## December 2023

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| * [Meland et al](https://pubs.acs.org/doi/10.1021/acs.estlett.3c00811?ref=pdf): Road tunnels play a crucial role in modern road networks, in both urban and non-urban areas, and necessitate frequent cleaning and washing due to the harsh tunnel environment. As a result, road tunnels are considered hot spots for the emission of road-related pollutants into the environment. In this study, researchers conducted extensive measurements of tire wear particles (TWPs) and 18 tire-derived chemicals (TDCs) during the washing process, throughout a 21-day treatment period in a rectangular sedimentation basin in concrete, and during the discharge of treated wash water. **Their key findings indicate that TWPs are effectively retained in the sedimentation basin, demonstrating that simple mitigation measures can prevent their release near the source. However, several TDCs displayed high concentrations, mobility, and leachability, leading to inadequate retention in the basin. Moreover, some TDCs exhibited negative treatment performance, resulting in higher concentrations in the treated wash water than in the untreated wash water**. Importantly, their findings can be applied to not only tunnel wash water but also normal road runoff, as sedimentation basins are widely used in many countries. * [Zhang et al](https://www.sciencedirect.com/science/article/abs/pii/S0048969723079214?via%3Dihub): Researchers conducted a stable isotope-assisted high-resolution mass spectrometry (HRMS) assay to unveil the distribution, metabolism, excretion, and toxicokinetic properties of 6PPD-q in a mouse model. Mice were fed with a single dose of deuterated 6PPD-Q-d5 at human-relevant exposure levels. **Results indicated that 6PPD-Q was quickly assimilated and distributed into bloodstream and main organs of mice, with the concentrations reaching peaks under 1 h following administration**. Notably, 6PPD-Q was primarily distributed in the adipose tissue, marked by a significant Cmax (p < 0.05), followed by the kidney, lung, testis, liver, spleen, heart, and muscle. In addition, their measurement demonstrated that 6PPD-Q can penetrate the blood-brain barrier of mice within 0.5 h after exposure. The half-lives (t1/2) of 6PPD-Q in serum, lung, kidney, and spleen of mice were measured at 12.7 ± 0.3 h, 20.7 ± 1.4 h, 21.6 ± 5.3 h, and 20.6 ± 2.8 h, respectively. Meanwhile, fecal excretion was identified as the main excretory pathway for 6PPD-Q and its hydroxylated metabolites. Collectively, our findings extend the current knowledge on the biological fate and exposure status of 6PPD-Q in a mouse model, which has the potential to be extrapolated to humans. * [Zhu et al:](https://www.sciencedirect.com/science/article/abs/pii/S004896972307955X?via%3Dihub) In this study, indoor dust samples (n = 97) were collected from Hangzhou, China, and analyzed for PPDs and PPDQs**. Results showed that nine PPDs were detected in indoor dust samples**, with the total concentrations of 1.7–223 ng/g. 6PPD (mean 17 ng/g) was the predominant PPDs in indoor dust, followed by DTPD(8.6 ng/g) and DMTPD (4.7 ng/g). Five PPDQs were detected in indoor dust samples. Among detected PPDQs, 6PPDQ (14 ng/g, 0.33–82 ng/g) had the highest mean concentration, followed by DTPDQ (5.9 ng/g, < LOD–31 ng/g) and DPPDQ (2.2 ng/g, < LOD–11 ng/g). **Notably, to their knowledge, this study first reports the occurrence of three novel PPDs and four novel PPDQs in indoor dust samples.** More studies are needed to reveal the potential human health risks of exposure to these newly identified chemicals. |

## November 2023

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| * [Chapelet et al](https://chemrxiv.org/engage/chemrxiv/article-details/65315e0d87198ede07cb645a): A technique for the multi-gram scale synthesis of 2,5-diaminoquinones was developed to prepare 2,5-bis((5-methylhexan-2-yl)amino)cyclohexa-2,5-diene-1,4-dione (77PD-quinone) for toxicity assessment. The toxicities of N,N'-bis(5-methyl-2-hexanyl)-1,4-benzenediamine (77PD) and 77PD-quinone were evaluated in coho salmon. Juvenile coho salmon were exposed to a geometric series of five test concentrations of 77PD or 77PD-quinone, a negative control (dilution water), and a solvent control (100 µL/L dimethylformamide) for 96 hours under flow-through conditions. **77PD was found to be toxic to coho salmon with a 96 hour LC50 value of 24 µg/L active ingredient (a.i.), and the NOEC was 13 µg a.i./L. No mortality was observed for 77PD-quinone at the highest attainable dose level, 226 µg a.i./L, at which signs of test water saturation were observed.