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Advancements in effect-based water quality assessment

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APPENDIX

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SUMMARY

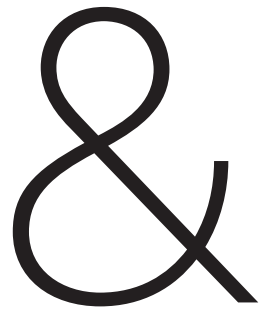
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AUTHOR CONTRIBUTIONS

ACKNOWLEDGEMENTS

CURRICULUM VITAE

LIST OF PUBLICATIONS



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SUMMARY - ADVANCEMENTS IN EFFECT-BASED WATER QUALITY ASSESSMENT

Background and aim

An increasingly wide variety of chemicals is emitted to the aquatic environment, where thousands of substances may be simultaneously present. The resultant complex and varying mixtures of chemicals exert a potential threat to human health and aquatic biodiversity. Current legally-prescribed chemical water quality assessment strategies focus on the chemical analysis of an only limited selection of legacy contaminants and overlook the risks of the complex mixtures of emerging contaminants that nowadays govern chemical water quality. As such, they are unfit for the risk assessment of present-day chemical contamination, and there is a need for future-proof monitoring methods that allow for the impact assessment of the ever-changing complex chemical burden on aquatic ecosystems.

The combination of time integrative sampling methods, known as passive sampling, and methods that employ living cells or organisms (bioanalyses or bioassays), known as effect-based methods, can overcome many of the limitations of traditional chemical water quality assessment methods. Over the past two decades, fundamental steps have been taken in the scientific underpinning of technological innovations for effect-based water quality assessment approaches and the interpretation of the obtained results. Nonetheless, their regular implementation is still in its infancy, and scientific knowledge gaps exist that need to be addressed to unleash the full potential of effect-based methods in chemical water quality assessment. Therefore, the present research aimed to fuel the paradigm shift towards new chemical aquatic environmental quality monitoring methods by providing a scientific basis for the advancement of effect-based water quality assessment. To meet this aim, the state-of-the-art of effect-based tools was explored and applied in five field- and laboratory-based studies.

Field and experimental work

To gain insight into the state-of-science of effect-based surface water quality assessment and its potential for implementation into regular water quality monitoring, the aim of **chapter 2** was to perform an effect-based nationwide water quality assessment to identify ecotoxicological risks in a wide variety of surface waters. To this end, passive sampling of polar and non-polar organic compounds was combined with a battery of *in situ*, *in vivo* and *in vitro* bioassays for 45 surface water locations. The bioassay battery was selected such that it could identify the risks posed by a wide range of chemical pollutants and their transformation products, while simultaneously allowing for targeted identification of groups of compounds that cause specific effects. Bioassay responses were compared to effect-based trigger values to identify potential ecotoxicological risks at the investigated locations. Responses were observed in all bioassays, and trigger values were exceeded in 9 out of the 21 applied assays, allowing for ranking of the investigated locations based on ecotoxicological risks. No relationship between land use and the identification of ecotoxicological risks was observed. Based on the results, considerations regarding future improvements of effect-based monitoring were given, which were addressed in the chapters 3-6. It was concluded that effect-based water quality assessment allowed the prioritization of sites



based on ecotoxicological risks, identified the presence of hazardous compounds regardless of being listed as priority substances and meanwhile could prevent costly chemical analysis at sites with low ecotoxicological risks.

The design of integrative passive samplers can affect the accumulation of compounds and therewith the detected bioassay responses. **Chapter 3** aimed to determine the effects of sampler housing and sorbent type on bioassay responses to polar passive sampler extracts. To this end, four integrative passive sampler configurations, resulting from the combination of polar organic chemical integrative sampler (POCIS) and Speedisk housings with hydrophilic-lipophilic balance and hydrophilic divinylbenzene sorbents, were simultaneously exposed at reference and contaminated surface water locations. To measure the toxicity of the accumulated polar organic compounds, a battery of five bioassays was exposed to the extracts. Extracts from POCIS caused higher bioassay responses in 91% of cases, while extracts from the two sorbents caused equally frequent but different bioassay responses. Hence, the passive sampler design critically affected the toxicity detection of polar organic contaminants, highlighting the importance of active choices in passive sampling for effect-based water quality assessment.

