A Failed Quest

The windmill is still standing. My quixotic quest to get a very flawed journal article retracted has come to an unsatisfying end. The paper now bears a second correction. Despite the significant math errors, despite the methodological mistakes, despite my efforts, the authors and the editors chose not to retract the paper. I shared the story of my failed quest at the American Chemical Society National Meeting. I've included a lot of detail creating a document that is longer than I would like. That detail is necessary to make the case that the author's responses are inadequate. The severity of the errors in both math and method warrant a restatement of much of the paper and, in my opinion, a retraction.

My quest began when I read about flame retardants getting into food-contact items. Reporting stated that toxic flame retardants were present in dangerous levels in 85% of black plastic items. The toxins were present due to inclusion of recycled content. Black takeout containers immediately came to mind. I was concerned that my favorite Indian takeout could be silently dosing me with brominated flame retardants. Recycling creating dangerous exposure to flame retardant was concerning. Headlines like "Black Plastic Kitchen Tools Might Expose You to Toxic Chemicals. Here's What to Use Instead" from the *New York Times* and "Throw Out Your Black Plastic Spatula" from *The Atlantic* began to appear. Spatulageddon was on. My deep dive was a response to the sensational headlines such as "toxic flame retardant chemicals were found in 85% of analyzed products". The headlines were not due to confusion among well-intentioned science journalists, the quote was lifted directly from the press release. The PR machine of Toxic-Free Future was responsible for the media picking up the story.

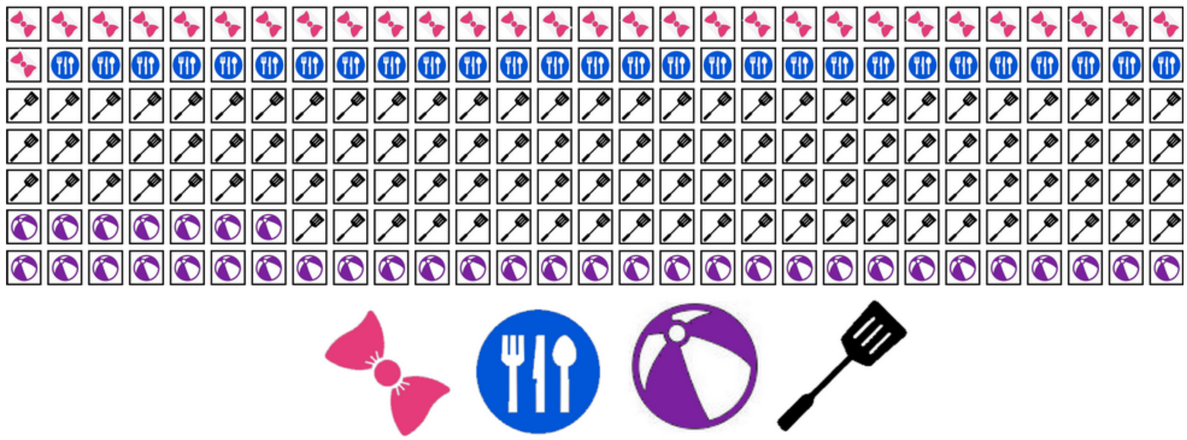
I went to the source, the *Chemosphere* article. *Chemosphere* is a peer-reviewed academic journal from the well-respected publisher Elsevier. As I carefully read the article, several very obvious math errors became evident. I pored over the paper's supplemental information. To my surprise, the risk of exposure to toxic flame retardant chemicals was negligible, zero. I wrote an article that published in *R&D World*. "Pull those black plastic spatulas out of the trash" published in January 2025. It got a little notice with others referencing spatulageddon but the black plastic damning articles continued to appear.

I felt I had to do more. I reached out to *Retraction Watch* and got a courteous, though somewhat unsatisfying, response. The first response was that *Chemosphere* is a discredited journal, recently removed from *Web of Science*. As such, it didn't warrant effort to correct. No one should believe it after the recent history of shoddy acceptances. Further email exchange pointed me to the Committee on Publication Ethics, *Guidlelines: Retraction Guidelines*. There are clear guidelines for what warrants a retraction, most dealing with ethical behavior, not mistakes. Mistakes are addressed: retraction is warranted if "clear evidence that the findings are unreliable, either as a result of major error (eg, miscalculation or experimental error), or as a result of fabrication (eg, of data) or falsification (eg, image manipulation). There are major errors both miscalculations and experimental error. This publication, I was sure, was ripe for retraction.