** * [Mitchell and Jayakaran](https://www.sciencedirect.com/science/article/pii/S0048969723068638?via%3Dihub): Researchers conducted three experiments at a high school in Tacoma, Washington, to quantify the treatment performance of permeable pavement (PP) formulations, a type of green stormwater infrastructure (GSI), for Tire Wear Particles (TWPs) and ten tire-associated contaminants, including 6PPDQ. The PPs comprised concrete and asphalt, with and without cured carbon fibers, to improve the mechanical properties of PPs. Our results showed that the PPs attenuated >96 % of the deposited cTPs mass. An estimated 52–100 % of potentially leachable 6PPDQ was removed by the PP systems between the influent and effluent sampling stations. Their results suggest that **PPs may be an effective form of GSI for mitigating tire-associated stormwater pollution.** |

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* [Cao et al.](https://pubs.acs.org/doi/10.1021/acs.est.3c03758?ref=pdf): In this study, authors performed a comprehensive investigation of a suite of PPD-Qs along with their parent compounds across the influent, effluent, and biosolids during each processing unit in four typical WWTPs in Hong Kong. The total concentrations of PPDs and PPD-Qs in the influent were determined to be 2.7–90 and 14–830 ng/L. In the effluent, their concentrations decreased to 0.59–40 and 2.8–140 ng/L, respectively. The median removal efficiency for PPD-Qs varied between 53.0 and 91.0% across the WWTPs, indicating that a considerable proportion of these contaminants may not be fully eliminated through the current processing technology. Mass flow analyses revealed that relatively higher levels of PPD-Qs were retained in the sewage sludge (20.0%) rather than in the wastewater (16.9%). **In comparison to PPDs, PPD-Qs with higher half-lives exhibited higher release levels via effluent wastewater, which raises particular concerns about their environmental consequences to aquatic ecosystems**.
* [Hagg et al](https://www.frontiersin.org/articles/10.3389/fenvs.2023.1219248/full).: The present study investigated the responses of the marine lumpfish (Cyclopterus lumpus) to crumb rubber exposure in a controlled feeding experiment. Juvenile fish were offered crumb rubber particles with their feed for 1 week, followed by 2 weeks of depuration. Crumb rubber (CR) particle ingestion occurred in >75% of exposed individuals, with a maximum of 84 particles observed in one specimen. Gastrointestinal tract retention times varied, with some organisms having no crumb rubber particles and others still containing up to 33 crumb rubber particles at the end of the experiment. Blood samples were analyzed for metals and organic chemicals, with ICP-MS analysis revealing there was no uptake of metals by the exposed fish. Interestingly, high resolution GC-MS analysis indicated that uptake of PPDs into lumpfish blood was proportionate to the number of ingested CR particles. Three of the PPDs found in blood were the same as those identified in the additive mixture Vulkanox3100. N-(1,3-dimethylbutyl)-N′-phenyl-p-phenylenediamine (6PPD) was the most concentrated PPD in both the crumb rubber and lumpfish blood. The transformation product 6PPD-quinone was detected in the rubber material, but not in the blood. **This study demonstrates that PPDs are specific and bioavailable chemicals in car tire rubber that have the potential to serve as biomarkers of recent exposure to tire chemicals, where simple blood samples could be used to assess recent tire chemical exposure in vertebrates, including humans.**
* [Hua et al](https://www.sciencedirect.com/science/article/abs/pii/S0269749123016512?via%3Dihub).: Authors examined the effect of exposure to N-(1,3-dimethylbutyl)-N′-phenyl-p-phenylenediamine quinone (6-PPDQ) on dopamine metabolism and underling molecular basis in nematodes. The dopamine content was reduced by 6-PPDQ (1 and 10 μg/L). Meanwhile, dopamine related behaviors (basal slowing response and area restricted searching) were changed by 6-PPDQ (1 and 10 μg/L). Exposure to 6-PPDQ (1 and 10 μg/L) decreased expressions of genes (cat-2 and bas-1) encoding enzymes governing dopamine synthesis and cat-1 encoding dopamine transporter. Development of dopaminergic neurons was also affected by 10 μg/L 6-PPDQ as reflected by decrease in fluorescence intensity, neuronal loss, and defect in dendrite development. Therefore, **6-PPDQ exposure disrupted dopamine metabolism and the altered molecular basis for dopamine metabolism was associated with 6-PPDQ toxicity induction.** Moreover, the defects in dopamine related behaviors and toxicity on locomotion and reproduction could be rescued by treatment with 0.1 mM dopamine.