Since algal photosynthesis is a sensitive process that can be applied to identify the presence of hazardous herbicides in surface water, the aim of **chapter 4** was to employ an algal photosynthesis bioassay to assess surface water toxicity to algae and to identify the compounds causing the observed effects. To this end, *Raphidocelis subcapitata* was exposed to surface water samples and after 4.5 h photosynthetic efficiency was determined using PAM fluorometry. In this rapid high throughput bioassay, algal photosynthesis was affected by surface water from only one of 39 locations. Single compounds toxicity confirmation elucidated that the observed effect could be solely attributed to the herbicide linuron, which occurred at 110 times the EQS concentration and which is not included in the WFD priority substances list. In conclusion, applying the algal photosynthesis bioassay enables more efficient and effective assessment of toxicity to primary producers because it: (i) identifies the presence of herbicides that would be overlooked by routine chemical WFD monitoring, and (ii) avoids redundant chemical analyses by focusing only on (non-)target screening in samples with demonstrated effects.

Sediment quality assessment methods that consider the risks caused by the combined action of all sediment-associated contaminants to benthic biota are still underrepresented in water quality assessment strategies. **Chapter 5** aimed to integrate effect-monitoring and chemical profiling of sediment contamination. To this end, 28-day life cycle bioassays with *Chironomus riparius* using intact whole sediment cores from contaminated sites were performed in tandem with explorative chemical profiling of bioavailable concentrations of groups of legacy and emerging sediment contaminants to investigate ecotoxicological risks to benthic biota. All contaminated sediments caused effects on the resilient midge *C. riparius*, stressing that sediment contamination is ubiquitous and potentially harmful to aquatic ecosystems. However, bioassay responses were not in line with any of the calculated toxicity indices, suggesting that toxicity was caused by unmeasured compounds. Hence, this study underlines the relevance of effect-based sediment quality assessment and provides smarter ways to do so.

It was hypothesized that the refined insights and methodological improvements obtained in the previous chapters would contribute to an improved strategy for the assessment of the aggregated risk of all bioavailable micropollutants present in the aquatic environment. **Chapter 6** aimed to advance effect-based water quality assessment by implementing the developed methodological improvements and to gain insight into contamination source-specific bioanalytical responses. To this end, passive sampling of non-polar and polar organic compounds and metals was applied at 14 surface water locations that were characterized by two major anthropogenic contamination sources, agriculture and WWTP effluent, as well as reference sites with an expected low impact from micropollutants. A revised battery of 20 *in vivo* and *in vitro* bioassays was exposed to the passive sampler extracts, and the bioanalytical responses were compared to effect-based trigger values to identify potential ecotoxicological risks. The bioanalytical assessment of the joint risks of metals and (non-)polar organic compounds resulted in the successful identification of pollution source-specific ecotoxicological risk profiles. Cumulative ecotoxicological risks were lowest for reference locations, followed by agriculture locations and the highest for WWTP locations, and were mainly driven by polar organic contaminants. It was concluded that the employed advanced effect-based methods can readily be applied in surface water quality assessment and that the integration of chemical- and effect-based monitoring approaches will foster future-proof water quality assessment strategies on the road to a non-toxic environment.

Recommendations and outlook

This thesis advanced the scientific basis of effect-based chemical water quality assessment by providing methodological and theoretical improvements to this emerging field of research. In the **synthesis (chapter 7)**, it was postulated that four specific requirements need to be met to achieve the full potential of effect-based water quality assessment.

First, the sampling methods should capture all relevant contaminants from the water. In the present research, this was pursued by i) developing an improved understanding of the characteristics that determine the uptake of contaminants in polar passive samplers, ii) applying a suite of passive samplers to capture organic contaminants from a very wide polarity range, iii) the expansion of the suite of passive samplers to include ecotoxicological risk assessment of metals, and iv) the expansion of the passive sampling strategy to allow the bioavailability-based extraction of sediment-associated contaminants.