I wrote to the editors seeking a retraction. I'll pick up this thread later. For now, let me go through the errors and the mistakes, what is covered in the two corrections and why I am certain they are insufficient. I remain convinced the work should be retracted.

Background:

The paper, "From e-waste to living space: Flame retardants contaminating household items add to concern about plastic recycling", by Liu M, Brandsma SH, Schreder E., *Chemosphere*. 2024 Oct 1;365:143319, set out to do something quite reasonable. The work looked at a collection of purchased items to determine whether there was a risk of exposure to brominated flame retardants. The 203 items collected could be lumped into four categories, food service, kitchen



Graphical summary of the 203 total items used in the study. They included 109 kitchen items, 30 hair accessories, 28 food service, and 36 toys.

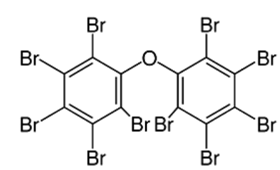
items, toys and hair accessories. More than half of the collected items were kitchen items. The entire collection of items were subjected to analysis by XRF to measure bromine level. This screening was used to eliminate those items with low bromine levels and the twenty highest bromine levels were subjected to more thorough analysis by LC-MS. This analysis allowed identification of the particular compounds present. As other studies have shown, brominated compounds that were no longer being used, in some cases banned, were present. None of the items collected required flame retardancy. They should not have been there.

Flame retardants are required in electronic items, things that are durable goods. The styrenic polymers, most notably ABS. Computer cases, TVs, keyboards, power supplies and such all require flame retardancy. There is a desire to recycle these products. Because the products are durable, they can spend a long time in use. That means products that are no longer in use may be present in the recycle stream. Having those products recycled into other items requiring flame retardancy may still pose some issues, but the real issues, the issues exposed in work like the paper in question, is recycling into items that do not require flame retardancy. Having recycled flame retardants present an exposure risk would be problematic. "From e-waste to living space" performed an analysis to estimate potential exposures. The study and subsequent press releases address the likely exposures caused by the presence of flame retardants and compare them to reference dose levels in drawing the conclusion that there is significant contaminations. The analysis performed addresses whether black plastic presents an unacceptable risk due to presence of flame retardants brought in through recycling. Determination requires two pieces of information, the level of exposure that represents acceptable risk and whether exposure from use of black plastic articles exceeds that level.

XRF analysis eliminates 183 of the 203 collected samples. Only 20 samples are retained for compound-specific LC-MS analysis.

Corrigendum One:

The compound decabromodiphenyl ether, also known as deca-BDE or BDE-209, was a focus of much the analysis. It was recognized in the Stockholm Convention as a persistent pollutant and phased out. It was widely used. Its presence in current items was viewed as particularly damning. The work concluded the potential exposure was 34,700 ng/day. The work compares this level with the EPA reference dose, used as a measure of exposure from dust and diet. It is, in essence, used as a measure of a safe exposure. The reference dose was reported as 42,000 ng/day.



Decabromodiphenyl ether, also known as deca-BDE or BDE-209, is the brominated flame retardant most discussed in the paper. It was banned by the Stockholm Convention and has not been used in over a decade.

There was a simple math error in calculation of the reference dose. The actual EPA reference dose is 420,000 ng/day, 420 μg/day. Rather than the dose being equal to the reference dose, it was at least 10 times less. This resulted in Corrigendum 1 which appeared in February 2025.

The error was not deemed sufficient to retract the work and the authors stood by the conclusions.

Additional Errors of Math and Method:

The correction does not delve into the errors that first caught my attention. They are both errors of method and math.

The study draws a distinction between *screening* and *analysis*. It is a distinction without merit. The XRF study of all 203 items was used to eliminate all of those with negligible bromine content. The eliminated materials, because they contained no bromine, could not contain brominated flame retardants. The 20 items that were not eliminated were those with the highest levels of bromine. Yet, only 17 of the 20 items, 85%, contained measurable levels of brominated flame retardants based on the compound-specific LC-MS analysis.