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* [Zhao et al](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fpubs.acs.org%2Fdoi%2F10.1021%2Facs.est.3c05026%3Fref%3Dpdf&data=05%7C01%7Clbin461%40ECY.WA.GOV%7Cbedc4f3c9116459dba4708dbc51bee6f%7C11d0e217264e400a8ba057dcc127d72d%7C0%7C0%7C638320495994742628%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=SLc5%2BtQ3JJwz1p5FGtZrhhcXXMlsBuYc4LmEQRWs%2Fvg%3D&reserved=0): The rubber antioxidant 6PPD has gained significant attention due to its highly toxic transformation product, 6PPD-quinone (6PPDQ). Despite their detection in urines of pregnant women, the placental transfer and developmental toxicity of 6PPD and 6PPDQ are unknown. Here, we treated C57Bl/6 mice with 4 mg/kg 6PPD or 6PPDQ to investigate their urine excretion and placental transfer. Female and male mice exhibited sex difference in excretion profiles of 6PPD and 6PPDQ. Urine concentrations of 6PPDQ were one order of magnitude lower than those of 6PPD, suggesting lower excretion and higher bioaccumulation of 6PPDQ. In pregnant mice treated with 6PPD or 6PPDQ from embryonic day 11.5 to 15.5, 6PPDQ showed ∼1.5–8 times higher concentrations than 6PPD in placenta, embryo body, and embryo brain, suggesting higher placental transfer of 6PPDQ. Using in vitro dual-luciferase reporter assays, we revealed that 6PPDQ activated the human retinoic acid receptor α (RARα) and retinoid X receptor α (RXRα) at concentrations as low as 0.3 μM, which was ∼10-fold higher than the concentrations detected in human urines. 6PPD activated the RXRα at concentrations as low as 1.2 μM. **These results demonstrate the exposure risks of 6PPD and 6PPDQ during pregnancy and emphasize the need for further toxicological and epidemiological investigations.**
* [Dos Santos and Snyder](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fpubs.acs.org%2Fdoi%2F10.1021%2Facs.estlett.3c00446%3Fref%3Dpdf&data=05%7C01%7Clbin461%40ECY.WA.GOV%7Cbedc4f3c9116459dba4708dbc51bee6f%7C11d0e217264e400a8ba057dcc127d72d%7C0%7C0%7C638320495994742628%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=NgCxUfDaP7RCZtCfLk4aNqnM91BUOnuaZCZx0NhygGk%3D&reserved=0): While the occurrence of polymer additives in the environment has gained much attention in recent years, particularly through the emission of tire wear particles (TWPs), evidence of the occurrence of such chemicals in drinking water systems is limited. Even less information is available regarding potential chlorination/chloramination transformation byproducts. In this study, we report the occurrence of N-(1,3-dimethylbutyl)-N′-phenyl-1,4-benzenediamine (6PPD), 1,3-diphenylguanidine (DPG), and three chlorinated byproducts (1,3-bis(2-chlorophenyl)guanidine (CC15), 1-(4-chlorophenyl)-3-(2,4-dichlorophenyl)guanidine (CC05), and 1-(2,4-dichlorophenyl)-3-phenylguanidine) (CC11)) in drinking water samples (n = 20). DPG showed detection frequency of 100%; median 4.3 ng/L (min = 0.25 ng/L; max = 32.6 ng/L), and a chlorinated by product of DPG (CC15) was also detected in 100% of samples; median 1.7 ng/L (min = 0.29 ng/L; max = 11.2 ng/L). CC11 was also found in 10% of samples and was previously reported as potentially genotoxic. **While most studies have focused on the tire rubber related origin of DPG and 6PPD in the environment, results show a potential major contribution of other polymer materials used in household devices such as tap water aerators, particularly O-rings and seals.** Leaching potential of such materials was demonstrated, and contact with free chlorine and monochloramine induced the formation of different halogenated transformation byproducts.