Second, the environmental samples should be transferred as representative mixtures at environmentally relevant concentrations to the bioassays. Here, several methods were applied for the approximation of field-relevant passive sampler extract concentrations. This highlighted the limitations of the currently available approaches, and resulted in the recommendation to apply passive dosing to obtain environmentally relevant mixtures and concentrations of both non-polar and polar organic contaminants in bioassays.

Third, the bioassay battery should represent all toxicity endpoints relevant to aquatic ecosystem health. Criteria that determine the relevance of bioassays for application in effect-

based water quality assessment were defined that consider the responsiveness of bioassays, the range of endpoints in a bioassay battery, and the early-warning function of bioassays. The application of these criteria to the bioassays applied in the present work resulted in the exclusion of several bioassays that appeared not fit-for-purpose and their replacement with more relevant and sensitive alternatives.

Last, the defined thresholds for the interpretation of bioassay responses should be indicative of ecotoxicological risks in the environment. Therefore, a novel approach was proposed that switches the point-of-departure of effect-based trigger value derivation from compound concentration-based thresholds to ecological protection goals. Despite existing challenges, the here postulated novel, more ecologically relevant, approach would strongly aid the achievement of the ultimate goal of effect-based trigger values: to protect natural populations of organisms in the aquatic environment.

It is concluded that in an ideal future, chemical water quality monitoring will result in a comprehensive assessment of the 'exposome of the natural aquatic environment', where (semi) continuous simultaneous biological and chemical analyses reveal the chemicals that (jointly) pose a threat to the biotic environment.

SAMENVATTING - PROGRESSIE IN EFFECTGEBASEERDE WATERKWALITEITSBEOORDELING

Achtergrond en doel van het promotieonderzoek

Er wordt een steeds grotere verscheidenheid aan chemicaliën uitgestoten in het aquatisch milieu, waar dientengevolge duizenden stoffen tegelijkertijd aanwezig kunnen zijn. Deze complexe en variërende mengsels van chemische stoffen vormen een potentiële bedreiging voor de menselijke gezondheid en de aquatische biodiversiteit. De huidige wettelijk voorgeschreven chemische waterkwaliteitsbeoordelingsstrategieën richten zich echter alleen op de chemische analyse van een beperkte selectie van bestaande verontreinigingen en zien hiermee de risico's over het hoofd van de complexe mengsels van nieuwe onbekende verontreinigingen die tegenwoordig de chemische waterkwaliteit bepalen. Daardoor zijn traditionele meetmethoden ongeschikt voor de risicobeoordeling van de hedendaagse chemische verontreiniging en is er behoefte aan toekomstbestendige monitoringsmethoden die het mogelijk maken om de effecten van de steeds veranderende complexe chemische belasting op aquatische ecosystemen te bepalen.

De combinatie van tijd-geïntegreerde bemonsteringsmethoden, bekend als passieve bemonstering (passive sampling), en methoden waarbij levende cellen of hele organismen worden gebruikt (bioanalyses en bioassays), bekend als effectgebaseerde methoden, kunnen veel van de beperkingen van de traditionele methoden voor de beoordeling van de chemische waterkwaliteit verhelpen. In de afgelopen twee decennia zijn grote stappen gezet in de fundamentele wetenschappelijke onderbouwing en de technologische innovatie van effectgerichte benaderingen van waterkwaliteitsbeoordeling en in de interpretatie van de verkregen resultaten. Desalniettemin staat de reguliere implementatie hiervan nog in de kinderschoenen en bestaan er lacunes in de wetenschappelijke kennis die moeten worden gevuld om het volledige potentieel van effectgebaseerde methoden bij de beoordeling van chemische waterkwaliteit tot haar recht te laten komen. Daarom was het doel van het huidige onderzoek de paradigma verschuiving naar nieuwe meetmethoden voor chemische waterkwaliteit te stimuleren door een wetenschappelijke basis te bieden voor de vooruitgang van effectgebaseerde waterkwaliteitsbeoordeling. Om dit doel te bereiken werden de meest recente ontwikkelingen in effectgebaseerde methoden onderzocht en toegepast in vijf veld- en laboratoriumstudies.

