to provide a robust review, and very few reviewers can be found who are qualified, available, and willing to donate a larger amount of their time to the review process. In these situations, the robustness of the peer review can suffer under a volunteer peer review model. For some peer reviews, SciPinion uses a compensated peer review model, in recognition that: (1) large and complex data sets can require a considerable amount of time to review; and (2) the peer reviewer's time is valuable, and is worthy of compensation. SciPinion adopts a compensated peer review model to add value to the peer review process, increasing its robustness both in terms of the number of scientists participating and the time spent per peer reviewer, so that the Sponsor can have confidence that they will receive a high-quality peer review to support decision-making.

Confidentiality

Due to the sensitive nature of the data under review, all participants in the review were required to sign a non-disclosure agreement as part of their contract.

2.2. Expert Panel

Eight panel members were identified and engaged using the following steps: (1) Panel Recruitment; (2) Panel Selection; and (3) Panel Engagement. Each of these steps is summarized below.

Panel Recruitment

The goal of the panel recruitment is to cast as wide a net to reach out to as many potential candidates as is feasible. Potential candidates were identified as having relevant experience in epidemiology and biostatistics using a variety of sources, including: (1) SciPinion's internal database; (2) searches for authors of recent publications on the topic of interest in online databases (e.g., Pubmed; Google Scholar); (3) searches of profiles on social media databases (e.g., LinkedIn); (4) general internet searches; and (5) referrals. An email invitation was sent to potential candidates, requesting interested candidates to volunteer on www.scipinion.com and upload a copy of their CV and provide a qualification statement for the advertised assignment.

Panel Selection

Based on initial recruitment efforts, 136 candidates applied to this opportunity. 16 applicants were excluded for failing to upload their CV. For the remaining 120 candidates, 5 panel members were selected from this pool of candidates based upon a consideration of objective expertise metrics (e.g., number of publications, years of experience, key word counts in CVs) and their qualification statements provided when they applied to the SciPi. A second round of recruiting was initiated to specifically target expertise in the conduction, interpretation, and application of OECD 301 biodegradation studies. From this effort, 29 applications were received, from which 3 additional experts with specific OECD 301 experience were identified and selected for inclusion on the panel. The panel of 8 experts represent 196 person-years of experience (Average=24.5 years of experience) and average number of publications of 235 manuscripts per expert (**Table 1**).

Panel Engagement

Panel members were placed under contract. A total of 8 topic-specific experts were engaged to the study of Rolsky and Kelkar (2021). The panel was tasked with reviewing this paper, along with a recently published paper on PVA biodegradation (Menzies et al., 2022), and answer initial charge questions. Experts were asked to provide the top three strengths and weaknesses of the paper they reviewed. Confidence in the study of Rolsky and Kelkar (2021) was rated based on a scale of 1 (lowest) to 10 (highest) based on a consideration of 3 factors: (1) Study methods; (2) Study results; (3) Study conclusions/discussion. Because of the short time frame for this project, a Delphi-formatted review was not included. Instead, after reviewing the responses to the initial charge questions, panel members were provided a .pdf file summary containing responses from their fellow panelists, and were tasked with answering follow-up questions. This engagement took place over an approximate 1-week period in November of 2022. Charge questions and expert responses are provided in **Appendix A**.

3. Results and Conclusions

Strengths and Limitations

A summary of the strengths and weaknesses of Rolsky and Kelkar (2021) is provided in **Table 2**. Overall, SciPinion concludes that the weaknesses of this study outweigh its strengths.

Study Quality

To assess study quality, each expert was asked to review the paper and score their confidence in the paper on a scale of 1-10 based for each of the following:

- Conceptual model (pathways and compartments): ***High (mean=7.3±1.8)***
- Model assumptions and equations (e.g., steady-state mass balance): ***Medium (mean=5.3±2.4)***
- Model predictions for polyvinyl alcohol degradation: ***Low (mean=2.8±1.2)***
- Model predictions for polyvinyl alcohol in post-treatment wastewater: ***Low (mean=2.5±0.9)***
- Sensitivity Analyses: ***Low (mean=2.9±1.9)***
- Uncertainty Analyses: ***Low (mean=3.0±0.9)***
- Author Conclusions: ***Medium (mean=3.8±1.6)***

Panel member explanations for these confidence ratings are provided in **Appendix A**. Although a Delphi-format was not incorporated into this review due to time constraints, panel members were asked to revisit their confidence in polyvinyl alcohol degradation and in post-treatment wastewater (components 3 and 4 above) after reviewing input from their fellow panel members. This interaction (i.e., reviewing each other's responses) resulted in a general reduction in confidence, initial were rated "Medium" for these two components (means of 4.4 and 4.1, respectively, and revised to "Low" in their final response (means of 2.8 and 2.5, respectively). Panel members also expressed low confidence in Rolsky and Kelkar's assumption that the adaptation of polyvinyl alcohol-degrading organisms will be minimal in wastewater treatment plants (mean=2.6±1.5).

Overall SciPinion concludes that confidence in Rolsky and Kelkar (2021) is ***Medium-Low (mean=3.9±1.7)***.