* [Prosser et al](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.sciencedirect.com%2Fscience%2Farticle%2Fabs%2Fpii%2FS0269749123015142%3Fvia%253Dihub&data=05%7C01%7Clbin461%40ECY.WA.GOV%7Cbedc4f3c9116459dba4708dbc51bee6f%7C11d0e217264e400a8ba057dcc127d72d%7C0%7C0%7C638320495994742628%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=CiwitlzKMAz4fcl9l5U%2BFU7vRvW89IONitRTg5RxiLQ%3D&reserved=0): The antioxidant N-(1,3-Dimethylbutyl)-N′-phenyl-p- phenylenediamine (6PPD) is used to protect the rubber in tires from oxidation, which extends the life of the tire. When oxidized, 6PPD is transformed into 6PPD-quinone (6PPDQ). 6PPDQ, along with other tire ingredients, can enter aquatic ecosystems through the transport of tire wear particles in runoff during a precipitation event. The mass mortality of coho salmon following precipitation events in urban areas lead to the discovery that 6PPDQ is the likely cause due to coho salmon's relatively high sensitivity to 6PPDQ. The assessment of 6PPDQ toxicity to other aquatic species has expanded, but it has focused on fish. This study investigated the toxicity of 6PPDQ to four freshwater invertebrate species, larval burrowing mayfly (Hexagenia spp.), juvenile cladoceran (Daphnia magna), file ramshorn snail embryo (Planorbella pilsbryi), and adult washboard mussel (Megalonaias nervosa). For all four species, the highest concentration of 6PPDQ tested did not result in significant mortality. This translated into the determination of the highest concentration that did not cause significant mortality (NOEC) for Hexagenia spp., D. magna, P. pilsbryi, and M. nervosa of 232.0, 42.0, 11.7, and 17.9 μg/L, respectively. **The data from this study indicate that freshwater invertebrates are not as sensitive to 6PPDQ as some salmonid species (e.g., coho salmon Oncorhynchus kisutch)**. This study also analyzed 6PPDQ in road runoff from around the city of Guelph in Ontario, Canada. 6PPQ was detected in all samples but the concentration was two orders of magnitude lower than the NOECs for the four tested species of freshwater invertebrate.