Experimentele benadering

Om inzicht te krijgen in de stand van de wetenschap betreffende de effectgebaseerde beoordeling van oppervlaktewaterkwaliteit en het potentieel ervan voor implementatie in reguliere waterkwaliteitscontrole, was het doel van **hoofdstuk 2** om een effectgebaseerde landelijke waterkwaliteitsbeoordeling uit te voeren om ecotoxicologische risico's te identificeren in een grote verscheidenheid aan oppervlaktewateren. Daartoe werd passieve bemonstering van hydrofiele en hydrofobe organische stoffen op 45 oppervlaktewaterlocaties gecombineerd met een batterij van veld- en laboratorium-bioassays. De bioassay-batterij werd zo gekozen dat deze de risico's van een breed scala aan verontreinigende stoffen en hun transformatieproducten

kon identificeren, terwijl het tegelijkertijd de identificatie mogelijk maakte van groepen van verbindingen die specifieke effecten veroorzaken. Bioassay-responsen werden vergeleken met effect signaalwaarden om potentiële ecotoxicologische risico's op de onderzochte locaties te identificeren. Alle bioassays vertoonden responsen en de effect signaalwaarden werden overschreden in 9 van de 21 toegepaste assays. Hierdoor konden de onderzochte locaties worden gerangschikt op basis van ecotoxicologische risico's. Er werd echter geen verband tussen landgebruik en specifieke ecotoxicologische risico's waargenomen. Op basis van de resultaten werden suggesties voor toekomstige verbeteringen van effectgebaseerde monitoring gegeven, welke vervolgens behandeld werden in de hoofdstukken 3-6. Er werd geconcludeerd dat effectgebaseerde waterkwaliteitsbeoordeling de prioritering van locaties op basis van ecotoxicologische risico's mogelijk maakte, de aanwezigheid van gevaarlijke verbindingen identificeerde, ongeacht hun status als prioritaire stoffen, en tegelijkertijd kostbare chemische analyse kon voorkomen op locaties met lage ecotoxicologische risico's.

Het ontwerp van methoden voor passieve bemonstering (het passive sampler ontwerp) kan de ophoping van stoffen en daarmee de responsen in bioassays beïnvloeden. In **hoofdstuk 3** werden daarom de effecten van de passive sampler behuizing en het sorptiemiddel op bioassay responsen op hydrofiele passive sampler extracten bepaald. Hiertoe werden vier passive sampler configuraties, die het resultaat waren van de combinatie van polaire organische chemische integratieve sampler (POCIS) en Speedisk- behuizingen met hydrofiel-lipofiele balans en hydrofiele divinylnbenzeen-sorptiemiddelen, tegelijkertijd blootgesteld op referentie- en verontreinigde oppervlaktewaterlocaties. Om de toxiciteit van de opgehoopte hydrofiele organische stoffen te bepalen, werd een batterij van vijf bioassays aan de extracten blootgesteld. Extracten van POCIS veroorzaakten in 91% van de gevallen hogere bioassay-responsen, terwijl extracten van de twee sorptiemiddelen even frequente, maar verschillende bioassay-responsen veroorzaakten. Het ontwerp van de passive sampler beïnvloedde dus de detectie van toxiciteit van hydrofiele organische verontreinigingen, wat het belang van het maken van actieve keuzes in passieve bemonstering voor een effectgebaseerde waterkwaliteitsbeoordeling benadrukte.

Aangezien fotosynthese een gevoelig proces is dat kan worden toegepast om de aanwezigheid van gevaarlijke herbiciden in oppervlaktewater te identificeren, was het doel van **hoofdstuk 4** om een bioassay voor algenfotosynthese in te zetten om de oppervlaktewatertoxiciteit voor algen te beoordelen en de stoffen te identificeren die de waargenomen effecten veroorzaakten. Hiertoe werd de microalg *Raphidocelis subcapitata* blootgesteld aan oppervlaktewater monsters en werd na 4.5 uur de fotosynthetische efficiëntie bepaald met behulp PAM fluorometrie. In dit snelle bioassay met een hoge monster doorvoercapaciteit werd de fotosynthese van algen beïnvloed door oppervlaktewater van slechts één van de 39 locaties. Toxiciteitstesten met individuele stoffen lieten zien dat het waargenomen effect uitsluitend kon worden toegeschreven aan het herbicide linuron, dat aanwezig was bij een 110 keer hogere concentratie dan de maximaal aanvaardbare concentratie, en dat bovendien niet is opgenomen in de KRW-lijst van prioritaire stoffen. Het toepassen van het algenfotosynthese-bioassay maakte dus een efficiëntere en effectievere beoordeling van de toxiciteit van oppervlaktewater voor primaire producenten mogelijk omdat het: (i) de aanwezigheid van herbiciden identificeert die over het hoofd zouden