Application of USEPA and OECD Guidelines

Questions 3.1 and 3.2 addressed the application of USEPA's and OECD's guidelines to decision-making for polyvinyl alcohol biodegradation. There was near consensus (7/8) for polyvinyl alcohol receiving a "pass" defined for readily biodegradable (**Figure 3A**). For the single "No" response, the panelist adopted a precautionary response and indicated that this conclusion depends upon specific environments. A clear majority of the panelists (6/8) did not feel Rolsky & Kelskar's assumption for the extent of polyvinyl alcohol was valid (**Figure 3B**). A clear majority of the panelists (6/8) believe that actual biodegradation would be higher or much higher, whereas one expert indicated more information on the wastewater treatment location/technology would be needed before making a conclusion, and one expert questioned the ability to scale from lab to treatment facility.

Overall SciPinion concludes that a conclusion of ***readily biodegradable*** is generally supported for polyvinyl alcohol.

Figure 1. SciPinion Peer Review Process

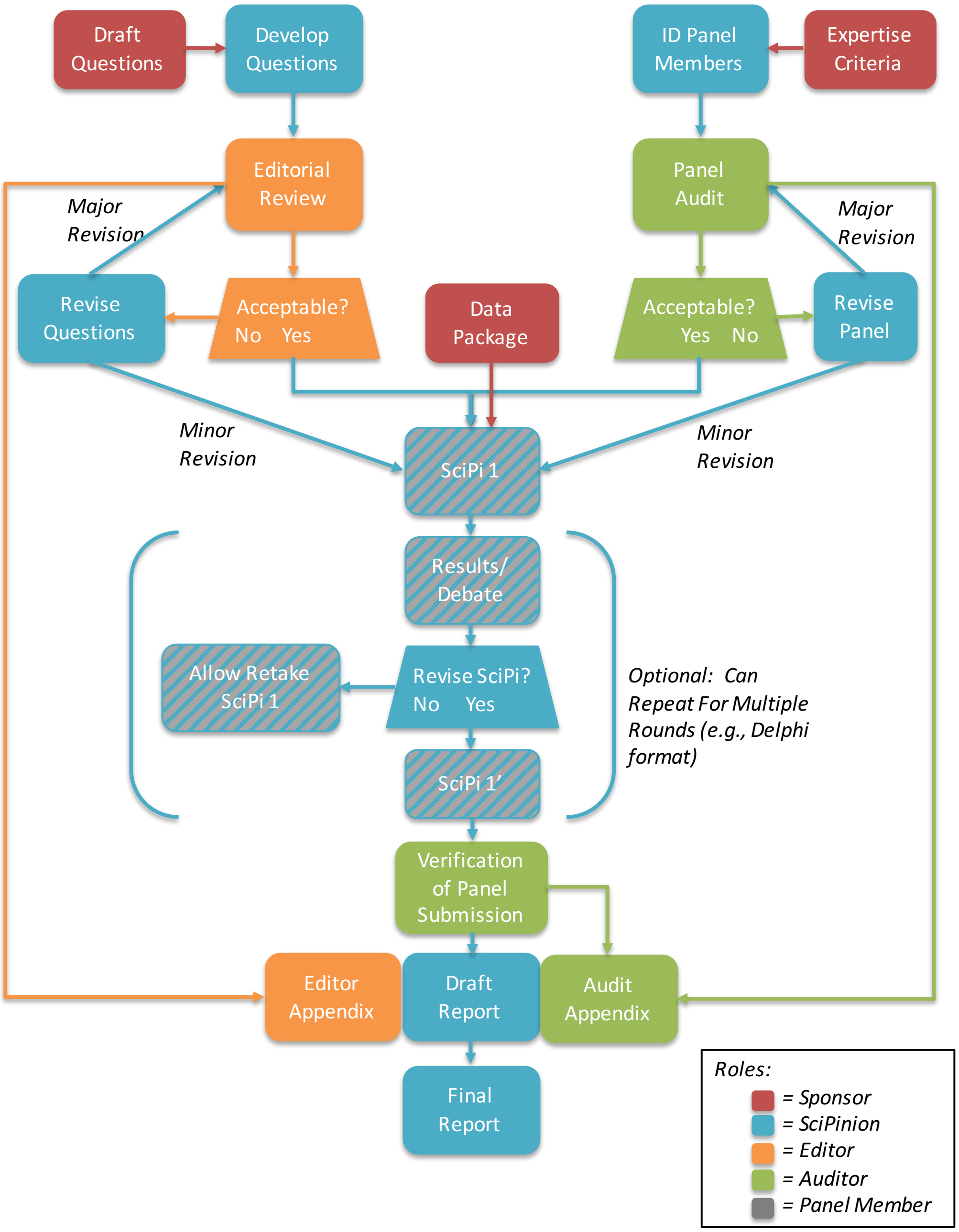


Figure 2. **Mean Reviewer Confidence Rating: Rolsky and Kelkar (2021) (1-10 scale, 1=low, 10-high):** ***Medium-Low (3.9±1.7)***