* [Sherman et al](https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fchemrxiv.org%2Fengage%2Fchemrxiv%2Farticle-details%2F650306c2b338ec988a77c900&data=05%7C01%7Clbin461%40ECY.WA.GOV%7Cbedc4f3c9116459dba4708dbc51bee6f%7C11d0e217264e400a8ba057dcc127d72d%7C0%7C0%7C638320495994742628%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=tshe0V23BwXq3GWQcXcaAPUZxEkpWLwEwM8ron3hjig%3D&reserved=0): There is increasing research focused on rubber-derived chemicals (RDCs), predominantly originating from tire and road wear particles. Other consumer products also contain RDCs, but the overall human exposure to these compounds is unknown. **This study investigated climbing shoes as a potential contributor to human indoor exposure to RDCs, including potentially harmful substances such as benzothiazoles, p-phenylenediamines (PPDs), and PPD-quinones**. The soles of climbing shoes contain high but variable concentrations of RDCs (mean 711 μg/g). In indoor climbing halls, abrasion particles from these shoes can be suspended in the air. Dust and air samples were collected in two climbing halls and particulate matter in the inhalable and respirable fractions were analyzed for 15 RDCs. Concentrations in dust (16 to 43 µg/g) and particulate matter (23 to 35 ng/m3) exceed those reported from other environments. For most RDCs, estimated daily intake via inhalation (EDIinh) for adults visiting or working in these facilities exceeds the EDI from other sources. **This highlights the potential concerns with using large amounts of rubber additives in consumer products**. RDCs profiles in shoe samples differed from those in dust and particulate matter, indicating that RDCs are chemically transformed in airborne rubber particles. This finding has broader implications as similar transformations are likely to occur in airborne tire wear particles.

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* [Zhou et al.](https://lnks.gd/l/eyJhbGciOiJIUzI1NiJ9.eyJidWxsZXRpbl9saW5rX2lkIjoxMDcsInVyaSI6ImJwMjpjbGljayIsInVybCI6Imh0dHBzOi8vcHVicy5hY3Mub3JnL2RvaS8xMC4xMDIxL2Fjcy5lc3RsZXR0LjNjMDA0OTk_cmVmPXBkZiZ1dG1fbWVkaXVtPWVtYWlsJnV0bV9zb3VyY2U9Z292ZGVsaXZlcnkiLCJidWxsZXRpbl9pZCI6IjIwMjMwOTA4LjgyMjk5NTkxIn0.bRmbogYk18UPJ4j8kFEpQYKreNmMNm-5SQw2tp_up-E/s/2994451501/br/225537933162-l): The huge consumption of the tire rubber antioxidant N-(1,3-dimethylbutyl)-N′-phenyl-p-phenylenediamine (6PPD) has resulted in pervasive contamination in aquatic environments. More importantly, the transformation product of 6PPD, i.e., 6PPD-quinone (6PPD-Q), is raising increasing concerns due to its high toxicity to aquatic organisms. However, whether and how 6PPD-Q can be formed from 6PPD in aquatic environments remain unknown. Herein, we reported the transformation of 6PPD to 6PPD-Q in water under sunlight irradiation and elucidated the underlying mechanisms. In result, the transformation of 6PPD to 6PPD-Q in water was confirmed with a noteworthy molar yield of ∼1.01% within 90 min at pH 7.0 under simulated sunlight irradiation. The experimental observations, including transient and stable intermediate identification and reactive species quenching, evidenced that the transformation pathways started with photoexcitation of 6PPD and followed by generation of hydroxyl intermediates to form 6PPD-Q. **This study revealed that sunlight-induced transformation of 6PPD could be an important origin of 6PPD-q in aquatic environments, providing significant insights to the potentially underestimated ecological risks of 6PPD.**