I will draw an analogy. Suppose these methods were used for measurement of the sugar levels in canned soda. Assume that a collection of 203 canned sodas were collected. Further assume that half were diet sodas. Screening by total calories, which could come from sugars as well as other components. Retaining only the highest caloric content would eliminate all the diet sodas and, in my version of the thought experiment, retain only Mountain Dew and Dr. Pepper. Analysis of the 20 retained cans for sugars produces a very skewed representation. The calculated average value would be off by at least a factor of two. The analysis would show that 85% of the sodas consumed were above 3.5 g/fluid ounce (those are the units commonly used). The reality would be that 50% of the consumption contained no sugar. The results that 85% of the soda consumed is about 3.5 g/fluid ounce would be an error of method. Screening using a technique that relates directly to the measurements being done is a flawed methodology. In the case of the brominated flame retardants, the screening was pertinent and those eliminated samples should have been considered. The combined screening and analysis, following the work's labeling, showed only 8.4% of the 203 samples collected had elevated brominated flame retardant levels.

Now back to the analysis done in the paper. 20 samples were analyzed for BDE-209. The measurement was of concentration. Concentration is the direct measurable. The work sought to determine the likely exposures due to the presence of BDE-209 in the objects. Just because a compound is present, it doesn't automatically equate to an exposure. Indeed, flame retardants used in computer equipment, phones and other electronic devices have not been shown to be sources of exposure.

Exposure = α * Concentration

Exposure can be estimated using the correlation and the coefficient determine by Kuang et al.

Connecting exposure and concentration requires a correlation. Luckily, previous work by Kuang and coworkers, Kuang J, Abdallah MA, Harrad S. "Brominated flame retardants in black plastic kitchen utensils: Concentrations and human exposure implications. ", *Science of The Total Environment.* 2018 Jan 1;610:1138-46, provided a correlation. Exposure was proportional to concentration in the correlation developed.

$$\text{Average Exposure} = \frac{\Sigma(\text{Exposure})_i}{N} = \frac{\Sigma(\alpha * \text{Concentration})_i}{N} = \frac{\alpha * \Sigma(\text{Concentration})_i}{N}$$

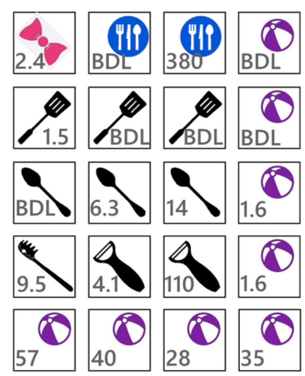
Order of operation doesn't matter in calculation of mean and median exposures.

The Kuang work looked at kitchen items and found brominated flame retardants. Their method took samples from random spots on the items. In attempting to look under realistic conditions, they looked at retardants leeching into food in use. They estimated exposure for items used in hot oil, developing a correlation linking concentration and exposure, the correlation used by Liu and coworkers. Under normal handling, Kuang concluded there would be no exposure. Brominated flame retardants present did not create exposure by touching.

In the Liu work, the correlation developed for immersion in hot oil was applied to all items. The median and average exposure were calculated from the median and average concentrations. The simple correlation is commutive. Order doesn't matter.

Twenty items were in the analysis cohort after eliminating 183 items with low bromine levels through XRF. Tables S5 and S6 detail the measured compounds. BDE-209 became the focus and the compound highlighted in the abstract and discussion. BDE-209 is one of the first flame retardants pulled from the market. Use in the U.S. ended in 2013.

Table S6 reports the average concentration of BDE-209 at 1095 mg/kg for all 20 items in the cohort. Applying the correlation to calculate an exposure produces an estimated exposure of 34,700 ng/day. The abstract and paper report "Estimation of exposure to BDE-209 from contaminated kitchen utensils indicated users would have a median intake of 34,700 ng/day". This is an error in math. Rather than being the median only of the kitchen utensils, all 20 items including toys and hair accessories were averaged and reported as kitchen items. The actual median of the kitchen serving items is 4,100 ng/day, more than 100 times less than the EPA reference dose. Far from being close to equal and cause for concern, had the reference dose been accurately reported and the median value correctly reported, this would not have been a newsworthy story.



