PROJEKTBESKRIVELSE

Elektrolytisk rensning af vinylkloridforurenet grundvand – forundersøgelse af nøgleteknologi bag realisering af Kraftcentrum Grindsted

INTRODUKTION

Nærværende projektbeskrivelse er en uddybende plan for gennemførelse af den projektidé, som konsortiet bag Kraftcentrum Grindsted (bl.a. GEV) og partnere (Aalborg Universitet) har fået en bevilling til fra Den Syddanske Udviklingspulje for rent vand og jord. Projektbeskrivelsen præsenterer således baggrunden for projektet og dets hovedelementer. Projektbeskrivelsen indeholder en konkretisering af projektets aktiviteter, en tidsplan over projektets faser, et overordnet budget og en bemandingsoversigt.

Formål

Det overordnede formål for Kraftcentrum Grindsted er at levere dokumentation for, om elektrolytisk vandrensning i samspil med varmeindvinding via varmepumpe kan rense forurenet grundvand fra forureningsfanen fra Grindstedsværkets fabriksgrund til en kvalitet, som efterfølgende kan bruges til industrielt kølevand samtidig med at der genereres overskudsvarme til fjernvarmenettet. Første trin, og dermed formålet med dette delprojekt, er at undersøge rensningseffektiviteten på den oppumpede forurenede grundvandsmatrice og betydningen af parametre som elektrodematerialer, tid for skiftende polarisering m.m. Vinylklorid (VC) er i samarbejde med Regionen udvalgt som den primære forureningskomponent, som teknologien dokumenteres på. Sideløbende med testdata på VC vil der blive analyseret for de andre nedbrydningsprodukter fra klorerede opløsningsmidler, da de er en del af samme analysepakke. Medicinrester, BTEX og anden organisk forurening kan også nedbrydes ved elektrolyse, og for at få indledende erfaring med teknologiens effektivitet over denne del af forureningen, vil enkelte prøver også blive analyseret for stofferne inkluderet i Grindstedpakke A. Forsøg udføres både i laboratoriet på Aalborg Universitet i Esbjerg og i felten ved en boring, der er filtersat i forureningsfanen (Renseanlæg Vest, Grindsted, boring 114.2567) og er udvalgt i samarbejde med Regionen. For at sørge for at udviklingsprojektet generer relevant data mhb. på videre kvalificering af Kraftcentrum Grindsted konceptet, prioriteres det ligeledes tidligt i projektet at opstarte feltforsøg. Derved bliver erfaringer fra feltforsøgene et væsentlig element i projektet.

Samspil med Clean Cluster Videnbro bevilling

Parallelt med formuleringen af denne projektbeskrivelse har konsortiet bag Kraftcentrum Grindsted også fået tilsagn om bevilling til ”Videnbro-projektet – Forundersøgelse af Kraftcentrum Grindsted projektkonceptet” fra innovationsklyngen Clean Cluster. Formålet med Videnbro-projektet er også at dokumentere, hvilken rensningseffekt der kan opnås med elektrolyse på Grindstedforureningen, og har således et stort overlap med nærværende projekt. Bevillingen fra Clean Cluster gives formelt til GEV og en kreds af virksomheder, og har den binding, at den kun kan bruges til timebetaling til involvering af videnpartnere såsom Aalborg Universitet og ikke til driftsudgifter og udstyr. I forhold til dette SUP projekt betyder det, at AAU’s timeforbrug til litteraturstudium, forsøgsplanlægning og afvikling således i stedet kan dækkes af Clean Cluster bevillingen, og at budgettet for nærværende SUP projekt kan fokuseres på udstyr, driftsudgifter, analyser samt GEV’s timeforbrug. Der inkluderes dog i budgettet for SUP projektet timer til AAU for projektadministrering jf. kontrakten med Region Syddanmark og afrapportering. Budgettet er nærmere forklaret sidst i denne projektbeskrivelse.

AKTIVITETER

Projektets overordnede aktiviteter (A1 til A7) og faser er beskrevet i nedenstående Gantt diagram. Startdato for projektet er 1. februar 2023 og projektet afsluttes ultimo oktober 2023.

	2023								
Aktivitet	Feb.	Marts	April	Maj	Juni	Juli	Aug.	Sep.	Okt.
A1: Litteraturstudium for fastlæggelse af testparametre for lab- og feltests. Planlægning af lab-test	🟧								
A2: Planlægning af felttest	🟪								
A3: Anskaffelse af vandprøve, karakterisering og laboratorieforsøg	🟩	🟩	🟩	🟩					
A4: Etablering af setup til afvikling af test i felten		🟥							
A5: Feltforsøg - 3 kampagner			🟫	🟫	🟫	🟫			
A6: Afrapportering og projektafslutning							▨	▨	▨
A7: Projektadministrering	■	■	■	■	■	■	■	■	■

A1: Fastlæggelse af testparametre baseret på litteraturstudie

Litteraturstudiet er en skriftlig opsummering af eksisterende viden om elektrolytisk vandrensning målrettet klorerede opløsningsmidler. Arbejdet afrapporteres i et notat, der danner fælles vidensgrundlag for konsortiet i forhold til detaljeret planlægning af laboratorie- og feltforsøg. Notat vil indeholde praktiske overvejelser om hvordan rensningseffektens sammenhæng med elektrodemateriale, strømstyrke, energioverførsel og rensningseffekt indledningsvis undersøges i laboratoriet og skal ligeledes bruges aktivt til planlægning af felttest (A2).

A1 udføres primært af Aalborg Universitet, inkluderer kun timeforbrug, og vil således blive dækket af Clean Cluster bevillingen.

A2: Planlægning af felttest

Planlægning af felttest startes parallelt med planlægning af laboratorieforsøg for dels at kunne påbegynde etablering af feltfaciliteter i begyndelsen af marts og dels for at sikre synergi mellem projektets aktiviteter. Planlægning involverer alle projektets parter inklusiv Electrocell A/S, som er påtænkt underleverandør af selve elektrolysecellen. Efter opstartsmødet med Regionen er det blevet besluttet, at feltforsøg udføres med udgangspunkt i vand fra filter 2 i boring DGU nr. 114.2567, som forefindes på Renseanlæg Vest og er placeret centralt i forureningsfanen fra fabriksgrunden. Analyser af grundvandet herfra viser et gennemsnitligt indhold af VC på 5575 µg/L (gennemsnit af 4 prøver fra okt. 2016 til maj 2020). Planlægningen fastlægger omfang af karakterisering af grundvandet, hvilke specifikke parametre (flow/reaktionstid, elektrodematerialer, strømstyrker, polariseringstider) der skal testes, og hvordan forsøgene skal udføres. Planlægningen vil tage udgangspunkt i anvendelse af Electrocell's Micro Flow Cell til laboratorieforsøg og Electrocell's Electro MP Cell til felt felttests. Lab-cellen har et aktivt elektrodeareal på 10 cm^2 og en maks. flowkapacitet på 90 L/time, mens felt-cellen har et skalerbart elektrodeareal fra 100 cm^2 og et maks. flow på 240 L per time. Disse to celler er baseret på et såkaldt sandwich-celle design, der giver en god fleksibilitet i forhold til tests, da elektrodematerialer, pakninger m.m. kan udskiftes forholdsvis nemt, og volumen af vand, der skal håndteres, kan begrænses mest muligt. Det sikres i planlægningsfasen, at data fra disse celler kan bruges til design af en opskaleret proces.

Ved planlægningen af felttests vurderes det ligeledes om det vil være nødvendigt at etablere forbehandling af grundvandet til feltforsøgene i form af sandfiltrering målrettet rensning for opløst jern og mangan. Der afsættes budget (50.000 kr.) til dette under posten Udstyr.

Aalborg Universitets timeforbrug i A2 dækkes af Clean Cluster bevillingen, mens resterende drifts og udstyrsudgifter dækkes af nærværende SUP projekt.

A3: Anskaffelse af vandprøve, karakterisering og laboratorieforsøg
Der indhentes en vandprøve på 25L fra filter 2 i boring DGU nr. 114.2567 og en prøve indsendes til analyse (boringskontrol, klorerede opløsningsmidler og nedbrydningsprodukter, samt Grindstedpakke A og BTEX). I laboratoriet foretages yderligere karakterisering (VC, klorid, NVOC, COD, ledningsevne) til sammenligning mellem interne og eksterne analyse og indledende erfaringer gøres i forhold til rensningseffektens sammenhæng med elektrodemateriale, strømstyrke, energioverførsel og rensningseffekt. Niveauerne for parametrene fastlægges pba. litteraturstudiet. Der analyseres for klorerede opløsningsmidler inkl. nedbrydningsprodukter, NVOC, klorid.

VC's flygtighed udgør en udfordring ved at udføre elektrokemiske nedbrydningsforsøg. I den elektrokemiske celle dannes der gasser (brint ved katoden og ilt ved anoden), som vil øge afdampning/stripningseffekten af stoffet. Det kan derfor vise sig vanskeligt at dokumentere, at fjernelse af vinylklorid skyldes nedbrydning og ikke stripning. Klorid er slutprodukt af nedbrydningen, og anvendes som oftest til at redegøre for massebalancen. Udfordringen her er, at grundvandets baggrundskoncentration af klorid er ~150 mg/L, og at den øgede tilførsel af klorid fra fuldstændig nedbrydning af VC er ~3mg/L, og således ligger tæt ved eller inden for forventet analyseusikkerhed. Forholdet mellem nedbrydning og stripning vil således blive forsøgt undersøgt i laboratoriet. Der udvikles derfor et setup, hvorved der kan analyseres for VC i gasfasen ved opsamling af headspace over et bestemt tidsrum. Dette gøres for at give et estimat af forholdet mellem nedbrydning og stripning og dette påtænkes gentaget i feltforsøgene.

Laboratorieforsøgene er planlagt at køre med varierende intensitet over 4 måneder med overlap med feltforsøgene. Dette medfører, at indledende erfaringer fra laboratorieforsøgene kan danne baggrund for planlægning af første kampagne feltforsøg, men lige så vigtigt, at erfaringer og problemer erfaret fra feltforsøgene kan undersøges nærmere i laboratoriet. Dette skal sikre en bedre dynamik i projektet med henblik på at øge projektets succesrate.

Der afsættes indledningsvist et eksternt analysebudget på ca. 20 analyser af klorerede inkl. nedbrydningsprodukter og BTEX til laboratorieforsøgene. De resterende parametre plus supplerende VC analyser varetages af Aalborg Universitet.

A3 indebærer timeforbrug for Aalborg Universitet, som dækkes af Clean Cluster bevillingen, men også udgifter til drift og analyser, som dækkes af nærværende SUP projekt.

A4: Etablering af setup til afvikling af test i felten
Aktiviteten starter primo marts 2023. Der skal skaffes pumpe til oppumpning af grundvand og etablering af strøm. Derudover er der brug for en mindre diffusionstæt udligningstank (fx Tedlar Bag, CEL Scientific Corp.), som kan indeholde det volumen af vand, der skal bruges til en felttest kampagnen (fx 100 L). Vandet pumpes fra udligningstanken, gennem cellen, evt. med recirkulation for at opnå nødvendig rensningstid, til en palletank (1000 L), der opsamler behandlet vand. Der anskaffes en pavillon eller lignende til at yde beskyttelse mod vejr og vind.

A4’s timeforbrug for Aalborg Universitet dækkes af Clean Cluster bevillingen, mens drifts- og udstyrsudgifter samt GEVs involvering som dækkes af nærværende SUP projekt.