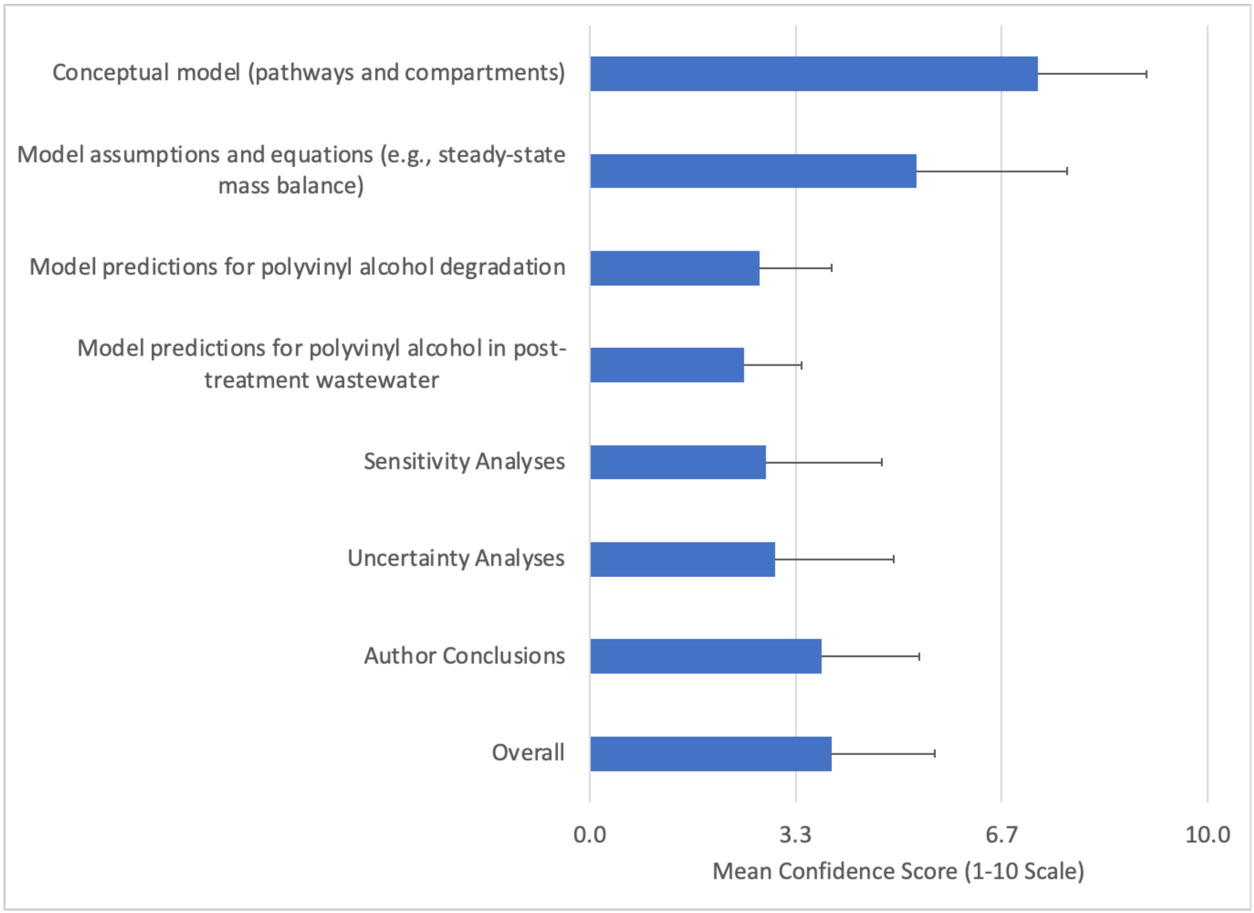
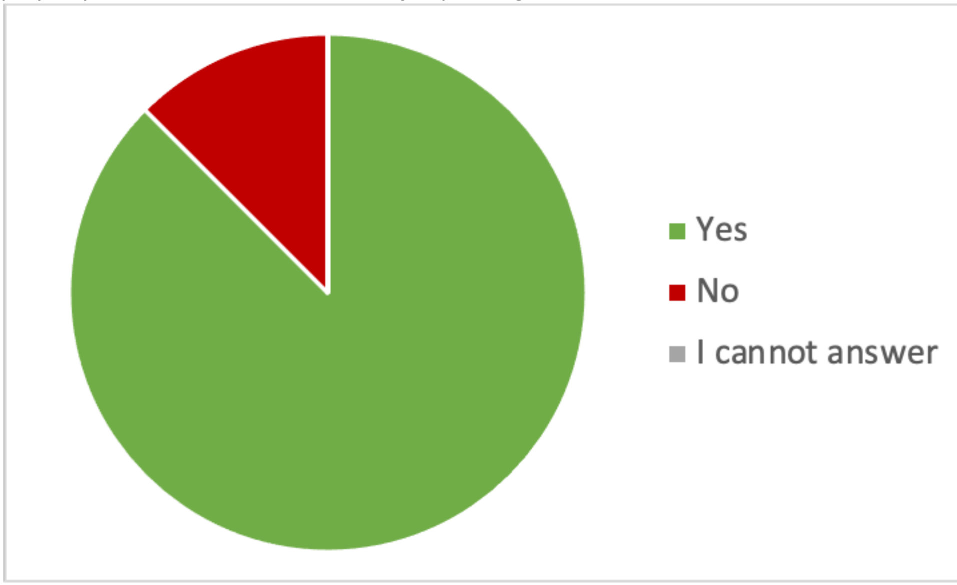


Figure 3: **Application of USEPA and OECD Guidelines**

(A) Question 3.1: USEPA (and OECD) provide guidelines for interpreting and applying the results from biodegradability tests (e.g., OECD 301 and 302 series studies). A "pass" for readily biodegradable is defined below. Based on this definition, and based upon the results of Menzies et al. (2022), do you believe that polyvinyl alcohol meets the criteria for passing?