BDE-209 exposures calculated in ug/day found in the 20 products analyzed. These are the values calculated in the original analysis The average concentration for the products shown is 34.7 μg/day when below detection limit, BDL, samples are input as zero.

At this point, three errors have been highlighted:

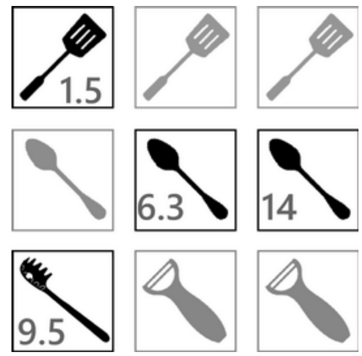
1. The reference dose was reported a factor of 10 too low and rather than being on par with a concerning exposure was more than 10 times less

2. 183 samples were ignored in spite of having analyses done indicating negligible levels of brominated flame retardants
3. The reported median exposure for kitchen items was actually a mean estimated exposure for all items in the 20-sample cohort including serving items, toys and hair accessories

It does, however, get worse and I've foreshadowed why.

Corrigendum 2:

Liu and coworkers applied the Kuang correlation to connect concentrations with potential exposures even though the correlation was only valid for items used in hot oil. Application to the hair accessories and toys was clearly in error. Application to kitchen items not used in hot oil is also in error. Remember, the Kuang work concluded exposures by normal handling would be zero. The correlation was applied incorrectly. This is what my letter to the editor called out suggesting that the error in methodology was sufficient to warrant retraction.



BDE-209 exposures calculated in μg/day found in the 9 products analyzed after excluding those determined not to be used in hot oil by the authors in Corrigendum 2. The peelers were excluded due to not being used in hot oil. All items below detection limit were ignored, not entered as zero. The calculated average is 7.9 μg/day.

The authors did not agree. Corrigendum 2 recalculates the potential exposure from kitchen items by excluding only peelers. Inexplicably, all items below the detection limit are simply ignored. The result is an average of a spatula, two spoons and a pasta server. Included in the analysis are the following samples:

S5	slotted turner
S7	basting spoon
S9	pasta server
S10	slotted spoon

Excluded from the revised analysis are:

S4	slotted spoon
S6&8	slotted turner
S11&12	peeler

Now, rather than reporting a median value, they report a miscalculated mean daily exposure of 7.9μg/day. Recall, the initial work cried foul because the median exposure was too close to the EPA reference dose. Now, the mean exposure they calculate is 53 times lower yet the authors stand behind the work.

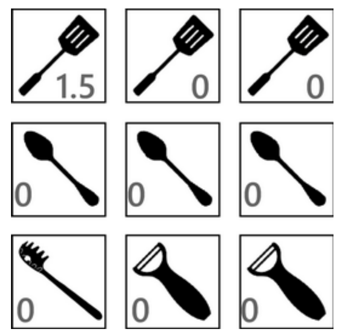
Letter To The Editor:

My initial letter to the editor was shared with the authors who admitted the error and proposed a second correction. The editor elected to share the response with me and I found it inadequate, still riddled with math errors. He offered to let me revise my letter and that eventually published on the heals of the second correction.

Continuing Problems in Method and Math:

I take exception with several aspects of the analysis, as outlined in my peer-reviewed and published letter to the editor. First, there is no justification for simply ignoring samples below the detection limit. They must enter into the calculation of median and mean values. Applying this correction further drops the calculated average to 3,480 ng/day approximately half of the value they report and 120 times lower than the EPA reference dose.

The Kuang correlation is still being misapplied by including items that are not used by immersion in hot oil. Only the spatulas, called slotted turners in the article, are likely to be used in that way. All other kitchen items have an exposure based on the analysis of Kuang of zero. There isn't sufficient transfer from handling, only from hot oil exposure. Therefore, the correct average exposure for the kitchen items must include all items. Including the 9 items and including those where the exposure was zero, either because it was below detection limit or because the use pattern would not lead to exposure yields a median exposure of zero and an average exposure of 176 ng/day. That is over 2000 times lower than the EPA reference dose.



BDE-209 exposures calculated in µg/day found in the 9 products analyzed after excluding those determined not to be used in hot oil used in the analysis presented here. Items not used in hot oil have a negligible exposure. The calculated average is 176 ng/day.