worden gezien door routinematige chemische KRW monitoring, en (ii) overbodige chemische analyses vermijdt door alleen chemische screening uit te voeren in monsters die daadwerkelijk effecten veroorzaakten.

Kwaliteitsbeoordelingsmethoden voor sedimenten die rekening houden met de risico's die worden veroorzaakt door de gecombineerde werking van alle in het sediment aanwezige verontreinigingen voor organismen die in de waterbodem voorkomen (benthische biota), zijn nog steeds ondervetegenwoordigd in strategieën voor waterkwaliteitsbeoordeling. Het doel van **hoofdstuk 5** was daarom het integreren van effectmetingen en chemische karakterisering van sedimentverontreiniging. Daartoe werden 28 dagen durende levenscyclus bioassays met de dansmug *Chironomus riparius* met intacte sedimentkernen van verontreinigde locaties uitgevoerd, in combinatie met exploratieve chemische karakterisering van de biologisch beschikbare concentraties van groepen bekende en nieuwe onbekende sedimentverontreinigingen om zo de ecotoxicologische risico's voor benthische biota te onderzoeken. Alle verontreinigde sedimenten veroorzaakten effecten op de relatief ongevoelige dansmuggen, wat benadrukte dat sedimentverontreiniging alomtegenwoordig is en mogelijk schadelijk is voor aquatische ecosystemen. De bioassay-responsen waren echter niet in overeenstemming met de berekende toxiciteitsindices gebaseerd op aanwezigheid van gemeten stoffen, wat erop wijst dat de toxiciteit werd veroorzaakt door niet-gemeten stoffen. Daarom onderstreepte deze studie de relevantie van effectgebaseerde beoordeling van sedimentkwaliteit en bood deze slimmere manieren om dit te doen.

Er werd verondersteld dat de verfijnde inzichten en methodologische verbeteringen die in de vorige hoofdstukken waren verkregen zouden kunnen bijdragen aan een verbeterde strategie voor de beoordeling van het geaggregeerde risico van alle biologisch beschikbare microverontreinigingen in het aquatisch milieu. **Hoofdstuk 6** beoogde daarom de ontwikkelde methodologische verbeteringen te implementeren in effectgebaseerde waterkwaliteitsbeoordeling en inzicht te krijgen in de bioanalytische reacties op bronspecifieke verontreinigingen. Daartoe werd passieve bemonstering van hydrofobe en hydrofiele organische verbindingen en metalen toegepast op 14 oppervlaktewaterlocaties die werden gekenmerkt door twee belangrijke antropogene verontreinigingsbronnen, landbouw en rioolwaterzuivering (RWZI) effluent, evenals referentielocaties met een verwachte lage impact van microverontreinigingen. Een herziene batterij van 20 bioassays met levende cellen en organismen werd blootgesteld aan de passieve sampler-extracten en de bioanalytische responsen werden vergeleken met effect signaalwaarden om potentiële ecotoxicologische risico's te identificeren. De bioanalytische beoordeling van de gezamenlijke risico's van metalen en organische stoffen resulteerde in de succesvolle identificatie van bronspecifieke ecotoxicologische risicoprofielen. De cumulatieve ecotoxicologische risico's waren het laagst voor de referentielocaties, gevolgd door de landbouwlocaties en het hoogst voor de RWZI locaties. Deze risico's werden voornamelijk veroorzaakt door hydrofiele organische verontreinigingen. Er werd geconcludeerd dat de gebruikte geavanceerde effectgebaseerde methoden makkelijk kunnen worden toegepast in de beoordeling van oppervlaktewaterkwaliteit en dat de integratie van chemische en

effectgebaseerde monitoring toekomstbestendige waterkwaliteitsbeoordelingsstrategieën mogelijk maakt op de weg naar een niet-giftig milieu.