(B) Question 3.2: The USEPA and the OECD have both provided guidance on how a "pass" results from a biodegradability test should be applied (i.e., using specific half-lives) in modeling wastewater treatment plant fate models. For compounds that are readily biodegraded, the half-lives range from 1 hr (US EPA) to 0.69 hrs (OECD). Based on the recommended half-lives (0.69-1 hr) for modeling readily biodegradable chemicals, is the assumption of Rolsky and Kelkar (2021; Table 2) valid that 1.5-20% of PVA will be degraded from the various treatment sections of a wastewater treatment plant? If no, please indicate if you think the actual percent of PVA biodegraded would be much higher, higher, lower, much lower?

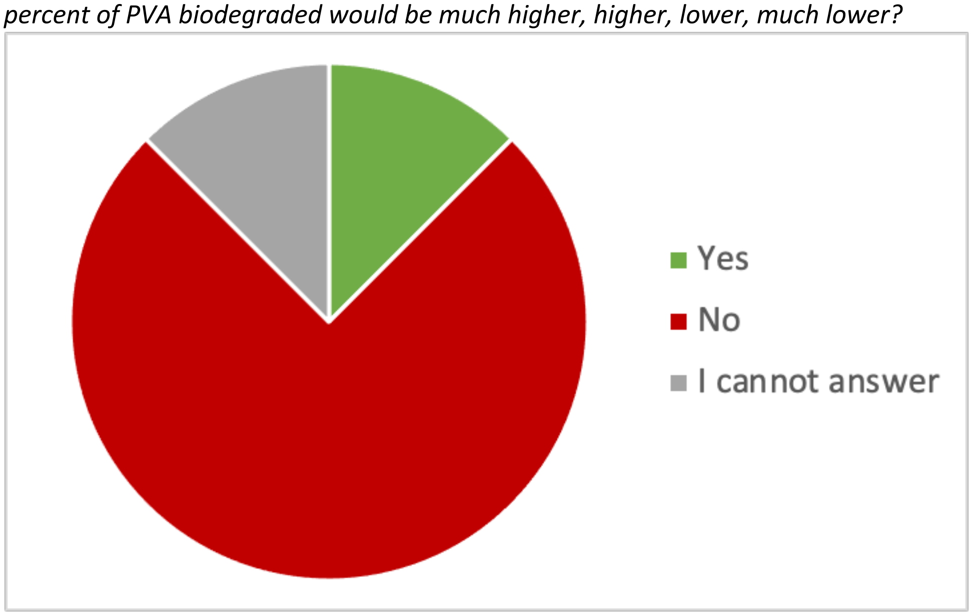


Table 1. Demographics and Expertise Metrics for Expert Panelists

Name (alphabetical order)	Country	Affiliation	Degree	Years Experience	Publications	Application Statement
Dr. Juan Antonio Baeza	Spain	Universitat Autonoma Barcelona	PhD	25	120	- I have publication experience on biopolymer production, specifically on polhydroxyalkanoate - I have experience on respirometric and titrimetric measurements for biodegradation of organic compounds, N and P processes - I have long experience on activated sludge modelling with IWA ASM models - I have publications on modelling of GHG emissions - I have long track record as reviewer and editor of international journals: https://www.webofscience.com/wos/author/record/408140
Dr. C.G. Ginkel	Netherlands	GinkelBiodeg	PhD	40	77	PhD in General microbiology Lots of experience with 301 tests and simulation tests of WWTP (>10 papers) Environmental Chemistry (biological treatment)
Dr. Su Shiung Lam	Malaysia	Universiti Malaysia Terengganu	PhD	10	395	I am currently an editor of Environmental Pollution (https://www.sciencedirect.com/journal/environmental-pollution/about/editorial-board) and have been handling manuscripts related to biodegradation and transport of polymers and plastics. This is in addition to my research team focusing on fate and interaction of plastics (e.g. microplastics, nanoplastics) as pollutants in aquatic and soil environments, particularly their occurrence, transformation and toxicity. Combining with my research work on sustainable management including recycling and conversion of plastic waste, this has led to about 100 manuscripts published on plastics/ polymers in journals.