A5: Feltforsøg – 3 kampagner
Aktiviteten starter primo april 2023 og planlægges at køre over en periode på 4 måneder. Feltforsøg afvikles i 3 kampagner. En kampagne består af oppumpning af vand til udligningstanken og udtagning af startprøve til ekstern analyse, og op til 10 tests af forskellige parametre. Når steady-state for en ny indstilling er opnået (når flowet og udløbskoncentrationer efter ca. 5 til 10 min er stabilt) udtages der prøver af cellens udløb til ekstern og intern analyse. I feltforsøgene er analyseparametrene klorerede opløsningsmidler og nedbrydningsprodukter, NVOC, klorid, samt sensorparametre såsom pH, redox, ledningsevne og temperatur. En kampagne forventes at bestå af 1 til 2 dages forsøgsarbejde på lokaliteten, ca. 2 ugers leveringstid på analyser (10 arbejdsdage) efterfulgt af databehandling. Første feltkampagne planlægges pba. erfaring fra de indledende laboratorietests. Planen for næste kampagne justeres på baggrund af de opnåede erfaringer. Det er som udgangspunkt de samme parametre (flow/reaktionstid, elektrodematerialer, strømstyrker, polariseringstider) der skal testes i feltforsøgene, men erfaringerne fra feltforsøgene inddrages ligeledes i laboratoriearbejdet, så opståede ideer kan afprøves. Feltkampagne 3 vil inkludere det optimerede setup, og herfra udtages ind- og udløbsprøver til analyse for Grindstedpakke A. Det grundvand, som har været brugt til tests, opsamles i palletanken, og det samlede volumen holdes under 1000L. Bortskaffelse af vandet vil ske efter anvisning fra Billund Kommune på baggrund af analyse for klorerede opløsningsmidler og nedbrydningsprodukter.

Der afsættes budget til yderligere analyser af rensningsmetodens effektivitet målrettet Grindstedpakke A stoffer og evt. andre stoffer som viser sig relevante.

A5’s timeforbrug for Aalborg Universitet dækkes af Clean Cluster bevillingen, mens drifts- og udstyrsudgifter samt GEVs involvering som dækkes af nærværende SUP projekt.

A6: Leverancer og projektafslutning
Der udarbejdes i løbet af projektet korte notater (fx som nævnt under litteraturstudie) som oplæg til statusmøder med Regionen. Ved afslutning af forsøgsarbejdet opsamles data, resultater og erfaringer i en teknisk rapport indeholdende anbefalinger til videre arbejde. Derudover formidles projektets resultater populærvidenskabeligt i form af artikler og nyhedsindlæg til miljøbranchen og lægmand. Projektets resultater vil også blive forsøgt publiceret i en videnskabelig artikel.

A6 dækkes af bidrag fra både Clean Cluster projektet og nærværende SUP projekt, da der er enslydende (fx litteraturstudium), men også på nogle punkter forskellige leverancer i de to projekter (afrapportering).

A7: Projektadministrering
I hele projektperioden pågår styring af projektets forskellige faser. Planen er at afholde et fysisk kickoff møde primo februar i Grindsted med besigtigelse af testlokaliteten, og derefter kortere statusmøder hver 14. dag eller lidt længere månedlige statusmøder alt efter behov. Der planlægges 3 formelle statusmøder, hvor Regionen inviteres; 1) opstart, 2) fremdrift under feltarbejdet, 3) diskussion af resultater inden afrapportering. Projektets økonomi og afrapportering administreres overfor Regionen af Aalborg Universitet.

A7 dækkes af nærværende SUP projekt.

OVERSIGT OVER EKSTERNE ANALYSER

Følgende eksterne analyser er planlagt.

Parameter	Aktivitet	Antal
Boringskontrol	A3 + A5	1 + 1 x 3 = 4
Klorerede opløsningsmidler og nedbrydningsprodukter	A3 + A5	1 + 20 + 11 x 3 = 54
Klorid	A5	10 x 3 = 30
NVOC	A5	10 x 3 = 30
BTEX	A5	10 x 3 + 2 = 32
Grindstedpakke A	A3 + A5	4

Derudover vil flere analyser blive planlagt under aktivitet A1, A2, og A3.

BUDGET

Budgettet for nærværende SUP projekt er opdelt på de forskellige poster som følger.

Partner	**Budgetpost**		**Beløb (kr.)**
GEV	Udstyr:		185.000
	Celler	110.000 kr.	
	Pumpe	10.000 kr.	
	Tanke	15.000 kr.	
	Forbehandling	50.000 kr.	
GEV	Feltetablering		70.000
GEV	Timer		123.326
Eksternt laboratorium	Analysebudget		35.731
Eksternt laboratorium	Buffer til ekstra analyser		36.562
AAU	Timer		102.096
AAU	Lab. Drift		97.075
Total			**649.790**

Gevinst ved samspil med Clean Cluster Videnbro-bevilling
Som beskrevet indledningsvist, giver en videnbro-bevilling fra Clean mulighed for også at teste elektrolyse-teknologien i en større skala end skitseret i den oprindelige projektidé, specifikt i Electrocell’s Electro MP Cell med et skalerbart elektrodeareal fra 100 cm^2 og et maks. flow på 240 L per time. Dette er en faktor 5 - 10 større end den celle, der oprindeligt var tiltænkt. Den oprindelige skala er tilstrækkelig til at indhente den påkrævede data på, om vinylklorid kan elimineres i tilstrækkelig grad, og hvilke strømstyrker (strømforbrug), der påkræves ved forskellige elektrodematerialer. Mulighed for også at teste i større skala vil bibringe data på opskalering, gasdannelse, varmeoverførsel, matriceafhængige udfældningsproblematikker og lignende. De tre planlagte test-kampagner bliver derved udvidet med parallelle tests med den større celle, der bibringer et bredere funderet vidensgrundlag i forhold til kvalificering af Kraftcentrum Grindsted konceptet. Clean cluster bevillingen giver derudover mulighed for, at sandfiltrering kan etableres som forbehandling, hvis opløst jern og mangan viser sig at være et problem for processens stabilitet ved tests af længere varighed. Endelig giver bevillingen mulighed for, at der kan inddrages flere analyser til evaluering af

renseteknologiens effektivitet overfor en række andre stoffer, heriblandt BTEX, men ikke mindst stofferne inkluderet i den bekostelige Grindstedpakke A. Der kan vælges at inkludere yderligere Grindstedpakke A analyser, da bevillingen giver mulighed for at allokere et analysebudget, der endnu ikke er disponeret. Slutteligt giver Clean bevillingen en budgetmæssig fleksibilitet i projektet til at kunne agere på de erfaringer, der drages undervejs i projektet. Projektet er et forsknings- og udviklingsprojekt, og feltforsøg i pilotskala er mere uforudsigelige end rene laboratorieforsøg under mere kontrollerede forhold.

BEMANDINGSPLAN

AAU og GEV bemander projektet jf. nedenstående bemandingsplan.

AAU (projektstiller)	Jens Muff (projektleder), Lektor Linda B. Madsen, Laboratorieteknikker Nicolai Præst, Laborant Leona Muslija, laborantelev Maria Hansen, Laborantelev
GEV	Martin Østergaard (projektleder), Udviklingschef Rene Heiselberg Gier, Direktør

Derudover deltager Bente Højlund Hyldegaard og Søren Skjold Andersen som sparringspartnere i projektet.

Notat – Litteraturstudium vedr. elektrokemisk nedbrydning af klorerede ethener

Tilgang: Med tilladelse fra forfatteren er litteraturgennemgangen baseret på state-of-the-art kapitlet i Bente Højlund Hyldegaard's Ph.D.-afhandling af. Der inddrages både *in-situ* og *ex-situ* (on-site) studier i litteraturgennemgangen.

Reference til Ph.D. afhandlingen: Hyldegaard, B. H. (2019). Electrochemical zone for degradation of chlorinated ethenes in aquifers. Technical University of Denmark, Department of Civil Engineering

Elektrokemisk oprensning af klorerede ethener

Elektrokemi er en mulig metode til *in-situ* og on-site *ex-situ* oprensning af grundvandsfaner forurenet med klorerede ethener, hvor en elektrisk strøm genereres ved at påføre en elektrisk spænding tværs over en mættet jordmatrice eller *ex-situ* i en elektrokemisk celle til rensning af oppumpet grundvand.

In-situ er elektrisk strøm blevet brugt til at forbedre stoftransporten i jord til ekstraktion af f.eks. tungmetaller [1,2] og tilførsel af injicerede reaktanter i primært lavpermeable jordmatricer for at stimulere nedbrydning [3–5] ved brug af elektrokinetiske transportmekanismer [6]. Kombinationer af elektrokinetik med PRB [7,8], ISCO [9] og ERD [5,10] til at overvinde udfordringerne ved disse teknologier er også blevet studeret. Elektrokemiske metoder adskiller sig fra elektrokinetiske metoder ved, at de snarere end at udnytte transportprocesser, udnytter elektrodeprocesserne, hvilket resulterer i etableringen af forskellige redox-zoner på grund af dissociation af vand, kendt som vandelektrolyse [2]. Når en elektrisk strøm påføres et sæt elektroder i et mættet medium, polariseres elektroderne til en katode og en anode. Ved anoden, som er positivt polariseret, skaber vandelektrolyse et oxiderende og surt miljø (Ligning 1), mens reduktive og basiske forhold etableres omkring den negativt polariserede katode (Ligning 2) [6].

$$2H_2O \rightleftharpoons O_2 + 4H^+ + 4e^- \qquad \text{Ligning 1}$$

$$2H_2O \rightleftharpoons H_2 + 2OH^- \qquad \text{Ligning 2}$$

Vandelektrolyse (Ligning 1-2) er en hurtig proces, som kan resultere i pH-værdier under 2 og over 12 ved henholdsvis anoden og katoden [6]. Reduktionspotentialer på -600 mV i forhold til standard brintelektrode (SHE) kan opnås nær katoden, hvilket er velegnet til reduktion af klorerede ethener [11,12]. Fordele ved elektrokemisk oprensning inkluderer a) kombinationen af reduktion og oxidation af forurenende stoffer, b) evnen til at designe redoxprocesserne for at forbedre ønskede processer og dermed tilpasning til stedsspecifikke karakteristika, f.eks. forureningssammensætning, c) muligheden for at installere flere sekvenser af elektroder for at dække omfanget af forureningen [2,4,13].

Et enkelt feltforsøg, omhandlende elektrokemisk oprensning af en fane forurenet med klorerede ethener, er blevet rapporteret; et pilotforsøg, hvor et elektrodenet blev installeret for gennemstrømning af forureningsfanen, demonstrerede en fjernelse på 95% af TCE med anvendelse af konstant spænding [13,14]. Konstruktion af et elektrodenet over en hel forureningsfane er dyrt, kompliceret og begrænset til lavvandede grundvandsmagasiner [13]. Der er publiceret flere laboratoriestudier, hvor de elektrokemisk inducerede processer er undersøgt i mere kontrollerede systemer. En opsummering af de væsentligste resultater i offentliggjorte laboratoriestudier, som har fokuseret på elektrokemisk fjernelse af vandopløselige klorerede ethener i simulerede grundvandssystemer, er vist i Tabel 1. Opsummeringen er baseret på studier, der anvender en konstant strøm til faste elektroder i udelte gennemstrømningsreaktorer, da disse designparametre er mest egnede og repræsentative for anvendelser i fuld skala.

Tabel 1: Opsummering af resultater fra studier der har undersøgt elektrokemisk fjernelse af vandige klorerede ethener i udelte gennemstrømningsreaktorer med faste elektroder og ved konstant strømstyrke.