Discussie en toekomstperspectief

Dit proefschrift heeft de wetenschappelijke basis van effectgebaseerde chemische waterkwaliteitsbeoordeling versterkt door methodologische en theoretische verbeteringen te bieden aan het bestaande onderzoeksgebied. In de *synthese* (hoofdstuk 7) werd gepostuleerd dat aan vier specifieke eisen moet worden voldaan om het volledige potentieel van effectgebaseerde waterkwaliteitsbeoordeling te kunnen benutten.

Ten eerste moeten de bemonsteringsmethoden alle relevante verontreinigende stoffen uit het water kunnen opnemen. In het huidige onderzoek werd dit nagestreefd door i) een beter begrip te ontwikkelen van de kenmerken die de opname van verontreinigingen in passieve samplers voor hydrofiele stoffen bepalen, ii) verschillende passieve samplers tegelijkertijd toe te passen om organische contaminanten met sterk uiteenlopende waterminnendheid op te nemen, iii) de toevoeging van passieve samplers om de ecotoxicologische risicobeoordeling van metalen mogelijk te maken, en iv) de uitbreiding van de passieve monsternamestrategie om de extractie van biologisch beschikbare sediment geassocieerde verontreinigingen mogelijk te maken.

Ten tweede moeten de milieumonsters naar de bioassays worden overgebracht als representatieve mengsels bij milieurelevante concentraties. In dit proefschrift werden verschillende methoden toegepast om milieurelevante concentraties te benaderen bij het gebruik van passieve sampler extracten in bioassays. Dit benadrukte de beperkingen van de momenteel beschikbare benaderingen, en resulteerde in de aanbeveling om passieve dosering toe te passen om voor het milieu relevante mengsels en concentraties van zowel hydrofobe als hydrofiele organische verontreinigingen in bioassays te verkrijgen.

Ten derde moet een bioassay batterij voorzien in de detectie van alle mogelijke vormen van toxiciteit die relevant zijn voor de gezondheid van aquatische ecosystemen. Daartoe werden criteria gedefinieerd die de relevantie van bioassays voor toepassing in effectgebaseerde waterkwaliteitsbeoordeling bepalen. Deze criteria omvatten de responsiviteit van de bioassays, selectie van eindpunten in een bioassaybatterij en de vroegtijdige diagnosefunctie van bioassays. De toepassing van deze criteria op de bioassays die in het huidige proefschrift zijn toegepast resulteerde in de uitsluiting van verschillende bioassays die niet geschikt bleken voor hun doel en in hun vervanging door relevantere en gevoeliger alternatieven.

Tot slot moeten de gedefinieerde normen voor de interpretatie van bioassay responsen een betrouwbare indicatie van ecotoxicologische risico's in het milieu geven. Daarom werd een nieuwe benadering voorgesteld die de afleiding van effect signaalwaarden verschuift van op stofconcentraties gebaseerde drempels naar ecologische beschermdoelen. Ondanks de bestaande uitdagingen zal de hier gepostuleerde vernieuwde en meer ecologisch relevante aanpak sterk helpen bij het bereiken van het uiteindelijke doel van effect signaalwaarden: het beschermen van natuurlijke populaties van organismen in het aquatisch milieu.

In een ideale toekomst zal de monitoring van de chemische waterkwaliteit leiden tot een alomvattende beoordeling van de 'blootstelling van het natuurlijk aquatisch milieu', waar (semi) continue gelijktijdige biologische en chemische analyses de chemicaliën aan het licht brengen die (gezamenlijk) een bedreiging vormen voor de levende omgeving.



AUTHOR CONTRIBUTIONS

Chapter 1: ML de Baat, MHS Kraak

Drafting the chapter: MLdB and MHSK. Critical revision of the chapter: MHSK. Final approval of the version to be published: all authors.