Dr. Rainer Lohmann	United States	University of Rhode Island	PhD	23	160	fate and transport review of fluoropolymers plastic and pollutants marine pollution
Dr. Oladele Ogunseitan	United States	University of California, Irvine	PhD	24	243	• I am currently the editor of Frontiers in Environmental Science section on Toxicology, Pollution, and the Environment. In that context, I oversee the review and publication of numerous articles on polymers, biodegradation, and environmental fate. • I am considered among the world's top experts on electronic waste (e-waste), including the life cycle analysis of polymers. I recently led a publication in Nature Reviews Materials on bio-based materials to replace the petrochemical-based polymers that are currently used in printed circuit boards, and part of the problem is the environmental recalcitrance of polymers (See: 1) Ogunseitan OA, Schoenung JM, Lincoln JD, Nguyen BH, Strauss K, Frost K, Schwartz, E, He H, and Ibrahim, M. 2022. Biobased Materials for Sustainable Printed Circuit Boards. Nature Reviews Materials. https://doi.org/10.1038/s41578-022-00485-2.) • For more than 30 years, I have conducted microcosm research on biodegradation of notorious organic pollutants. I am credited for the discovery of a strain of caffeine-degrading Pseudomonas putida with a broad spectrum cytochrome-P450 enzyme. For examples, see: (1) Ogunseitan O.A., Tsai Y-L., Delgado I.L. and B.H. Olson. 1991. Effect of 2-hydroxybenzoate on the maintenance of naphthalene-degrading bacteria in seeded and unseeded soil. Applied and Environmental Microbiology. 57: 2873-2879.; (2) Ogunseitan O.A. and B.H. Olson. 1993. Effect of 2-hydroxybenzoate on the rate of naphthalene mineralization in soil. Applied Microbiology and Biotechnology 38:799-807. (3) Ogunseitan, O.A. 2002. Caffeine inducible enzyme activity in Pseudomonas putida ATCC 700096. World Journal of Microbiology and Biotechnology 18:423-428.

Dr. Willie Peijnenburg	Netherlands	RIVM	PhD	34	385	I am an expert in fate assessment of chemicals, including plastics and I have been working on the biodegradation assessment of chemicals and of plastics. Thereupon I have been working in the area of biodegradation prediction. Results have been published in various scientific journals.
Dr. Peter Ryan	South Africa	University of Cape Town	PhD	30	499	Expert on transport and fate of environmental plastics, especially in marine systems Published over 70 papers on the amounts, sources and impacts of plastics in the environment Member of UN's GESAMP working group 40 on marine plastics and SCOR FLOTSAM working group on plastics at sea Currently working on variability in environmental degradation of known-age plastic bottles (HD, PET)

Dr. Niels Timmer	Netherlands	Charles River Laboratories	PhD	10	7	- I work at a CRO where we perform >50 301B, >80 301F, ~10 301D studies each year. I have been working here since 6.5 years and thus have experience with 500-1000 studies. - We regularly work with industry partners to test difficult to test substances, including (cationic) polymers, UVCBs, refined petroleum products, etc. As such, I usually have a good feeling on which measures may supplement the quality of a study, and which measures (or lack thereof) might negatively impact the quality. - I have a PhD in environmental chemistry and my thesis specifically focuses on optimizing 301 and 310 studies for difficult to test materials in the last three chapters. All seven chapters where published and some of this work has been referenced in the recent Cefic-LRI ECO 52 report. - Within my company, I am considered the global expert on the ECHA Annex XV Microplastic Restriction Proposal. I also have knowledge about several ISO Standard dealing with the testing of polymers, and should be able to apply any insights from those designs when evaluating data based on OECD 301-type designs. - I am also involved in the design, performance and reporting of higher-tier studies (e.g., OECD 307/308/309; sometimes OECD 312 and 316, and their international counterparts), where different modeling steps are usually required.
		Total	PhD (8)	196	1886	

Table 2. Peer Review Summary for Rolsky and Kelkar (2021): Strengths and Weaknesses