Eksperimentelt design	**Strøm [mA]**	**Resultater**	**Ref.**
Væske: Syntetisk Geologi: Kalksten grus Konfiguration: A→C→A Anode: Cast Fe, MMO Katode: Cu Katalysator: -	15-120	Cast Fe anode forbedrede fjernelse af TCE. Anvendelse af 3-elektrodesetup forbedrede yderligere fjernelsen. Lavere flowhastighed forbedrede fjernelsen til mere end 82,2 %. Korrelation mellem strømtæthed og fødekoncentration med en øvre grænse for strømstyrke.	[16]
Væske: Syntetisk Geologi: "Glasperler" Konfiguration: C→C→A, A→C, C→A Anode: MMO, cast Fe Katode: MMO, cast Fe Katalysator: Pd/C, Pd/Al pellets	30-90	Øget elektrodeafstand og flowhastighed reducerede effektiviteten. Højere overfladeareal (skum) forbedrede omdannelsen af TCE. Fjernelsesrater ved 60 mA oversteg dem ved 30 og 90 mA. C→C→A og Pd-belægning øgede signifikant fjernelsesrater og effektivitet. >99 % TCE-fjernelse blev opnået.	[17]
Væske: Syntetisk Geologi: "Glasperler" Konfiguration: A→C→C Anode: MMO Katode: MMO Katalysator: Pd/Al2O3 pellets	60	Tilstedeværelsen af Fe(II) forbedrede signifikant TCE-fjernelse via Fenton-reaktioner. Tilsætning af sulfitter forbedrede TCE-fjernelse på grund af omdannelse til SO_4^{2-}, hvilket opnåede en fjernelseseffektivitet på 71 %. Forurening af Pd med sulfid blev vurderet og fundet ubetydelig.	[18]
Væske: Syntetisk Geologi: Kalksten grus, "glasperler" Konfiguration: C→A Anode: MMO Katode: Fe Katalysator: Pd	60	Tilstedeværelsen af humusstoffer (HS) reducerede TCE-fjernelse i en lineær sammenhæng. HS påvirkede de elektrokemiske processer ved katoden. TCE-nedbrydning i kalksten uden HS nåede 82,9 %, hvilket var overlegen i forhold til det i glasperler.	[19]
Væske: Syntetisk Geologi: Kalksten blok Konfiguration: Anode: Cast Fe Katode: Cu Katalysator: -	90	HS sænkede TCE fjernelsen fra 90 til 80%, dikromat fra 53-70 %, selenat fra 76-89 %, nitrat fra 81-91 %. En blanding af de sidste tre forureningskomponenter nedsatte TCE fjernelsen til ca. 40%. Fjernelsen i kalksten var bedre end fjernelse i kunstigt akryl medium.	[20]
Væske: Syntetisk Geologi: - Konfiguration: A→C, C→A Anode: MMO Katode: MMO Katalysator: Pd/Al2O3 pellets	30-120	C→A konfigurationen var overlegen i forhold til A→C med TCE-fjernelse på henholdsvis 54,5 % og 34,8 %. Polaritetsskifte forbedrede fjernelsen til 69,3 %. Optimalt design af polaritetsskift for TCE-fjernelse var 15 cyklusser h^{-1} ved 60 mA, hvilket resulterede i et strømforbrug på 13 W cm^{-2}.	[21]
Væske: Syntetisk Geologi: - Konfiguration: C→A Anode: MMO Cathode: Fe, Ni, Cu, C, Al Katalysator: Pd	30-90	Højeste TCE-fjernelse blev opnået med skumkatoder af Ni > C > Cu > Fe ~ Al. 60 mA var mest effektivt. Fe-skum øgede fjernelsen fra 43,5 % til 99,8 %, når det var belagt med Pd, med en øvre grænse for fjernelse vs. Pd-loading. Belægning med Pd ændrede katodematerialets ydeevne til Fe > Cu > C > Al > Ni. Nitrat hæmmede fjernelsen.	[22]
Væske: Syntetisk Geologi: - Konfiguration: C→A Anode: MMO Katode: 304 SS, 316SS, 430 SS, Ni/Fe, Ni Katalysator: -	60	Mængden af Ni indlejret i SS påvirkede TCE-fjernelsen: 430 SS < 304 SS < 316 SS på henholdsvis 37,5 %, 52,6 % og 61,7 %. Højeste fjernelse ved ren Ni-skumkatode på 68,4 %.	[23]
Væske: Syntetisk Geologi: - Konfiguration: C→A Anode: C Katode: C Katalysator: -	60-120	Monopolær tilstand resulterede i TCE-fjernelse på 29 %. Introduktion af to bipolare elektroder øgede fjernelsen til 66 % på grund af forbedret peroxiddannelse. I bipolær tilstand forbedrede en strøm på 120 mA fjernelsen, mens den højeste strømeffektivitet blev opnået ved 60 mA.	[24]

Væske: Syntetisk Geologi: - Konfiguration: C→A Anode: BDD Katode: BDD Katalysator: -	2-20 mA/cm^2	TCE-fjernelse > 85 % ved direkte og indirekte oxidation via OH•. Cl-massebalance blev regnet for ved TCE, Cl- og ClO3-. Ingen klorerede mellemprodukter akkumuleredes. TCE-halveringstiden var < 3 min.	[25]
A: Anode. C: Katode. →: Flowretning. MMO: Mixed metal oxide coating på titanium. SS: Stainless steel. BDD: Boron-doped diamond.			

Fra studierne præsenteret i Tabel 1 ses det, at fokus for undersøgelserne har været på indflydelsen af elektrodens sammensætning, elektrodekonfiguration, strømintensitet, forureningskoncentration og flowhastighed på fjernelse af TCE. Høje fjernelsesrater på over 99% blev demonstreret ved strømstyrke på 60 mA ved brug af palladium (Pd) belagte jern (Fe) skumkatoder i en sekvens af katode efterfulgt af anode.

Elektrodematerialer

Brugen af forskellige elektrodematerialer til elektrokemisk oprensning af klorerede ethener i gennemstrømningsreaktorer, som beskrevet i Tabel 1, har demonstreret elektrodemateriale-specifikke egenskaber. De rapporterede fordele og ulemper ved materialer anvendt som anoder, katoder og katalysatorer ses i Tabel 2, Tabel 3 og Tabel 4. Listerne er udvidet med nogle resultater fra andre studier, der bruger elektrodematerialerne rapporteret i Tabel 1, f.eks. i studier, der undersøger elektrokemisk fjernelse af klorerede ethener i statiske eller cirkulerede reaktorsystemer.

Tabel 2: Fremhævede fordele og ulemper for anodematerialer anvendt til elektrokemisk fjernelse af ethener i udelte gennemstrømningsreaktorer driftet ved konstant strømstyrke.

Anodemateriale	**Fordele**	**Ulemper**	**Ref.**
Cast iron, Fe	• Jernfrigivelse snarere end O_2 (korrosion); lav VOC-stripping • Genererer et reducerende miljø egnet til hurtig reduktiv deklorering • Let tilgængeligt i forskellige renheder og priser	• Dannelse af Fe-komplekser, dvs. mulig tilstopning og elektrodedækning • Forhøjet pH nedstrøms for den elektrokemiske zone på grund af lav H^+-dannelse • Potentiel frigivelse af urenheder indlejret i Fe	[11,17,26] [11,16,26] [15,23]
Mixed metal oxide, MMO	• Dimensionelt stabilt, dvs. bevarer sin struktur; kan genbruges • Opbevarer pH-værdien og oxidation-reduktionspotentialet i vandet	• Lav O_2-overpotentiale: skaber oxiderende forhold, dvs. VOC-stripping kan øges • O_2-udvikling konkurrerer med oxidation af de klorerede ethener	[11,17,26] [16,17]
Graphite	• Langsom nedbrydning af H_2O_2 genererer •OH	• Oxiderer klorid til klor	[24]
Diamond (boron-doped), BDD	• Affinitet til at danne •OH	• Fjernelse af organiske stoffer i konkurrence med •OH-omdannelse til O_2	[25,27]
VOC: Volatile organic carbon. Overpotentiale: Forskellen mellem det teoretiske og observerede energiniveau, der er nødvendigt for at drive en reaktion.			

Jernanoder (Fe) er bedst egnet til fjernelse af klorerede ethener, opnår op til 99% TCE-fjernelse, på grund af frigivelse af ferro-ioner i stedet for ilt, hvilket skaber stærkt reducerende forhold [11,16,26]. Dog kan dannelse af Fe-komplekser udfordre anvendelsen af Fe-anoder på grund af f.eks. tilstopning af porer i porøse matricer (Tabel 2). Fe anoder er offeranoder med begrænset levetid.

Nikkel (Ni) har vist sig at være overlegen som katodemateriale til fjernelse af klorerede ethener, med rapporterede TCE-fjernelsesrater på 68% (Tabel 3) [22,21].

Tabel 3: Fremhævede fordele og ulemper ved katodematerialer anvendt til elektrokemisk fjernelse af ethener i udelte gennemstrømningsreaktorer driftet ved konstant strømstyrke.

Katodemateriale	**Fordele**	**Ulemper**	**Ref.**
Iron, Fe	• Yder bedre end MMO til fjernelse af klorerede ethener • Pd-belagt Fe er overlegen i forhold til belagt Ni, Al, C, Cu • Lav pris	• Højt H_2-overpotentiale; langsommere hydro-deklorering end ædle metaller	[17] [22] [11,23]
Mixed metal oxide, MMO	• Lav pris	• Interagerer med H_2 på dets overflade, danner oxider, dvs. mindre H_2 til hydro-deklorering	[11,17,26]
Carbon, C	• Stort overfladeareal og porøsitet • Overlegen i forhold til Fe, Cu, Al til fjernelse af klorerede ethener • Lav reaktivitet • Lav pris	• Skrøbelig, dvs. ikke egnet i felten	[17,22] [22] [17] [11]
Graphit	• Producerer H_2O_2 og •OH • Billigt, sikkert materiale	• Langsom H_2-dannelse på grund af begrænset reaktivitet	[24]
Copper, Cu	• Yder bedre end Fe og Al til fjernelse af klorerede ethener • Lav pris	• Forårsager udfældning og dækning af elektroden • Højere H_2-udviklingsoverpotentiale end ædle metaller; langsommere hydro-deklorering	[11,26] [11,22,26]
Nickel, Ni	• Lavere H_2-overpotentiale understøtter højere hydro-deklorering end C, Cu, Al, Fe	• Akkumulerer H_2-bobler på dets overflade	[22]
Aluminum, Al	• Lav pris	• Korroderer med dannelse af Al-komplekser • Svag bindingsevne med hydrogen reducerer hydro-deklorering	[22] [22]

Pd: Palladium. H_2O_2: Hydrogen peroxid. H_2: Hydrogen.

Katodematerialernes ulemper peger I retning af nødvendigheden i loade katoderne med partikler af katalysatorer (Tabel 4).

Tabel 4: Fremhævede fordele og ulemper ved brug af katalysatorpartikler på katoderne anvendt til elektrokemisk fjernelse af ethener i udelte gennemstrømningsreaktorer driftet ved konstant strømstyrke.