Even this is problematic. Inclusion of all 109 kitchen items analyzed both by XRF and LC-MS drops the average exposure to 14.5 ng/day. This is 29,000 times less than the reference dose. Rather than 85% of samples tested showing levels capable of creating a significant exposure, only 0.5 percent did. Even using the only the LC-MS analyzed samples, only 5%, one in twenty, could create significant exposure in intended use.

The second corrigendum also makes a clarification that represents a significant flaw in methodology. The study is "basing the exposure estimate on four kitchen utensil grips".

They are not testing the part of the kitchen item touching hot oil, they analyzed the grip. Multiple studies demonstrate that brominated flame retardants represent minimal risk of exposure via handling. There is little evidence of dangerous transfer from polymeric materials used in computer mice and other electronic items where the retardants find use. The Kuang paper states there is no exposure potential through touching, through holding handles. The risk of transfer from a plastic spatula is the same as for a steel spatula with a plastic handle. They are both negligible. The exposure risk is not 34,700 ng/day or even the revised 7900 ng/day. It is zero.

BDE-209 exposures calculated in µg/day found in the 109 kitchen products analyzed after excluding those determined not to be used in hot oil. Only one spatula, or slotted turner, remains with a detectable level of BDE-209. The calculated average is 14.5 ng/day.

Further, sampling only the handles is a departure from what is described in the experimental section which stated they followed the Kuang protocol of taking multiple samples from different places on each item. It is also another type of cherry-picking samples. Brominated flame retardants are most likely in styrenic polymers. Analyzing only the parts of items most likely to have brominated materials while ignoring the parts that actually touch food in use is an egregious lapse in methodology.

Let that sink in. The study purposely looked at handles likely to be ABS and ignored the parts that actually touch food. To make matters worse, that was not clearly explained in the original article. The method is incredibly flawed and incorrectly reported.

The data shows that the likelihood of exposure is extremely low, yet the conclusions state "toxic flame retardants used in plastics can significantly contaminate products made from recycled materials." Those conclusions still stand.

Response to My Letter to the Editor:

My letter and Corrigendum 2 published essentially coincidently. My letter was shared with the authors and they were allowed to offer a rebuttal which now adorns the article. I was not allowed to respond. The editor suggested moving the discussion to PubPeer. I posted there only to find another post questioning the validity of the Kuang correlation, offering that it overestimates exposures. Given that the authors now clearly state testing did not involve any polymer touching hot oil, the Kuang correlation is irrelevant. There simply are no exposures.

The authors still resist retraction and assert they indeed reported the median value for the kitchen items in the original work. I've presented the math here showing they were sloppy and misreported the value calculated. The mean BDE-209 concentration for all 20 samples was incorrectly converted to an exposure and that average exposure was what was reported.

Further, they go on to largely dismiss their choosing the EPA reference dose as a point of comparison and create a narrative where any level of brominated flame retardants is too much. It was their choice to use the EPA dose. I simply followed their comparison. There will always be a potential for contamination in a recycle stream. A narrative that any is too much is not supported by science but is an extrapolation that will forever damn recycling.

I corresponded with the editor and the publisher. Elsevier has their own retraction guidelines, I was informed. Those guidelines, like the COPE guidelines lead with retraction being warranted when there is "clear evidence that the findings are unreliable, either as a result of major error (e.g., miscalculation or experimental error), or as a result of fabrication (e.g., of data) or falsification (e.g., image manipulation)." That, to my eye, sure applies here.

Initially, my letter and the rebuttal did not accompany the article. That is, going to the original article showed two corrigendums, but nothing more. I nagged the publisher and my letter and the author's rebuttal now appear when you go to the article on the Elsevier/*Chemosphere* site. I'm a retired guy with no funding and didn't pay page charges. The article is open, as are the corrigendums. My letter and the response to it are paywalled. That seems a little problematic but publishing is a business. It is not about sharing truth.

A small cherry on top is that my efforts were favorably reported by Retraction Watch when they picked up the story of the second correction.

Conclusion:

My quixotic quest to get a paper with severe math and methodological errors is over. The metaphorical windmill still stands. I still think it should be retracted. The paper, with two corrections, has not been retracted. Popular press articles and blogs still appear suggesting all black plastic should be avoided. Countless spatulas were sacrificed and more are likely to be trashed.