Strengths	Weaknesses
<u>Expert 1</u> • 1. Rolsky and Kelkar (2021) has provided qualitative, quantitative, and spatial analysis to estimate the emissions of PVA resulting from domestic use of LDPs in US. • 2. The authors provided a comprehensive literature review on removal of PVA in WWTPs, and the amount of waste water treated in USA. • 3. The authors compiled the amount of treated of untreated water and the degree of PVA degradation in the treated waste water, and visualised the environmental emissions of PVA in every USA states. <u>Expert 2</u> • 1. Estimates the possible environmental release of PVA from laundry and detergent pods in the USA • 2. Clearly outlines the basis of the estimate (although variance estimates are not well explained; see weakness 2)" <u>Expert 3</u> • 1 - This paper presents an impressive integrated model of emissions, fate, and environmental emission of polyvinylalcohol via the effluent of WWTPs.	<u>Expert 1</u> • 1. Lack of concrete evidence in supporting the research results especially on the amount and degree of degradation of PVA in treated waster water. Some of the data from the method cannot be found in the Results & Discussion section. For example, the data/graph/figure on the GIS and Mapping cannot be found. The outcome resulted from the Equations (7 & 9) might be inaccurate and not representative since the authors adopted the outdated data (i.e. 2015 state-wise population numbers from the USGS report) for calculation. Hence, the overall estimate obtained might be overestimated or underestimated. The responses obtained from the online survey seems vague. The authors mentioned ""60% of the responses were from the top 20 designated market areas (DMAs)"", however the authors did not specify what and why are these DMAs. • 2. Reviewer did not find much novelty in this publication. This publication hardly advanced the understanding of PVA degradation and emissions in the USA as most of the data were derived from existing literature. • 3. The method use in this study is quite brief and unclear. For example, Section 2.4. How the GIS and Mapping were performed? What are the parameters involve for the GIS and Mapping? What do you mean by collecting data from outside sources? Please be more specific. It was not clear how authors derived and processed some of their data. For example, the data source of US states and environmental emissions of PVA was not given and the numerical values of the fractions of PVA in laundry and dish pods in equation (8) were not given. Very unclear description of the research methodology. Each method and equation were not properly defined and explain. For example, how the authors calculate the mass balance in Fig 2? How the environmental release in Fig 4 was measured? <u>Expert 2</u> • 1. Consumption estimates appear to be based on a modest online survey (527 respondents); no data are given on how representative this sample was of the US population (just a sex ratio and age range). I wondered why industry production data were not used to estimate PVA use in these products - perhaps these are not readily available? They would provide a much better estimate of the amount of PVA used in the production of laundry and detergent pods in the USA. • 2. There is limited attempt to account for the considerable uncertainty inherent in the gross extrapolation to reach a national estimate of PVA leakage. The basis of various error terms is poorly explained; indeed, even the meaning of the "±" term associated with most estimates is not explained. It is specified as being standard deviation in relation to the average retention in sand filters (Table 1), but not for any other error terms. I assume the authors mean them to be 'plausible bounds' for estimates, but it is likely that a more robust assessment would yield a much greater uncertainty around the final values, given the lack of confidence in parameters used throughout the model. That said, lack of certainty in the estimate should not detract from the broad message of the paper - the current best estimate is that a substantial amount of PVA is entering the environment in the USA alone. It is true that the amount inferred by Rolsky and Kelkar (2021) might overestimate actual leakage, but it could equally be a substantial underestimate. • 3. The spatial analyses (state-by-state use and release patterns) appear to be based entirely on differences in human population size and waste water treatment practices (i.e. relative proportion of untreated vs treated waste water). It is not clear how the per capita state-by-state emissions are estimated (Fig. S2). The signal range shown in Fig. S2 (3.7-5.2

• 2 - The model is simple in design and this is in itself a major positive achievement. Related to this, a key strength of the model described in the paper is that it can also be applied to other chemicals of emerging concern.
• 3 - The key research needs are clearly presented.
Expert 4
• 1. The most important strength of the article is the integration of multiple sources of data to generate a seemingly coherent conclusion about the discharge of polyvinyl alcohol into the environment through wastewater discharges. Data were collated from published results of research one the rates of PVA degradation through various wastewater treatment processes, and these results were complemented with information gleaned from a limited survey of households in the United States to estimate PVA loading into wastewater streams. Finally, information from 'typical' discharges of treated effluent and sludge was used to generate approximate proportions released into each compartment. Such studies require a wide range of methodologies, and the authors are to be commended for the research approach.
	mtu/yr/100,000 people) is trivial relative to the uncertainty in other input parameters, and had I been asked to review the paper I would have suggested dropping this figure.
	Expert 3
	• 1 - The first weakness is the parametrization of the model and the way in which in some cases the literature is interpreted. As an example: On page 7 - lines 6 and 7 - reference 36 is used to support the claim of PVA being 'likely' eliminated from the aqueous phase. Reference 36 has, however, nothing to do with PVA.
	• 2 - Probably the top weakness is presented in sub-paragraph 3.2.1. where it is stated that adaptation of PVA-degrading organisms is likely to occur only in WWTPs receiving a heavy influx from textile industry. It is fully ignored that actually all WWTPs - except industrial ones - are receiving continuous inputs of large quantities of PVA. It is thus highly likely that adaptation of the microbial community to PVA degradation, has occurred in domestic WWTPs across the USA. The extent of biodegradation used to feed the model, might thus be an underestimation of the actual amount of PVA biodegraded in a WWTP.
	• 3 - In general terms, the model suffers from validation on the basis of measured PVA levels in influent and effluent of WWTPs. Especially effluent concentrations are of relevance in this respect.
	Expert 4
	• 1. The most important weakness of the article is the section on ""Online Survey"". The weakness is sufficiently serious that it jeopardizes the usefulness of the results from that section and how it is integrated into the other methods. The sampling of the population surveyed is not described, and there could have been selection biases introduced. The overall response rate was not discussed. The survey questions (in the supplemental section) were not piloted or vetted. Critically, there is no evidence that the authors sought institutional review board (IRB) approval for the study. It is surprising that the journal editors allowed the manuscript review to proceed with the following designation ""Institutional Review Board Statement: Not applicable"" as stated on page 13. Studies with human participants have to be reviewed and approved, even if it is designated as ""exempt"".
	• 2. The second weakness is that the study was funded by ""Blueland"" which is a company that sells products that are not packaged with PVA, in direct competition with companies that utilize PVA packaging of detergents. In fact, Blueland advertises their products specifically on this point. We do not learn this fact until the end on page 13, and a reader will have to go online to find out what ""Blueland"" is and why the company is funding this research even though they claim not to use PVA. Shockingly, on page 13, the authors declare two seemingly contradictory statements:
	  • Acknowledgments: This work was supported in part by Blueland. Their sponsorship and critical input greatly assisted with the study. We thank Shireen Dooling for her assistance with graphic design.
	  • Conflicts of Interest: The funders had no role in the design of the study; collection, analyses, or interpretation of data; writing of the manuscript; or decision to publish the results.
	  • The reader is left to wonder what constituted ""critical input"" under the acknowledgments section.
	• 3. A third weakness is the section on filtration, and comparison with pharmaceutical compounds with known log Kow values. The prediction of PVA behavior is not compelling. The accompanying Table is not well described (for example, a reader has to go find out what ""RE (%)"" means). The weakness in this section is an example of general weakness in the execution of the