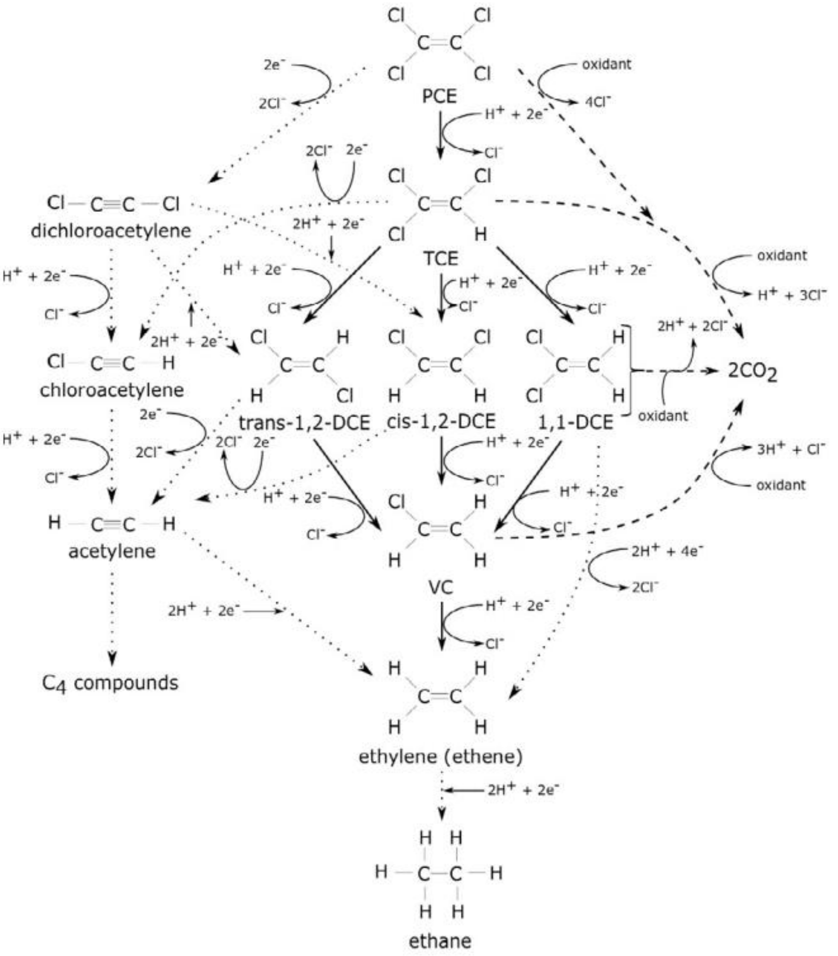
Katalysator	**Fordele**	**Ulemper**	**Ref.**
Ædelmetaller, e.g. Ag, Pt	• Lave H_2-overpotentialer, dvs. hurtig reduktion ved hydro-deklorering	• Dyrt	[17,25]
Palladium, Pd	• Katalyserer dannelsen af H_2O_2, dvs. oxidation af klorerede ethener • Forbedrer hydro-deklorering af Fe > Cu > C > Al > Ni og reaktionshastigheder	• Lav Pd-belastning kan ikke binde reaktivt hydrogen på sin overflade • Høj Pd-belastning forbedrer protonreduktion, dvs. konkurrerer med hydro-deklorering	[17,22] [22]

	- Højere overfladeareal og tilstrækkelig bindingsstyrke med hydrogen	- Dyrt	[17,26]
Ag: Silver. Pt: Platinum.			

Katalysatoren Pd ændrer effektiviteten af katodematerialerne med hensyn til fjernelse af klorerede ethener. Med anvendelse af Pd har Fe-katoder demonstreret TCE-fjernelsesrater over 99% [22]. Fjernelseffektiviteten er ikke-lineært korreleret med mængden af Pd på katoden, dvs. der findes en optimal loading, som foreslås at være 0,76 mg Pd pr. cm^2 elektrodeoverflade [22]. I laboratoriestudier påvirker elektrodematerialet signifikant fjernelsen af klorerede ethener. Derfor, når man designer en elektrokemisk oprensning; (1) skal elektrodematerialerne nøje udvælges, (2) en anden overvejelse for valg af katodematerialer og brug af katalysator er, om der vil blive anvendt polaritetsskift for f.eks. fjernelse af udfældninger på elektrodeoverfladen, da Pd og andre giftige metaller i elektrodematerialet frigives under anodisk polarisering [28], (3) relateret til valg af elektrode er formen på elektrodematerialet, f.eks. stang, net, skum. Skum har et større overfladeareal, hvilket forbedrer fjernelsen af forurenende stoffer [11,16,29,30], (4) sekvensen af elektroder i gennemstrømningsreaktorer bestemmer rækkefølgen af redoxzonerne og er derfor vigtig. En sekvens af reducerende zoner efterfulgt af oxiderende zoner har vist den højeste TCE-fjernelse på op til 87% [16,17]. Udvidelse af redoxzonerne ved at anvende tre elektroder i sekvens kan øge reaktionskinetikken og dermed forbedre fjernelsesresultaterne [17], (5) den anvendte strømstyrke påvirker også fjernelsen. I litteraturen er forskellige optimale strømstyrker blevet rapporteret [16,17,24,26], hvilket antyder en korrelation med en eller flere af de fire andre designparametre nævnt. Derfor ser den optimale strømstyrke ud til at være systemspecifik. Desuden er strømstyrken fundet at være ikke-lineært korreleret med fjernelsen af klorerede ethener [17], hvorfor intelligent design af de elektrokemiske zoner er nødvendigt.

Elektrokemisk inducerede nedbrydningsveje for klorerede ethener

Klorerede ethener, der strømmer gennem elektrokemiske zoner, er generelt underlagt reduktion og oxidation. De dominerende nedbrydningsveje for klorerede ethener ses i Figur 1.



Figur 1: Mulige in-situ elektrokemisk inducerede nedbrydningsveje for de klorerede ethener tetrachloroethylen (PCE), trichloroethylen (TCE), dichloroethylen (DCEs) and vinylklorid (VC); biotisk reduktion (pil), abiotisk reduktion (prikket pil) og/eller abiotisk oxidation (stiplet pil) [45].

Detaljeret, elektrokemiske reduktions- og oxidationstransformationsmekanismer er mere komplekse og kan inkludere direkte abiotisk reduktion, indirekte abiotisk reduktion, direkte abiotisk oxidation og indirekte abiotisk oxidation [31]. Sekundært kan biotisk reduktion [12,32,33] og/eller oxidation [34,35] stimuleres, hvis specifikke mikrobielle nedbrydere er til stede i systemet. Direkte abiotisk reduktion er, når de klorerede ethener, adsorberet på katodeoverfladen, modtager elektroner direkte fra elektroden [31,36–38]. Indirekte abiotisk reduktion er, når elektroner overføres via brint dannet fra vandelektrolyse [31,36,37]. Det specifikke bidrag fra direkte og indirekte abiotisk reduktion af klorerede ethener afhænger f.eks. af katodematerialet og den anvendte strømintensitet [31]. Som et eksempel er den indirekte abiotiske reduktion forbedret, når der anvendes metaller med lav H_2 overpotentiale, f.eks. Ni eller Pd (Tabel 3, Tabel 4) [31,39]. Desuden kan abiotisk reduktion opdeles i β-elimination (Figur 3, stiplede pile fra klorerede ethener til (klorerede) acetylen), hydrogenering (Figur 1, stiplede pile fra (klorerede) acetylen til (klorerede) ethener), og hydrolyse (Figur 1, solide pile og stiplede pile mellem (klorerede) acetylener) [40,41]. Direkte abiotisk oxidation er, når elektroner overføres direkte til anoden under transformation af de adsorberede klorerede ethener [31,42]. Indirekte oxidation er oxidation via elektrogenererede oxidanter, f.eks. brintoverilte (H_2O_2), hydroxylradikaler (•OH), klor (Cl_2), ozon (O_3), persulfat (SO_5^{2-}, $S_2O_8^{2-}$) (Figur 1, stiplede pile) [18,31,43,44]. Som for abiotisk reduktion, afhænger abiotiske oxidationsmekanismer af elektrodematerialet, f.eks. lav ilt (O_2) overpotentiale og stabilitet [31]. For eksempel katalyserer Pd dannelsen af H_2O_2 (Tabel 4).

Opsummering

Litteraturen om elektrokemisk nedbrydning af organiske forurenende stoffer *ex-situ* er omfattende, og flere reviews diskuterer den alsidige nedbrydning af forskellige forurenende stoffer med elektrodematerialer med høj oxidationsevne, især BDD. Men, den specifikke litteratur om elektrokemisk oprensning af klorerede ethener, emnet for dette litteraturstudium, er sparsom, og offentliggjorte studier omhandler både *in-situ* og *ex-situ* applikationer. En særlig katalysator-dopet katode er udviklet til effektiv reduktion af klorerede ethener (Pd dopet Fe), men disse katalytiske materialer er dyre og har lav teknologisk modenhed (TRL). Langvarig drift af elektrolyse på grundvand kræver et behov for at skifte potentiale mellem elektroderne, og derfor skal de anvendte materialer være stabile som både anode og katode. Billige elektrodematerialer som grafit og jern kan ikke opfylde dette kriterium. De mange eksotiske forurenende stoffer, der er specielle for forureningen i Grindsted, kan muligvis ikke nedbrydes alene gennem en reduktiv vej, så mere alsidige elektrodematerialer er en bedre match. MMO og BDD er dimensionelt stabile, velafprøvede elektrodematerialer, der gennem oxidative (og reduktive) veje nedbryder organiske stoffer til fuldstændig mineralisering eller delvist til nedbrydningsprodukter af carboxylsyrer. Tabel 1 inkluderer studier med disse materialer.

Referencer

1. A.B. Ribeiro, E.P. Mateus, Electrokinetics Across Disciplines and Continents, New Strategies for Sustainable Development, Springer, London, 2016. doi:10.1007/978-3-319-20179-5.
2. A.N. Alshawabkeh, Electrokinetic soil remediation: Challenges and opportunities, Sep. Sci. Technol. 44 (2009) 2171–2187. doi:10.1080/01496390902976681.
3. A.T. Lima, A. Hofmann, D. Reynolds, C.J. Ptacek, P. Van Cappellen, L.M. Ottosen, S. Pamukcu, A.N. Alshawabkeh, D.M. O'Carroll, C. Riis, E. Cox, D.B. Gent, R. Landis, J. Wang, A.I.A. Chowdhury, E.L. Secord, A. Sanchez-Hachair, Environmental Electrokinetics for a sustainable subsurface, Chemosphere. 181 (2017) 122–133. doi:10.1016/j.chemosphere.2017.03.143.
4. K.R. Reddy, C. Cameselle, Electrochemical remediation technologies for polluted soils, sediments and groundwater, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009.
5. B.H. Hansen, L.W. Nedergaard, L.M. Ottosen, C. Riis, M.M. Broholm, Experimental design for assessment of electrokinetically enhanced delivery of lactate and bacteria in 1,2-cis-dichloroethylene contaminated limestone, Environ. Technol. Innov. 4 (2015) 73–81. doi:10.1016/j.eti.2015.04.006.
6. Y.B. Acar, A.N. Alshawabkeh, Principles of Electrokinetic Remediation, Environ. Sci. Technol. 27 (1993) 2638–2647. Doi:10.1021/es00049a002.
7. J.-W. Moon, H.-S. Moon, H. Kim, Y. Roh, Remediation of TCE-contaminated groundwater using zero valent iron and direct current: experimental results and electron competition model, Environ. Geol. 48 (2005) 805– 817. doi:10.1007/s00254-005-0023-1.
8. C.C. Liu, S.F. Liau, D.H. Tseng, Effects of the electrode arrangements on reductive dechlorination of trichloroethylene in an electro-enhanced iron wall, Environ. Technol. 27 (2006) 683–693. doi:10.1080/09593332708618681.
9. M.Z. Wu, D.A. Reynolds, A. Fourie, H. Prommer, D.G. Thomas, Electrokinetic in situ oxidation remediation: Assessment of parameter sensitivities and the influence of aquifer heterogeneity on remediation efficiency, J. Contam. Hydrol. 136–137 (2012) 72–85. doi:10.1016/j.jconhyd.2012.04.005.
10. X. Mao, J. Wang, A. Ciblak, E.E. Cox, C. Riis, M. Terkelsen, D.B. Gent, A.N. Alshawabkeh, Electrokinetic- enhanced bioaugmentation for remediation of chlorinated solvents contaminated clay, J. Hazard. Mater. 213– 214 (2012) 311–317. doi:10.1016/j.jhazmat.2012.02.001.
11. X. Mao, A. Ciblak, M. Amiri, A.N. Alshawabkeh, Redox Control for Electrochemical Dechlorination of Trichloroethylene in Bicarbonate Aqueous Media, Environ. Sci. Technol. 45 (2011) 6517–6523. doi:10.1021/es200943z.
12. F. Aulenta, L. Tocca, R. Verdini, P. Reale, M. Majone, Dechlorination of Trichloroethene in a Continuous- Flow Bioelectrochemical Reactor: Effect of Cathode Potential on Rate, Selectivity, and Electron Transfer Mechanisms, Environ. Sci. Technol. 45 (2011) 8444–8451. doi:10.1021/es202262y.
13. D. Gilbert, T. Sale, M.A. Petersen, Electrolytic reactive barriers for chlorinated solvent remediation, in: H.F. Stroo, C.H. Ward (Eds.), Situ Remediat. Chlorinated Solvent Plumes, Springer, New York, USA, 2010: pp. 573–590. doi:10.1007/978-1-4419-1401-9.