Chapter 2: ML de Baat, MHS Kraak, R van der Oost, P de Voogt, PFM Verdonchot

Conception of the work: MLdB, MHSK, RvdO and PFMV. Data collection: MLdB. Data analysis and interpretation: MLdB, RvdO and MHSK. Drafting the article: MLdB. Critical revision of the article: MHSK, RvdO, PdV and PFMV. Final approval of the version to be published: all authors.

Chapter 3: ML de Baat, J de Weert, D Giesen, H Beeltje, T Hamers, P de Voogt, MHS Kraak

Conception of the work: MLdB and JdW. Data collection: MLdB, JW and HB. Data analysis and interpretation: MLdB and JdW. Drafting the article: MLdB. Critical revision of the article: JdW, DG, TH, PdV and MHSK. Final approval of the version to be published: all authors.

Chapter 4: ML de Baat, DA Bas, SAM van Beusekom, F van der Meer, M de Vries, PFM Verdonchot, MHS Kraak

Conception of the work: MLdB and MHSK. Data collection: MLdB, DAB, SAMvB, FvdM and MdV. Data analysis and interpretation: MLdB, FvdM and DAB. Drafting the article: MLdB and DAB. Critical revision of the article: SAMvB, PFMV and MHSK. Final approval of the version to be published: all authors.

Chapter 5: ML de Baat, N Wieringa, STJ Droge, BG van Hall, F van der Meer, MHS Kraak

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Chapter 6: ML de Baat, R van der Oost, GH van der Lee, N Wieringa, T Hamers, PFM Verdonchot, P de Voogt, MHS Kraak

Conception of the work: MLdB, GHvdL, NW, PFMV and MHSK. Data collection: MLdB, GHvdL and NW. Data analysis and interpretation: MLdB. Drafting the article: MLdB. Critical revision of the article: RvdO, GHvdL, NW, TH, PFMV, PdV and MHSK. Final approval of the version to be published: all authors.



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CURRICULUM VITAE

Milo Leon de Baat was born on the 4th of February 1989 in Amsterdam, The Netherlands. While pursuing a Bachelor's degree in Biology at the University of Amsterdam (2008-2011), he was introduced to the research field of Aquatic Ecotoxicology under the enthusiastic supervision of Dr. Michiel Kraak. Inspired by several courses on Aquatic Biology, he finalized his undergraduate studies with a thesis on the adaptative mechanisms of non-biting midges to high levels of metal toxicity and solar radiation in high-altitude tropical mountain streams.



After his BSc graduation, he obtained his Open Water SCUBA diving certification in Colombia, which fueled a deeper interest in the underwater world. Growing ever-more passionate about Aquatic Biology and the processes that define life below the surface, he decided to pursue a Master's degree in Limnology and Oceanography at the University of Amsterdam (2012-2014). Jumpstarted by the work he did for his Bachelor's thesis, he initiated his graduate studies with a research project in Peru, where he studied the effects of metal pollution and high altitude on insect species assemblages in the tropical Andes. During his studies, he followed courses on freshwater as well as marine Biology, in tropical and temperate ecosystems. This was followed by his final research project, in which he studied the genetic diversity and toxicity of cyanobacterial mats on the reefs of the Caribbean island of Curaçao.

After his MSc graduation, he went on to further his diving skills and obtained a Rescue Diver certification. This turned out to be a valuable asset when he collaborated as a scientific diver on a research project on the distribution of Queen Conch populations around the Caribbean island of St. Eustatius. It was during this research project that Milo decided that he wanted to pursue a career in which scientific research plays a central role.

At the end of 2015, Milo started his doctoral studies at the Department of Freshwater and Marine Ecology of the University of Amsterdam. The Ph.D. project was supervised by Michiel Kraak, Piet Verdonchot, Ron van der Oost and Pim de Voogt, a supervisory committee with expertise ranging from Aquatic Ecology to Analytical Chemistry. In collaboration with the Dutch water authorities, the project aimed to advance the field of effect-based chemical water quality assessment. This time, the research was conducted in the temperate river delta of The Netherlands. Working in these murky waters came with its own particular set of challenges, but Milo hopes the resulting findings can be transferred to other aquatic ecosystems and contribute to improved chemical water quality assessment around the globe.

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