• 2. A second strength of the article is the section on modeling of water use and wastewater generation in the United States. The model is not too sophisticated and it is explained through equations, and the assumptions are mostly well described. • 3. The third strength of the article is the use of Figures to complement the text. The Figures contain pertinent information such that readers who may not be experts on each of the various methods used can visualize how the integrative research approach worked together to generate the conclusions in the final figure about modeled usage and emissions of PVA into various applications. <u>Expert 5</u> • 1) A thorough review of the use, purchasing patterns and mass flow of PVA from consumption into wastewater and its likely fate across different untreated or WWTP treatment processes. • 2) Establishment of first model of PVA fate through literature review of likely degradation and coupling to a WWTP mass balance model • 3) Extrapolation of results across the US, by relying on GIS data. <u>Expert 6</u>	study and the conclusion of approximate proportions instead of conducting sensitivity analysis and better, more quantitative, clarification of uncertainties and assumptions. <u>Expert 5</u> • 1) The conclusions are often very speculative, such as the ability of the PVA to mobilize heavy metals or pharmaceuticals, and cause their enrichment in the food chain. • 2) The extrapolation is very generic, as WWTP plant operations vary tremendously across the US, and this is not captured in the current Figure 3 panels. • 3) There seems to be a math problem, 34 billion gallons daily across 16,000 WWTPs yields 2.12 million gallons daily per facility. The text claim 2.21 billions daily per facility. <u>Expert 6</u> • The model contains several sources of potential bias/confounding. An online survey with 527 respondents is used to estimate LDP use across the entire US, which is not sufficiently robust; I estimate at least 10,000-20,000 respondents are needed for any decent statistical power. Online surveys could have selection bias towards a demographic more likely to use LDPs. The authors assume each WWTP in the US has the same capacity. While such a simplification is understandable, it will likely lead to overestimation of effects in populous states (which are likely to have a higher proportion of very large WWTPs) and underestimate effects in rural states (which are likely to have a relatively high number of relatively small WWTPs). The different sources of bias/confounding could reinforce total bias/confounding in some states, depending on the combination between population density and socioeconomic make-up. • There is high variability in the dry weight recorded for LDPs, especially laundry pods (1.0 +/- 0.6 grams). Pods from three laundry and two dish pod brands were evaluated, which seems like a very small sample size (especially considering the high variability in recorded dry weight). While the PVA output estimates contain an error margin, this margin is much smaller than the error margin for the dried pods. It is not clear how the error margin for PVA output estimates is calculated, but it appears that the error margin in the dry weight determination was disregarded or underestimated. • The authors state that adaptation of activated sludge requires a long lag-time and heavy influx from textile industries. The last part of that statement is quite perplexing, I truly wonder what kind of research is required to conclude that heavy influx from textile industries is an absolute requirement to obtain adapted micro-organisms. More importantly though, the statement of the authors about long lag-times is not in agreement with the generally accepted phenomenon that continuous influx at any relevant concentration would lead to adaptation of activated sludge. This concept is actually supported by the text in Chapter 4 of the manuscript itself, where 10 % of total PVA is captured in return activated sludge, which means that even with semi-continuous influx the sludge will be continuously exposed to relevant concentrations of PVA. <u>Expert 7</u> • Predictions of a model are only as good as its parameters. 1) Data used to estimate anaerobic and aerobic biodegradation in digesters and aeration tanks, respectively, are not very useful (blends tested, often not clear what polymer was tested, test periods too short (e.g 100 hours when testing anaerobic degradation), no continuously-fed activated sludge test (experiment), no regulatory tests, etc. Recently excellent data obtained with OECD tests became available (Byrne et al 2021). • Little understanding of wastewater treatment systems hampers data interpretation. For instance the following stated in the paper is not correct: ""¬®The average hydraulic retention time (HRT) in the ASP is approximately 18,Äì24 h, and the sludge