14. T. Sale, M. Petersen, D. Gilbert, Electrically Induced Redox Barriers for Treatment of Groundwater, Colorado, USA, 2005. https://clu-in.org/download/contaminantfocus/dnapl/Treatment_Technologies/CU-0112-fr-01.pdf.
15. B.H. Hyldegaard, R. Jakobsen, E.B. Weeth, N.D. Overheu, D.B. Gent, L.M. Ottosen, Challenges in electrochemical remediation of chlorinated solvents in natural groundwater aquifer settings, J. Hazard. Mater. 368 (2019) 680–688. doi:10.1016/j.jhazmat.2018.12.064.
16. X. Mao, S. Yuan, N. Fallahpour, A. Ciblak, J. Howard, I. Padilla, R. Loch-Caruso, A.N. Alshawabkeh, Electrochemically Induced Dual Reactive Barriers for Transformation of TCE and Mixture of Contaminants in Groundwater, Environ. Sci. Technol. 46 (2012) 12003–12011. doi:10.1021/es301711a.
17. L. Rajic, N. Fallahpour, A.N. Alshawabkeh, Impact of electrode sequence on electrochemical removal of trichloroethylene from aqueous solution, Appl. Catal. B Environ. 174–175 (2015) 427–434. doi:10.1016/j.apcatb.2015.03.018.
18. S. Yuan, M. Chen, X. Mao, A.N. Alshawabkeh, A three-electrode column for Pd-catalytic oxidation of TCE in groundwater with automatic pH-regulation and resistance to reduced sulfur compound foiling, Water Res. 47 (2013) 269–278. doi:10.1016/j.watres.2012.10.009.
19. L. Rajic, N. Fallahpour, R. Nazari, A.N. Alshawabkeh, Influence of humic substances on electrochemical degradation of trichloroethylene in limestone aquifers, Electrochim. Acta. 181 (2015) 123–129. doi:10.1016/j.electacta.2015.03.121.
20. N. Fallahpour, X. Mao, L. Rajic, S. Yuan, A.N. Alshawabkeh, Electrochemical dechlorination of trichloroethylene in the presence of natural organic matter, metal ions and nitrates in a simulated karst media, J. Environ. Chem. Eng. 5 (2017) 240–245. doi:10.1016/j.jece.2016.11.046.
21. L. Rajic, N. Fallahpour, S. Yuan, A.N. Alshawabkeh, Electrochemical transformation of trichloroethylene in aqueous solution by electrode polarity reversal, Water Res. 67 (2014) 267–275. doi:10.1016/j.watres.2014.09.017.
22. L. Rajic, N. Fallahpour, E. Podlaha, A.N. Alshawabkeh, The influence of cathode material on electrochemical degradation of trichloroethylene in aqueous solution, Chemosphere. 147 (2016) 98–104. doi:10.1016/j.chemosphere.2015.12.095.
23. L. Rajic, N. Fallahpour, E. Oguzie, A.N. Alshawabkeh, Electrochemical transformation of thichloroethylene in groundwater by Ni-containing cathodes, Electrochim. Acta. 181 (2015) 118–122. doi:10.1016/j.electacta.2015.03.112.
24. L. Rajic, R. Nazari, N. Fallahpour, A.N. Alshawabkeh, Electrochemical degradation of trichloroethylene in aqueous solution by bipolar graphite electrodes, J. Environ. Chem. Eng. 4 (2016) 197–202. doi:10.1016/j.jece.2015.10.030.
25. K.E. Carter, J. Farrell, Electrochemical Oxidation of Trichloroethylene Using Boron-Doped Diamond Film Electrodes, Environ. Sci. Technol. 43 (2009) 8350–8354. doi:https://doi.org/10.1021/es9017738.
26. N. Fallahpour, S. Yuan, L. Rajic, A.N. Alshawabkeh, Hydrodechlorination of TCE in a circulated electrolytic column at high flow rate, Chemosphere. 144 (2016) 59–64. doi:10.1016/j.chemosphere.2015.08.037.
27. B. Marselli, J. Garcia-gomez, P. Michaud, M.A. Rodrigo, M. Mo, Electrogeneration of Hydroxyl Radicals on Boron-Doped Diamond Electrodes, J. Electrochem. Soc. 150 (2003) 79–83. doi:10.1149/1.1553790.
28. X. Mao, K. Baek, A.N. Alshawabkeh, Iron Electrocoagulation With Enhanced Cathodic Reduction for the Removal of Aqueous Contaminant Mixtures, Environ. Eng. Manag. J. 14 (2015) 2905–2911. http://omicron.ch.tuiasi.ro/EEMJ.
29. X. Mao, A. Ciblak, K. Baek, M. Amiri, R. Loch-Caruso, A.N. Alshawabkeh, Optimization of electrochemical dechlorination of trichloroethylene in reducing electrolytes, Water Res. 46 (2012) 1847–1857. doi:10.1016/j.watres.2012.01.002.
30. V. Sáez, M.D. Esclapez, I. Tudela, P. Bonete, J. González-García, Electrochemical degradation of perchloroethylene in aqueous media: Influence of the electrochemical operational variables in the viability of the process, Ind. Eng. Chem. Res. 49 (2010) 4123–4131. doi:10.1021/ie100134t.
31. C.A. Martínez-Huitle, M.A. Rodrigo, I. Sirés, O. Scialdone, Single and Coupled Electrochemical Processes and Reactors for the Abatement of Organic Water Pollutants: A Critical Review, Chem. Rev. 115 (2015) 13362–13407. doi:10.1021/acs.chemrev.5b00361.
32. R. Verdini, F. Aulenta, F. de Tora, A. Lai, M. Majone, Relative contribution of set cathode potential and external mass transport on TCE dechlorination in a continuous-flow bioelectrochemical reactor, Chemosphere. 136 (2015) 72–78. doi:10.1016/j.chemosphere.2015.03.092.
33. S.T. Lohner, D. Becker, K.M. Mangold, A. Tiehm, Sequential reductive and oxidative biodegradation of chloroethenes stimulated in a coupled bioelectro-process, Environ. Sci. Technol. 45 (2011) 6491–6497. doi:10.1021/es200801r.
34. F. Aulenta, R. Verdini, M. Zeppilli, G. Zanaroli, F. Fava, S. Rossetti, M. Majone, Electrochemical stimulation of microbial cis-dichloroethene (cis-DCE) oxidation by an ethene-assimilating culture, N. Biotechnol. 30 (2013) 749–755. doi:10.1016/j.nbt.2013.04.003.

35. A. Tiehm, S.T. Lohner, T. Augenstein, Effects of direct electric current and electrode reactions on vinyl chloride degrading microorganisms, Electrochim. Acta. 54 (2009) 3453–3459. doi:10.1016/j.electacta.2009.01.002.
36. J. Farrell, N. Melitas, M. Kason, T. Li, Electrochemical and Column Investigation of Iron-Mediated Reductive Dechlorination of Trichloroethylene and Perchloroethylene, Environ. Sci. Technol. 34 (2000) 2549–2556. doi:10.1021/es991135b.
37. J. Wang, J. Farrell, Investigating the role of atomic hydrogen on chloroethene reactions with iron using Tafel analysis and electrochemical impedance spectroscopy, Environ. Sci. Technol. 37 (2003) 3891–3896. doi:10.1021/es0264605.
38. B. Huang, J. Long, W. Chen, Y. Zhu, G. Zeng, C. Lei, Linear free energy relationships of electrochemical and thermodynamic parameters for the electrochemical reductive dechlorination of chlorinated volatile organic compounds (Cl-VOCs), Electrochim. Acta. 208 (2016) 195–201. doi:10.1016/j.electacta.2016.04.182.
39. J.H. Brewster, Mechanisms of Reductions at Metal Surfaces. I. A General Working Hypothesis, J. Am. Chem. Soc. 76 (1954) 6361–6363. doi:10.1021/ja01653a034.
40. W.A. Arnold, A.L. Roberts, Pathways and Kinetics of Chlorinated Ethylene and Chlorinated Acetylene Reaction with Fe(0) Particles, Environ. Sci. Technol. 34 (2000) 1794–1805. doi:10.1021/es980252o.
41. A.L. Roberts, L.A. Totten, W.A. Arnold, D.R. Burris, T.J. Campbell, Reductive elimination of chlorinated ethylenes by zero-valent metals, Environ. Sci. Technol. 30 (1996) 2654–2659. doi:10.1021/es9509644.
42. P. Lakshmipathiraj, G. Bhaskar Raju, Y. Sakai, Y. Takuma, A. Yamasaki, S. Kato, T. Kojima, Studies on electrochemical detoxification of trichloroethene (TCE) on Ti/IrO2-Ta2O5 electrode from aqueous solution, Chem. Eng. J. 198–199 (2012) 211–218. doi:10.1016/j.cej.2012.05.092.
43. M. Cheng, G. Zeng, D. Huang, C. Lai, P. Xu, C. Zhang, Y. Liu, Hydroxyl radicals based advanced oxidation processes (AOPs) for remediation of soils contaminated with organic compounds: A review, Chem. Eng. J. 284 (2016) 582–598. doi:10.1016/j.cej.2015.09.001.
44. S. Yuan, X. Mao, A.N. Alshawabkeh, Efficient Degradation of TCE in Groundwater Using Pd and Electro- generated H2 and O2: A Shift in Pathway from Hydrodechlorination to Oxidation in the Presence of Ferrous Ions, Environ. Sci. Technol. 46 (2012) 3398–3405. doi:10.1021/es204546u.
45. L.M. Ottosen, T.H. Larsen, P.E. Jensen, G.M. Kirkelund, H. Kerrn-Jespersen, N. Tuxen, B.H. Hyldegaard, Electrokinetics applied in remediation of subsurface soil contaminated with chlorinated ethenes – A review, Chemosphere. 235 (2019) 113–125. doi:10.1016/j.chemosphere.2019.06.075.
46. S.S. Zumdahl, Electrochemistry, in: R.B. Schwartz, C.L. Brooks, A. Galvin (Eds.), Chem. Princ., 6th ed., Houghton Mifflin Company, Boston, MA, 2009: pp. 472–520.
47. P.H. Fallgren, J.J. Eisenbeis, S. Jin, In situ electrochemical manipulation of oxidation-reduction potential in saturated subsurface matrices, J. Environ. Sci. Heal. Part A. 53 (2018) 517–523. doi:10.1080/10934529.2017.1422951.
48. T.H. Wiedemeier, H.S. Rifai, C.J. Newell, J.T. Wilson, Overview of intrinsic bioremediation, in: T.H. Wiedemeier, H.S. Rifai, C.J. Newell, J.T. Wilson (Eds.), Nat. Attenuation Fuels Chlorinated Solvents Subsurf., John Wiley & Sons, Inc., 1999: pp. 162–188. doi:10.1016/S0169-7722(99)00099-6.
49. E. Strandgaard Andersen, P. Jespersgaard, O. Østergaard, Databog fysik kemi, 8th ed., F & K Forlaget, Copenhagen, DK, 1993.
50. W.W. Nazaroff, L. Alvarez-Cohen, eds., A Further Look at Transformation Processes, in: Environ. Eng. Sci., John Wiley & Sons, Inc., New York, USA, 2010: pp. 641–650.