The data collected show the opposite of the paper's conclusions: recycling is not creating a significant risk of exposure to brominated flame retardants. Concerning materials may be present, but those materials are unlikely to get into items where a significant exposure is likely and, even when they get into items not requiring flame retardancy, the levels are so low as to not create a significant risk.

This is an interesting case of science going viral because of mistakes. Had the EPA reference dose been correctly calculated, had the Kuang correlation been correctly applied, there would have been no viral story. It wouldn't have been sensational. Correctly reporting that the risk of from recycling is low, that black plastic doesn't constitute an unacceptable risk, wouldn't have gone viral.

For the life of me, I can't understand how the editors let the sloppy math in the paper and the second corrigendum through. There is no justification for ignoring the samples that are ignored in the original and revised calculations.

My efforts taught me a couple of lessons. It introduced me to PubPeer and *Retraction Watch*. I learned that no one likes retractions. They don't make money for publishers. They are viewed as a black eye for the journal. They are viewed negatively so authors don't want them. They are unlikely to sway public opinion. The number of articles written about the errors pales by comparison to the reporting on the original more sensationalized press release from Toxic-Free Future. *The Atlantic* article by Zoë Schlanger, "Throw Out Your Black Plastic Spatula," was one of the magazine's most popular of 2024. It hit a nerve. They did a webinar suggesting tossing spatulas. It was echoed everywhere. More recent articles have not dug into the errors corrected in the second corrigendum, but most are questioning spatulageddon. Quietly questioning. The Atlantic has not done an article or webinar to correct the record.

We do seem to like a scary story, but it goes deeper than that. Proving a positive is easy. Proving a negative is hard. Showing something is capable of causing harm is actually easier than proving something doesn't cause harm. So long as flame retardants lurk in plastics, no self-respecting scientist would argue there is no chance of harm. That same scientist could well conclude that risks are low in a particular use. The difference between hazard and risk is nuanced and not well understood by most people. The Kuang and Liu studies show hazards can be present due to recycling. The Liu study goes on to show that the risk of exposure is exceedingly low while claiming otherwise. In refusing to retract the paper, they lean into the hazard and ignore their own work showing the risk is low. They showed that in a collection of random, purchased items, most do not contain brominated flame retardants. In the subset that do, the risk of exposure is low, exceedingly low.

The paper should have been retracted.

Table: Analysis of food contact items by MS for BDE-209. Measured concentrations are reported on the top line of the table labeled mg/kg. All other numerical values are exposures consistent with the Kuang analysis. Corrigendum 2 shows the analysis done in Corrigendum 2. It ignores samples with an undetectable level of BDE-209. Samples under MS Cohort only correctly include those items with undetectable levels of BDE-209 in the calculation of mean and median. The oil-only calculation includes only those items designed for use in hot oil. Full set includes the samples analyzed by both XRF and MS.

	Sushi Tray	Fast Food Tray	Slotted Spoon	Slotted Turner	Slotted Turner	Basting Spoon	Slotted Turner	Pasta Server	Slotted Spoon	Peeler	Peeler	median	mean
BDE-209	S1	S2	S4	S5	S6	S7	S8	S9	S10	S11	S12		
concentration (mg/kg)	11900	<2.0	<4.0	50	<30	200	<30	300	440	130	3570		
exposure from Kuang correlation (ng/day)	376000	0	0	1580	0	6320	0	9480	13900	4100	113000	4110	47600
exposure from Kuang correlation – kitchen only (ng/day)			0	1580	0	6320	0	9480	13900	4100	11300	4110	16500
appropriate to use hot oil correlation of Kuang appropriate	N	N	N	Y	Y	N	Y	N	N	N	N		
Corrigendum 2 - ng/day				1580		6320		9480	13900			7900	7820
MS Cohort Only													
all food - ng/day	0	0	0	1580	0	6320	0	9480	13900	0	0	0	2840
kitchen only - ng/day			0	1580	0	6320	0	9480	13900	0	0	0	3480
oil only - ng/day				1580	0		0					0	527

Full Set Kitchen and Service	0	0	0	1580	0	0	0	0	0	0	0	0	11.5
Full Set Kitchen			0	1580	0	0	0	0	0	0	0	0	14.5