• All stages of the WWTP are evaluated separately for their ability to degrade, remove, and disperse PVA. Although the authors could have included a more thorough assessment of AOPs, the approach is robust and very informative. I would welcome such an approach for any kind of (modelled) assessment of WWTP removal efficiency. <u>Expert 7</u> • Conceptual model <u>Expert 8</u> • Survey generating information for the estimation of PVA used by domestic users in the USA. • Literature review of works studying PVA degradation in WWTPs. • Attempts to summarize the fate of PVA in wastewater in the USA, including treated and untreated flows, and the fate of PVA in a WWTP, including fractions in effluent and sludge.	retention time (SRT) is 12,Äì15 days [42]. Due to the hydrophilic nature of PVA, the majority of PVA is expected to be in the water phase, in which the HRT would subsequently play a larger role in its degradation.¬® The HRT is only indirectly important in activated sludge systems because the HRT influences 1) the load and thereby the F/M ratio and most importantly the SRT and 2) the operation of the settling tanks which might result in varying sludge concentrations and thereby the SRT. Primarily SRT and growth rate (doubling time) of competent microorganisms (those degrading PVA) determine the removal of a specific substance water-soluble and water-insoluble alike. When the doubling time of the competent microorganisms is higher than the SRT no degradation will occur. In other qords, the competetnt microorganisms will be washed out of the reactor. Schonberger et al does contain most likely the most useful data as for instance monitoring data of a full-scale plant. This is little valued by the authors. • The rate of biodegradation is inversely correlated to the degree of adsorption (Chielini et al 2006). This is not clearly explained whereas this might explain some of the test results showing little degradation. <u>Expert 8</u> • Figure 2 represents the mass balance of PVA in a default WWTP. Some basic errors are detected that can produce important changes in the estimations. The most important error appears at the bottom outlet of the secondary clarifier. If 48 is the total output of concentrated sludge, the PVA distribution should be based on the flow rate, but it is not. The return activated sludge (RAS) flow is usually around 50% of influent flow, but the waste activated sludge (WAS) flow should normally be lower than 1% of the influent flow. This would lead to about 1/51 of the PVA in the WAS versus 50/51 in the RAS, because the PVA content will be based only on the respective flows, since the composition of the RAS and WAS is the same. These values are very different with respect the reported values (10 and 38). Even if the sludge can adsorb and concentrate PVA on its surface, that gives the possibility for the activated sludge to degrade more PVA in the aeration tank. Hence if the 20% removal is maintained, the absolute removal will be higher because the concentration in the reactor will be higher (dissolved + adsorbed in the sludge). This error also implies that the PVA finally in the effluent of the anerobic reactor will be lower and will depend mainly on the fraction separated in the primary clarifier. Furthermore, the assumptions made on page 10 appear to be arbitrary and based on non-relevant works, as for example reference [50] that describes anaerobic treatment at 37 ¬∫C reporting 20% degradation of PVA, but this value is used as reference for the aerobic conditions of an activated sludge system. • The equation for wastewater generation (Equation 2) considers 20% losses of wastewater in volume. This estimation appears to be based on data from reference [27], but this reference reports data from India, which does not necessarily share similar values to the USA. Moreover, the calculations of treated/untreated wastewater are incorrect. Wastewater generated (equation 2) is supposed to be 80% of the water supplied for public, domestic and industry use. Then, overall losses should always be the rest (20%). However, the authors estimate the wastewater treated based on the number of WWTPs per state and an average size USA-WWTP (equation 3). The size of cities of each state is not considered, which will have impact on the size of the WWTP. Then, using equation (4) for the calculation of untreated wastewater is only reflecting the error that is generated by considering an equal size for all WWTPs. A very clear example, considering that Los Angeles WWTPs are of the average size will imply the estimation of a huge amount of untreated wastewater being generated. Then, the information reported in Figure 3 appear to be useless. Moreover, if 34 BGD of wastewater are treated daily by 16,000 US WWTPs, the average flowrate treated per plant should be 0.0021 BGD/WWTP, and not 2.12 BGD/WWTP, as reported in equation (2). In any case, the use of an average size per WWTP is an inaccurate generalization.

	• P7. Section 3.2.1. The works reported in this section do not appear to be representative of what is happening in an urban WWTP. There are no data on full-scale WWTPs with PVA input and output. The removal performance is a very rough estimate. It is my understanding that this information is not available and therefore the estimates are not accurate. I have tried to find examples of this type of operation in the literature, but they do not appear to be available. Long-term pilot or full-scale operation under relevant environmental conditions would be necessary to have reliable data. Long-term operation with significant input of PVA would be necessary to enrich the microbial community in PVA-degrading microorganisms. Otherwise, testing biodegradability in non-acclimated biomass would give unreliable results on what is the possible PVA removal in a full-scale WWTP. In any case, accurate estimations of the real emission of WWTPs in USA would require measurement of PVA concentrations in the effluent, developing reliable analytical methods if the concentrations are very low. Two additional limitations: i) information of industrial use of PVA is not included, and its possible emissions by industrial WWTPs are not considered. The composition of industrial effluents can be very different to that of domestic wastewater. Ii) Wastewater considered to be treated in WWTPs is calculated based on water supply (Equation 1). If separate stormwater collectors are not used, it is expected that some of the wastewater treated will be mixed with rainwater before entering the WWTP, which could dilute PVA concentration.

*See Appendix A for complete input from the expert panel