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

DANAK
TEST Reg.nr. 361

ANALYSERAPPORT

Aalborg Universitet
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 24-05-2023
Version: 1
Modtaget: 04-04-2023
Analyseperiode: 04-04-2023 - 24-05-2023
Ordrenr.: 778822

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøvested: DGU 114.2567 BE6-2, 0 Grindsted
Udtaget: 03.04.2023
Prøvetype: Råvand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 74297/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.12	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.067	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.4	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.8	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	1.2	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.92	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.0090	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	25	mg/l	0.3	15	Granplot
Chlorid, Cl-	190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	24	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	117	mg/l	2	15	DS 236:1977
Inddampningsrest	390	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	0.037	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	5.3	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.4	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	8.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	0.19	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.62	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	1.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	2.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.2	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	56	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	56	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.89	µg/l	0.020	20	DS/EN ISO 10301:2000

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

Prøvenr.: 74297/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Tetrachlorethylen		2.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.23	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		930	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		23	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		120	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		0.53	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.079	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000
Grindstedpakke A - Vand			-			AK186 - LC-GC/MS/MS
Acetylsulfaguanidin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Acetylsulfanilsyre	#	76	µg/l	0.1	30	AK186 - LC/MS/MS
Aetallymal	#	1.7	µg/l	0.1	30	AK186 - GC/MS
Allyl-n-butylbarbityrat	#	11	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-isobutyl-barbitursyre (Butalbital)	#	11	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-(methylbutyl)-barbitursyre	#	11	µg/l	0.1	30	AK186 - GC/MS
Barbital	#	14	µg/l	0.1	30	AK186 - GC/MS
Butobarbital (N-butylethylbarbitursyre)	#	5.1	µg/l	0.1	30	AK186 - GC/MS
Butylbarbiturat	#	15	µg/l	0.1	30	AK186 - GC/MS
5,5-diallylbarbitursyre (Allobarbital)	#	10	µg/l	0.1	30	AK186 - GC/MS
N-N-diethylnicotinamid	#	2.5	µg/l	0.1	30	AK186 - GC/MS
Dipropenylamin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
5-ethyl-5-sec-butylbarbitursyre (Butabarbital)	#	7.9	µg/l	0.1	30	AK186 - GC/MS
Ethylurethan	#	<0.10	µg/l	0.1	30	AK186 - GC/MS
Phthalylsulfathiazol	#	8.7	µg/l	0.1	30	AK186 - LC/MS/MS
Hexobarbital	#	<1.0	µg/l	0.1	30	AK186 - GC/MS
Isobutylbarbitursyre	#	440	µg/l	0.1	30	AK186 - GC/MS
Isopropylbarbitursyre	#	12	µg/l	0.1	30	AK186 - GC/MS
Meprobamat	#	110	µg/l	0.1	30	AK186 - GC/MS
Methoxyproprionitril	#	<0.10	µg/l	0.1	30	AK210 - HS GC/MS
N-methyldiethylbarbitursyre (Metharbital)	#	<1.0	µg/l	0.1	30	AK186 - GC/MS
Monoethylbarbitursyre	#	7.8	µg/l	0.1	30	AK186 - GC/MS
Pentobarbital	#	61	µg/l	0.1	30	AK186 - GC/MS
Amobarbital	#	69	µg/l	0.1	30	AK186 - GC/MS
Sulfanilamid	#	8.3	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfaguanidine	#	82	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamethazin (Sulfadimidin)	#	73	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfamethizol	#	6.5	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfadiazin	#	1.9	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilsyre	#	130	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfacetamid	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfadoxin	#	<0.5	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamerazin	#	3.2	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilylurinstof	#	6.9	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfapyridin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfathiazol	#	0.66	µg/l	0.05	30	AK186 - LC/MS/MS

Kommentar

Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 200 °C.

Sofie Askjær Hass

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	25-05-2023
Version:	1
Modtaget:	03-05-2023
Analyseperiode:	03-05-2023 - 25-05-2023
Ordrenr.:	785120

Sagsnavn	Svinget 12, Grindsted
Lokalitet:	565-32009, Svinget 12, Grindsted
Prøvested:	DGU 114.2567 BE6-2-2
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	SKI/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101198/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.15	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.080	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.4	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.9	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	1.0	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.73	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.0013	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.018	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	22	mg/l	0.3	15	Granplot
Chlorid, Cl-	200	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	21	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	127	mg/l	2	15	DS 236:1977
Inddampningsrest	490	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	0.079	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	6.4	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.0	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	4.1	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	24	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	0.69	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.99	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	2.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	3.5	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	4.5	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	65	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	65	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	1.2	µg/l	0.020	20	DS/EN ISO 10301:2000

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

Prøvenr.: 101198/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Tetrachlorethylen	2.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.13	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	690	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.25	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	27	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	52	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.10	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

Laboratoriet vurderer: Prøvens totalkulbrinter har sin oprindelse i autobenzin. det påviste produkt har en anden sammensætning end det tilsvarende friske produkt grundet udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	25-05-2023
Version:	1
Modtaget:	03-05-2023
Analyseperiode:	03-05-2023 - 25-05-2023
Ordrenr.:	785120

Sagsnavn	Svinget 12, Grindsted
Lokalitet:	565-32009, Svinget 12, Grindsted
Prøvested:	Lab forsøg
Prøve ID:	AAU1
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	SKI/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101199/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.13	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.068	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.4	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.7	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.83	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.85	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning

ANALYSERAPPORT

Prøvenr.: 101199/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Total phosphor, P		0.016	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		24	mg/l	0.3	15	Granplot
Chlorid, Cl-		190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		20	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		124	mg/l	2	15	DS 236:1977
Inddampningsrest		460	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		0.017	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		4.3	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		3.9	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		15	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		0.75	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.48	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.48	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		1.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		1.9	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	2.4	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	51	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		51	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.61	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.7	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.25	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		970	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.17	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		24	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		79	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.060	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

Laboratoriet vurderer: Prøvens totalkulbrinter har sin oprindelse i autobenzin. det påviste produkt har en anden sammensætning end det tilsvarende friske produkt grundet udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU2
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101200/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+		0.15	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn		0.066	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++		3.6	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++		2.4	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+		1.0	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+		140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe		0.82	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-		0.0012	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-		<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P		0.017	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		25	mg/l	0.3	15	Granplot
Chlorid, Cl-		190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		21	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		121	mg/l	2	15	DS 236:1977
Inddampningsrest		420	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		0.013	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		1.6	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		4.4	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		490	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		6.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		1.6	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		1.3	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		3.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	4.8	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	530	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	6.1	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		540	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		0.36	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000

Prøvenr.: 101200/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Trichlorethylen	1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	2.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.29	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	1300	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.27	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	39	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	400	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.085	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	25-05-2023
Version:	1
Modtaget:	03-05-2023
Analyseperiode:	03-05-2023 - 25-05-2023
Ordrenr.:	785120

Sagsnavn	Svinget 12, Grindsted
Lokalitet:	565-32009, Svinget 12, Grindsted
Prøvested:	Lab forsøg
Prøve ID:	AAU3
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	SKI/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101201/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.037	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.068	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.5	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	2.2	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.96	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.83	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013

Prøvenr.: 101201/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Nitrat, NO3-		0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P		0.019	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		26	mg/l	0.3	15	Granplot
Chlorid, Cl-		190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		23	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		117	mg/l	2	15	DS 236:1977
Inddampningsrest		400	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		0.94	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		8.7	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		420	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		5.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		1.7	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		3.6	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	4.6	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	460	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		460	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		67	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.92	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		2.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.36	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		32	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		340	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		89	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU4
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101202/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.075	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.069	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.2	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.6	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.81	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.85	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.0011	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.23	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.016	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	26	mg/l	0.3	15	Granplot
Chlorid, Cl-	190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	22	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	123	mg/l	2	15	DS 236:1977
Inddampningsrest	390	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	2.6	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.4	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	530	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	6.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	1.4	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	1.1	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	2.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	3.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	4.6	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan

Prøvenr.: 101202/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Kulbrinter n-C6 - n-C10	#	570	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	7.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		580	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		3.8	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		1.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		2.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.47	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1600	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.42	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		33	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		370	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		38	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.12	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	25-05-2023
Version:	1
Modtaget:	03-05-2023
Analyseperiode:	03-05-2023 - 25-05-2023
Ordrenr.:	785120

Sagsnavn	Svinget 12, Grindsted
Lokalitet:	565-32009, Svinget 12, Grindsted
Prøvested:	Lab forsøg
Prøve ID:	AAU5
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	SKI/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

ANALYSERAPPORT

Prøvenr.: 101203/23

Parameter	**Resultat**	**Enhed**	**DL**	**Urel (%)**	**Metode Navn**
Ammonium+ammoniak, NH4+	0.029	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.067	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.1	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.6	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.76	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.83	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.11	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.019	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	180	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	24	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	35	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	118	mg/l	2	15	DS 236:1977
Inddampningsrest	420	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	1.3	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.9	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	360	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	3.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.80	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.31	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.87	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	1.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.0	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	420	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	420	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	86	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.040	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.84	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	2.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.64	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	1200	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.25	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	26	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	280	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	87	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.16	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	1.5	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU6
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101204/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.015	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.063	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.1	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.4	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.77	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.82	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.058	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.14	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.021	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	170	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	23	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	49	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	94	mg/l	2	15	DS 236:1977
Inddampningsrest	420	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	0.46	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.9	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	4.2	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	320	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	2.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.41	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	1.8	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.39	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	2.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.6	µg/l	0.06	20	DS/EN ISO 10301:2000

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

ANALYSERAPPORT

Prøvenr.: 101204/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	400	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	21	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		420	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		320	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		0.023	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.037	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.49	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		1.0	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		870	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		20	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		260	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		96	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.38	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		4.1	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU7
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101205/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.0048	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.060	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.2	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.3	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.79	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.82	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.091	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.35	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.019	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	120	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	23	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	77	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	66	mg/l	2	15	DS 236:1977
Inddampningsrest	560	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	0.11	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.8	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	5.0	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	200	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	0.32	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.063	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.062	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.36	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.42	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	0.49	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	250	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	250	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	980	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.026	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	0.077	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.37	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	180	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	2.4	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	150	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	86	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.077	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	1.9	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU8
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101206/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.033	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.069	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.2	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.7	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.76	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.83	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.14	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.016	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	26	mg/l	0.3	15	Granplot
Chlorid, Cl-	190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	21	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	123	mg/l	2	15	DS 236:1977
Inddampningsrest	370	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	3.1	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	5.0	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.7	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	430	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	5.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	1.3	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.73	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	1.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	2.0	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	3.3	µg/l	0.06	20	DS/EN ISO 10301:2000

ANALYSERAPPORT

Prøvenr.: 101206/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	490	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	15	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		510	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		73	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		0.021	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.021	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.88	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		2.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.55	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1300	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.33	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		31	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		340	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.17	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		2.5	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	25-05-2023
Version:	1
Modtaget:	03-05-2023
Analyseperiode:	03-05-2023 - 25-05-2023
Ordrenr.:	785120

Sagsnavn	Svinget 12, Grindsted
Lokalitet:	565-32009, Svinget 12, Grindsted
Prøvested:	Lab forsøg
Prøve ID:	AAU9
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	SKI/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101207/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.029	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.066	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.1	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.6	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.76	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.82	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.15	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.020	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	180	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	20	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	35	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	112	mg/l	2	15	DS 236:1977
Inddampningsrest	400	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	1.4	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.8	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.8	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	370	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	4.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.35	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.73	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	1.1	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.1	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	450	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	450	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	210	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	0.037	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.037	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.77	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	2.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.88	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	1200	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	31	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	290	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	99	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.34	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	4.7	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU10
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101208/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.035	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.072	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.3	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.7	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.84	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.87	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.11	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.016	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	29	mg/l	0.3	15	Granplot
Chlorid, Cl-	180	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	23	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	116	mg/l	2	15	DS 236:1977
Inddampningsrest	400	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	2.9	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	5.0	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.8	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	430	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	4.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.97	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.38	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	1.4	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.4	µg/l	0.06	20	DS/EN ISO 10301:2000