* [Li et al.](https://lnks.gd/l/eyJhbGciOiJIUzI1NiJ9.eyJidWxsZXRpbl9saW5rX2lkIjoxMDgsInVyaSI6ImJwMjpjbGljayIsInVybCI6Imh0dHBzOi8vd3d3LnNjaWVuY2VkaXJlY3QuY29tL3NjaWVuY2UvYXJ0aWNsZS9hYnMvcGlpL1MwMzA0Mzg5NDIzMDE0MTAzP3V0bV9tZWRpdW09ZW1haWwmdXRtX3NvdXJjZT1nb3ZkZWxpdmVyeSZ2aWElM0RpaHViPSIsImJ1bGxldGluX2lkIjoiMjAyMzA5MDguODIyOTk1OTEifQ.6xjpT--GmQgRx11ukJWOc5MhE150wC08SkkJfIMWShg/s/2994451501/br/225537933162-l): p-Phenylenediamines (PPDs), an important type of rubber antioxidants, have received little study on their environmental fate, particularly for their vital photodegradation process in water environment. Accordingly, N-(1,3-dimethylbutyl)-N′-phenyl-1,4-phenylenediamine (6PPD), as a representative of PPDs, was investigated experimentally and theoretically for its photodegradation in water. Rapid photodegradation occurred when 6PPD was exposed to illumination especially UV region irradiation. Under acidic conditions, the photodegradation of 6PPD accelerated mainly due to the increased absorption of long wavelength irradiation by ionized 6PPD. Nine photodegradation products (e.g., 6PPD-quinone (6PPDQ)) of 6PPD were identified by an ultra-performance liquid chromatography QTOF mass spectrometry. Molar yields of photoproducts such as 6PPDQ, aniline, 4-aminodiphenylamine, and 4-hydroxydiphenylamine were 0.03 ± 0.00, 0.10 ± 0.01, 0.03 ± 0.02, and 0.08 ± 0.01, respectively. Mechanisms involved in 6PPD photodegradation include photoexcitation, direct photolysis, self-sensitized photodegradation, and 1O2 oxidation, as demonstrated by electron paramagnetic resonance (EPR) analysis, scavenging experiments, and the time-dependent density functional theory (TD-DFT). Notably, the toxicity of the reaction solution formed during the photodegradation of 6PPD was increased by the formation of highly toxic products (e.g., 6PPDQ). **This study provides the first explanation for photodegradation mechanisms of 6PPD and confirms the pathway of 6PPDQ produced by the photoreaction in water environment.**
* [Qian et al.](https://lnks.gd/l/eyJhbGciOiJIUzI1NiJ9.eyJidWxsZXRpbl9saW5rX2lkIjoxMDksInVyaSI6ImJwMjpjbGljayIsInVybCI6Imh0dHBzOi8vcHVicy5hY3Mub3JnL2RvaS8xMC4xMDIxL2Fjcy5hbmFsY2hlbS4zYzAyODMzP3JlZj1wZGYmdXRtX21lZGl1bT1lbWFpbCZ1dG1fc291cmNlPWdvdmRlbGl2ZXJ5IiwiYnVsbGV0aW5faWQiOiIyMDIzMDkwOC44MjI5OTU5MSJ9.kH8TnuTaKNLmfAYITIcnLV2xwzEJU85Fer0iDIyllGg/s/2994451501/br/225537933162-l): Stable isotope-assisted metabolomics (SIAM) is a powerful tool for discovering transformation products (TPs) of contaminants. Nevertheless, the high cost or lack of isotope-labeled analytes limits its application. In-house H/D (hydrogen/deuterium) exchange reactions enable direct 2H labeling to target analytes with favorable reaction conditions, providing intuitive and easy-to-handle approaches for environmentally relevant laboratories to obtain cost-effective 2H-labeled contaminants of emerging concern (CECs). We first combined the use of in-house H/D exchange and 2H-SIAM to discover potential TPs of 6PPD (N-1,3-dimethylbutyl-N′-phenyl-p-phenylenediamine), providing a new strategy for finding TPs of CECs. 6PPD-d9 was obtained by in-house H/D exchange with favorable reaction conditions, and the impurities were carefully studied. Incomplete deuteride, for instance, 6PPD-d8 in this study, constitutes a major part of the impurities. Nevertheless, it has few adverse effects on the 2H-SIAM pipeline in discovering TPs of 6PPD. The 2H-SIAM pipeline annotated 9 TPs of 6PPD, and commercial standards further confirmed the annotated 6PPDQ (2-anilino-5-(4-methylpentan-2-ylamino)cyclohexa-2,5-diene-1,4-dione) and PPPD (N-phenyl-p-phenylenediamine). Additionally, a possible new formation mechanism for 6PPDQ was proposed, highlighting the performance of the strategy. **In summary, this study highlighted a new strategy for discovering the transformation products of contaminants of emerging concern and broadening the application of stable isotope-assisted metabolomics in environmental studies.**