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

ANALYSERAPPORT

Prøvenr.: 101208/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	510	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	19	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		530	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		80	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		0.037	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.035	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.98	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		2.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.97	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1600	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.33	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		34	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		340	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		110	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.30	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		5.6	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU11
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101209/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.023	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.067	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.2	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.6	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.78	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.84	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.17	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.021	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	170	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	20	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	39	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	112	mg/l	2	15	DS 236:1977
Inddampningsrest	450	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	1.5	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.8	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	3.8	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	380	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	5.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	1.1	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.37	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.85	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	1.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.3	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	440	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	440	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	160	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	0.055	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.039	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.82	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	2.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	1.3	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	1100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.17	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	29	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	310	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.45	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	6.7	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU12
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 101210/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.012	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.063	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.1	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.4	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.72	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	120	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.82	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.072	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.15	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.014	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	160	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	22	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	50	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	97	mg/l	2	15	DS 236:1977
Inddampningsrest	450	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	0.52	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.7	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	4.1	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	260	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	2.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.58	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.13	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.35	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.48	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	1.1	µg/l	0.06	20	DS/EN ISO 10301:2000

Prøvenr.: 101210/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	330	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	18	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		350	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		500	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		0.059	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.045	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.46	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		1.6	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		530	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.066	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		16	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		200	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		84	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.45	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		9.4	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 25-05-2023
Version: 1
Modtaget: 03-05-2023
Analyseperiode: 03-05-2023 - 25-05-2023
Ordrenr.: 785120

Sagsnavn Svinget 12, Grindsted
Lokalitet: 565-32009, Svinget 12, Grindsted
Prøvested: Lab forsøg
Prøve ID: AAU13
Udtaget: 03.05.2023
Prøvetype: Råvand
Prøvetager: SKI/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

ANALYSERAPPORT

Prøvenr.: 101211/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	<0.0040	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.060	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.1	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.4	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.71	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	130	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.80	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.089	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.36	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.017	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	110	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	25	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	78	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	54	mg/l	2	15	DS 236:1977
Inddampningsrest	510	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S	<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4	0.11	mg/l	0.01	20	AK129 - HS GC/FID
NVOC	4.2	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni	4.6	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	820	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	1.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.18	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.042	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.042	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	0.22	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	860	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	860	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	370	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	0.055	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.043	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.13	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	0.63	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	1.2	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	580	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.022	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	6.6	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	590	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	98	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.40	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	11	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af delvist nedbrudt benzin.
De påviste chlorerede opløsningsmidler er kvantiseret ved GC/MS, og er således ikke medtaget ved beregning af totalkulbrinter.

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

Sofie Askjær Hass

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

-
-
- -
Att.: -

Udskrevet: 12-07-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 12-07-2023
Ordrenr.: 792202

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: Lille Celle 5 timer
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.:	137524/23				
Parameter	**Resultat**	**Enhed**	**DL**	**Urel (%)**	**Metode Navn**
Grindstedpakke A - Vand		-			AK186 - LC-GC/MS/MS
Acetylsulfaguanidin	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Acetylsulfanilsyre	0.54	µg/l	0.1	30	AK186 - LC/MS/MS
Aetallymal	<0.10	µg/l	0.1	30	AK186 - GC/MS
Allyl-n-butylbarbityrat	<0.10	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-isobutyl-barbitursyre (Butalbital)	<0.10	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-(methylbutyl)-barbitursyre	<0.10	µg/l	0.1	30	AK186 - GC/MS
Barbital	<0.10	µg/l	0.1	30	AK186 - GC/MS
Butobarbital (N-butylethylbarbitursyre)	<0.10	µg/l	0.1	30	AK186 - GC/MS
Butylbarbiturat	<0.10	µg/l	0.1	30	AK186 - GC/MS
5,5-diallylbarbitursyre (Allobarbital)	<0.10	µg/l	0.1	30	AK186 - GC/MS
N-N-diethylnicotinamid	1.6	µg/l	0.1	30	AK186 - GC/MS
Dipropenylamin	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
5-ethyl-5-sec-butylbarbitursyre (Butabarbital)	<0.10	µg/l	0.1	30	AK186 - GC/MS
Ethylurethan	27	µg/l	0.1	30	AK186 - GC/MS
Phthalylsulfathiazol	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Hexobarbital	<0.10	µg/l	0.1	30	AK186 - GC/MS
Isobutylbarbitursyre	<0.10	µg/l	0.1	30	AK186 - GC/MS
Isopropylbarbitursyre	<0.10	µg/l	0.1	30	AK186 - GC/MS
Meprobamat	16	µg/l	0.1	30	AK186 - GC/MS
Methoxyproprionitril	<0.10	µg/l	0.1	30	AK210 - HS GC/MS
N-methyldiethylbarbitursyre (Metharbital)	<0.10	µg/l	0.1	30	AK186 - GC/MS
Monoethylbarbitursyre	<0.10	µg/l	0.1	30	AK186 - GC/MS
Pentobarbital	<0.10	µg/l	0.1	30	AK186 - GC/MS
Amobarbital	<0.10	µg/l	0.1	30	AK186 - GC/MS
Sulfanilamid	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfaguanidine	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamethazin (Sulfadimidin)	0.13	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfamethizol	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfadiazin	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilsyre	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfacetamid	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfadoxin	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamerazin	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilylurinstof	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfapyridin	<0.10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfathiazol	<0.050	µg/l	0.05	30	AK186 - LC/MS/MS

Kommentar

Ingen kommentar

Sofie Askjær Hass

Tegnforklaring,Resultat
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

TEST Reg.nr. 361

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøvested: DGU 114.2567 BE6-2, 0 Grindsted
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137525/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+		0.19	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn		0.088	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++		3.7	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++		1.8	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+		1.0	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+		140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe		0.75	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-		0.0011	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-		<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P		0.011	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		23	mg/l	0.3	15	Granplot
Chlorid, Cl-		180	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		26	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		120	mg/l	2	15	DS 236:1977
Inddampningsrest		380	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		0.069	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		4.0	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		4.5	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		7.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		2.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		1.5	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		1.2	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		2.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		3.5	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	5.0	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	63	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	33	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		96	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		0.13	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		1.0	µg/l	0.020	20	DS/EN ISO 10301:2000

ANALYSERAPPORT

Prøvenr.:	137525/23				
Parameter	**Resultat**	**Enhed**	**DL**	**Urel (%)**	**Metode Navn**
Tetrachlorethylen	1.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	<0.10	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	710	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.25	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	18	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	88	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	5.8	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.068	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

Laboratoriet vurderer: Prøvens totalkulbrinter har sin oprindelse i autobenzin. det påviste produkt har en anden sammensætning end det tilsvarende friske produkt grundet udvaskning af delvist nedbrudt benzin.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU1 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.:	137526/23				
Parameter	**Resultat**	**Enhed**	**DL**	**Urel (%)**	**Metode Navn**
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	79	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.69	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.59	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	1.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	2.0	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	2.7	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	112	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan

ANALYSERAPPORT

Prøvenr.: 137526/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		112	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		0.071	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.83	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.22	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1300	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.29	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		31	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		170	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		5.8	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.081	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart svarer til et normalt kulbrinteprodukt. De påviste stoffer kan komme ved udvaskning af enten delvist nedbrudt benzin eller diesel/fyringsgasolie.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	28-06-2023
Version:	1
Modtaget:	08-06-2023
Analyseperiode:	08-06-2023 - 28-06-2023
Ordrenr.:	792208

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøve ID:	AAU2 DSA
Udtaget:	07.06.2023
Prøvetype:	Vand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137527/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	340	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	2.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.59	µg/l	0.020	20	DS/EN ISO 10301:2000

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Prøvenr.: 137527/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
m/p-xylen		0.15	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.54	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.69	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	1.3	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	450	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	15	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		470	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		240	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.073	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.68	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.69	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		970	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.19	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		31	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		220	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		78	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt.
Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	28-06-2023
Version:	1
Modtaget:	08-06-2023
Analyseperiode:	08-06-2023 - 28-06-2023
Ordrenr.:	792208

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøve ID:	AAU3 DSA
Udtaget:	07.06.2023
Prøvetype:	Vand
Prøvetager:	AAU/LBM

TEST Reg.nr. 361

ANALYSERAPPORT

Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137528/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		200	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		2.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.39	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.031	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.24	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.27	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.66	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	310	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	52	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		360	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		460	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.080	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.36	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.88	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		170	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.038	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		11	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		140	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		52	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.088	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt.
Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU4 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137529/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		200	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		2.7	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.54	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.050	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.34	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.39	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.93	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	310	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	16	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		330	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		330	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.087	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.54	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		1.1	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		250	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.084	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		11	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		140	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		56	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.10	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har endvidere et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt.
Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023

Tegnforklaring Resultat
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

ANALYSERAPPORT

Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU5 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137530/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	91	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	2.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.40	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.24	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.24	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	0.64	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	170	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	48	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	220	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	1000	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.096	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.31	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	0.95	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.53	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	140	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.090	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	14	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	57	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	54	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.094	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.
Prøven indeholder også et højt indhold af benzen, der er medtaget i beregningen af total kulbrinter.

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

TEST Reg.nr. 361

ANALYSERAPPORT

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	28-06-2023
Version:	1
Modtaget:	08-06-2023
Analyseperiode:	08-06-2023 - 28-06-2023
Ordrenr.:	792208

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøve ID:	AAU6 DSA
Udtaget:	07.06.2023
Prøvetype:	Vand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137531/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		110	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		1.7	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.31	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.21	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.21	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.52	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	220	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	18	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		240	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		440	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.067	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		0.64	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.66	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		120	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.039	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		15	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		93	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		40	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.095	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

ANALYSERAPPORT

Kommentar

Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.
Prøven indeholder også et højt indhold af benzen, der er medtaget i beregningen af total kulbrinter.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	28-06-2023
Version:	1
Modtaget:	08-06-2023
Analyseperiode:	08-06-2023 - 28-06-2023
Ordrenr.:	792208

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøve ID:	AAU7 DSA
Udtaget:	07.06.2023
Prøvetype:	Vand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137532/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		150	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.34	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.17	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.17	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.51	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	220	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	47	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		270	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		2400	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.12	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		0.68	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.43	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		19	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.16	µg/l	0.020	20	DS/EN ISO 10301:2000

Prøvenr.: 137532/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
trans-1,2-dichlorethylen	7.9	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	95	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	39	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.097	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU8 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137533/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		210	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		3.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.66	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.50	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.61	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	1.3	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	310	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	27	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		340	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000

Prøvenr.: 137533/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Trichlormethan (Chloroform)	87	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.077	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.77	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	1.5	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.58	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	440	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.20	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	13	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	160	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	57	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.14	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	1.0	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU9 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137534/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	120	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	2.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.42	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.035	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.25	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.29	µg/l	0.04	20	DS/EN ISO 10301:2000

ANALYSERAPPORT

Prøvenr.: 137534/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.71	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	210	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	13	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		220	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		350	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.090	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.42	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.94	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		180	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.056	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		5.8	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		39	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU10 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

ANALYSERAPPORT

Prøvenr.: 137535/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		380	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		2.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.43	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.11	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.35	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.46	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.89	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	490	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	17	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		510	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		970	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.047	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.37	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		0.70	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.60	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		560	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.10	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		13	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		6.4	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.098	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU11 DSA

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

ANALYSERAPPORT

Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137536/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	230	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.37	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.052	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.20	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.25	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	0.62	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	310	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	50	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	360	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	1400	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.081	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.23	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	0.65	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	0.47	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	110	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.14	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	8.3	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	180	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	51	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.088	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU12 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137537/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+		0.014	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn		0.064	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++		3.5	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++		1.6	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+		0.95	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+		140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe		0.90	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-		0.098	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-		0.16	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P		0.020	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		-	mg/l	0.3	15	Granplot
Chlorid, Cl-		180	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		28	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		81	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		75	mg/l	2	15	DS 236:1977
Inddampningsrest		370	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		0.16	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		5.7	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		4.5	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		410	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		2.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.51	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.082	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.27	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.35	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.86	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	510	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	19	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		530	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		1100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.067	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.38	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		0.98	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.62	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		400	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.076	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		14	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		360	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		100	µg/l	0.020	20	DS/EN ISO 10301:2000

Prøvenr.: 137537/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
1,1-dichlorethan	0.12	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 28-06-2023
Version: 1
Modtaget: 08-06-2023
Analyseperiode: 08-06-2023 - 28-06-2023
Ordrenr.: 792208

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU13 DSA
Udtaget: 07.06.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 137538/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Ammonium+ammoniak, NH4+	0.015	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn	0.067	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++	3.5	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++	1.9	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+	0.97	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+	140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe	0.95	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-	0.12	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-	0.67	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P	0.019	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3	-	mg/l	0.3	15	Granplot
Chlorid, Cl-	170	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-	<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--	23	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-	180	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2	45	mg/l	2	15	DS 236:1977
Inddampningsrest	360	mg/l	10	10	DS 204:1980

ANALYSERAPPORT

Prøvenr.: 137538/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Hydrogensulfid, H2S		<0.010	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		0.043	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		5.6	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		360	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		1.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.39	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.042	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.19	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.23	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	0.62	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	410	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	39	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		450	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		4000	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.099	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.27	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		0.62	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.35	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		66	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.21	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		7.2	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		290	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		78	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.082	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000

Kommentar

De påviste kulbrinter udgøres hovedsageligt af benzen.
Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 275 °C.

Sofie Askjær Hass

TEST Reg.nr. 361

Ordrenr: 785116
Sagsnavn: Grindsted By
Udtaget: 03.05.2023
Prøvested: DGU 114.2567 BE6-2, 0 Grindsted

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	15-09-2023
Version:	1
Modtaget:	31-08-2023
Analyseperiode:	31-08-2023 - 15-09-2023
Ordrenr.:	785116

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøvested:	DGU 114.2567 BE6-2, 0 Grindsted
Udtaget:	03.05.2023
Prøvetype:	Råvand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 198533/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		340	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		4.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		1.8	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.69	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		2.3	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		3.0	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	4.8	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	390	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	9.3	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		399	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.99	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		2.4	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		<0.10	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1000	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.19	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		24	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		220	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		17	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.067	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.10	20	DS/EN ISO 10301:2000

Kommentar

Ingen kommentar

Gry S Janniche

Gry Sander Janniche

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

Ordrenr: 807706
Sagsnavn: Grindsted By
Udtaget: 29.05.2023

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	13-09-2023
Version:	1
Modtaget:	30-08-2023
Analyseperiode:	30-08-2023 - 13-09-2023
Ordrenr.:	807706

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøve ID:	AAU1 pose
Udtaget:	29.05.2023
Prøvetype:	Vand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 198534/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		380	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		4.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.58	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.40	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		1.0	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		1.4	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	2.0	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	433	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	18	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	24	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		475	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.48	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		1.2	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1500	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.24	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		33	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		320	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		21	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.075	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.10	20	DS/EN ISO 10301:2000

Kommentar

Ingen kommentar

Gry S Janniche

Gry Sander Janniche

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 13-09-2023
Version: 1
Modtaget: 30-08-2023
Analyseperiode: 30-08-2023 - 13-09-2023
Ordrenr.: 807706

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU2 10. min
Udtaget: 29.05.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 198535/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN		-			DS/EN ISO 10301:2000
Benzen	410	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen	3.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen	0.66	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen	0.13	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen	0.67	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)	0.80	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen) #	1.5	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen	0.085	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand		-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10 #	474	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15 #	17	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20 #	6.4	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35 #	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)	497	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.		-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)	120	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan	0.039	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan	0.050	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen	0.55	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen	1.8	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan	1.3	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid	1000	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen	0.18	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen	27	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen	260	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan	92	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan	0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan	6.4	µg/l	0.10	20	DS/EN ISO 10301:2000

Kommentar

Ingen kommentar

Gry S Janniche

Gry Sander Janniche

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 13-09-2023
Version: 1
Modtaget: 30-08-2023
Analyseperiode: 30-08-2023 - 13-09-2023
Ordrenr.: 807706

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU3 20. min
Udtaget: 29.05.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 198536/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		410	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		3.1	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		0.68	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.13	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		0.63	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		0.76	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	1.4	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		0.025	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	480	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	18	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	8.8	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		507	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		110	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		0.038	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		0.053	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.57	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlorethylen		1.9	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		1.4	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		1100	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.18	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		26	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		260	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		98	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.28	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		7.4	µg/l	0.10	20	DS/EN ISO 10301:2000

Kommentar

Ingen kommentar

Gry S Janniche

Gry Sander Janniche

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Sektion for Kemi og Ingeniørvidenskab
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet: 12-10-2023
Version: 1
Modtaget: 14-09-2023
Analyseperiode: 14-09-2023 - 12-10-2023
Ordrenr.: 811124

Sagsnavn Grindsted By
Lokalitet: 565-00072, Grindsted By
Prøve ID: AAU Mix
Udtaget: 14.09.2023
Prøvetype: Vand
Prøvetager: AAU/LBM
Kunde: Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 213197/23

Parameter	Resultat	Enhed	DL	Urel (%)	Metode Navn
Grindstedpakke A - Vand		-			AK186 - LC-GC/MS/MS
Acetylsulfaguanidin	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Acetylsulfanilsyre	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Aetallymal	<1.0	µg/l	0.1	30	AK186 - GC/MS
Allyl-n-butylbarbityrat	<1.0	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-isobutyl-barbitursyre (Butalbital)	<1.0	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-(methylbutyl)-barbitursyre	<1.0	µg/l	0.1	30	AK186 - GC/MS
Barbital	<1.0	µg/l	0.1	30	AK186 - GC/MS
Butobarbital (N-butylethylbarbitursyre)	<1.0	µg/l	0.1	30	AK186 - GC/MS
Butylbarbiturat	<1.0	µg/l	0.1	30	AK186 - GC/MS
5,5-diallylbarbitursyre (Allobarbital)	<1.0	µg/l	0.1	30	AK186 - GC/MS
N-N-diethylnicotinamid	1.1	µg/l	0.1	30	AK186 - GC/MS
Dipropenylamin	<10	µg/l	0.1	30	AK186 - LC/MS/MS
5-ethyl-5-sec-butylbarbitursyre (Butabarbital)	<1.0	µg/l	0.1	30	AK186 - GC/MS
Ethylurethan	<1.0	µg/l	0.1	30	AK186 - GC/MS
Phthalylsulfathiazol	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Hexobarbital	<1.0	µg/l	0.1	30	AK186 - GC/MS
Isobutylbarbitursyre	<1.0	µg/l	0.1	30	AK186 - GC/MS
Isopropylbarbitursyre	<1.0	µg/l	0.1	30	AK186 - GC/MS
Meprobamat	1.3	µg/l	0.1	30	AK186 - GC/MS
Methoxyproprionitril	<0.1	µg/l	0.1	30	AK210 - HS GC/MS
N-methyldiethylbarbitursyre (Metharbital)	<1.0	µg/l	0.1	30	AK186 - GC/MS
Monoethylbarbitursyre	<1.0	µg/l	0.1	30	AK186 - GC/MS
Pentobarbital	<1.0	µg/l	0.1	30	AK186 - GC/MS
Amobarbital	<1.0	µg/l	0.1	30	AK186 - GC/MS
Sulfanilamid	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfaguanidine	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamethazin (Sulfadimidin)	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfamethizol	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfadiazin	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilsyre	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfacetamid	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfadoxin	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamerazin	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilylurinstof	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfapyridin	<10	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfathiazol	<5.0	µg/l	0.05	30	AK186 - LC/MS/MS

Kommentar

Detektionsgrænser er forhøjet grundet interferens.

Ordrenr: 811124
Sagsnavn: Grindsted By
Udtaget: 14.09.2023

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

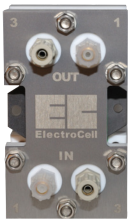
ANALYSERAPPORT

Camilla Højsted

Electrochemical Flow Cells

Technical Data

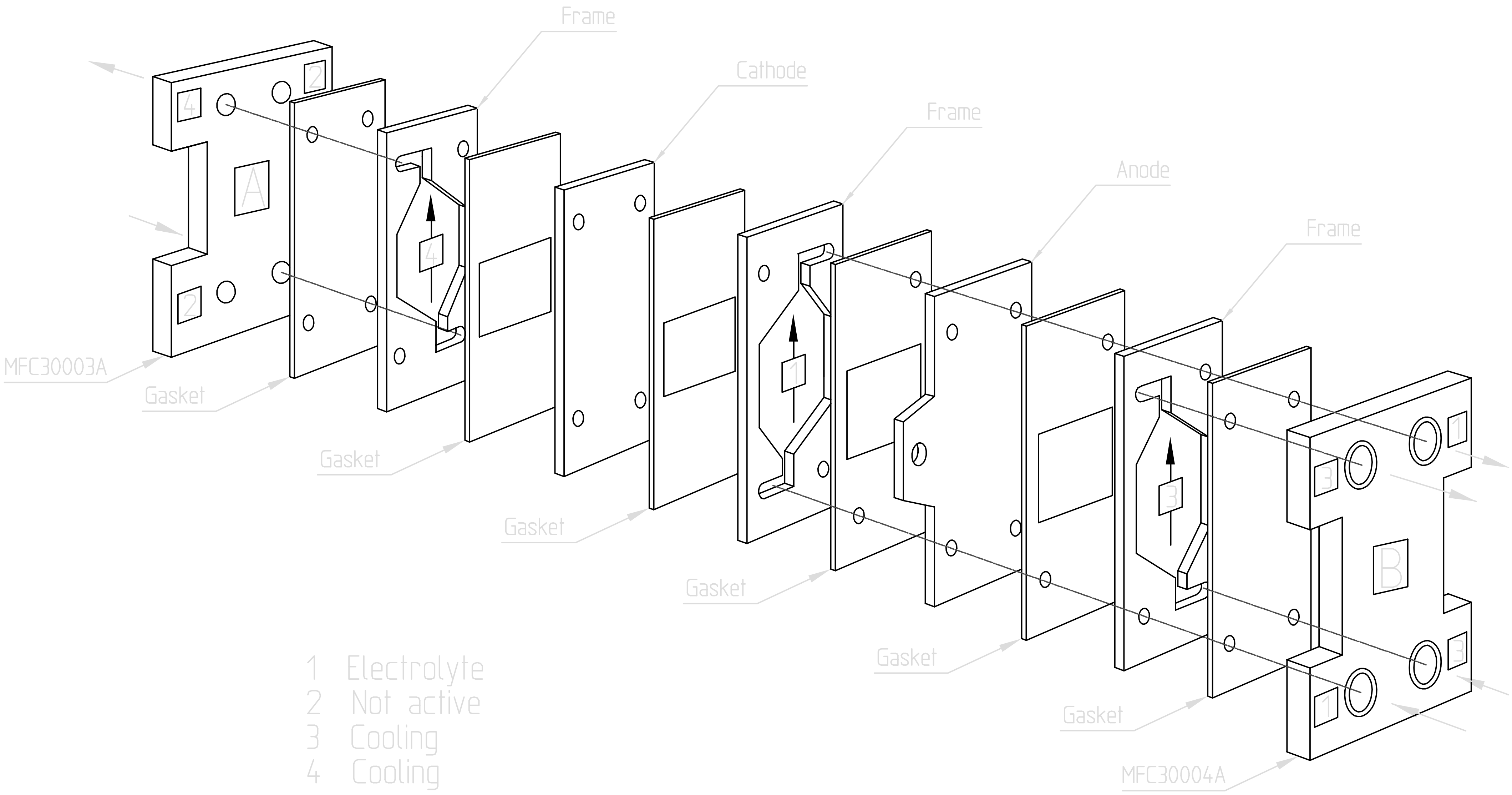
(V1_2017)



SPECIFICATIONS	Micro Flow Cell	Electro MP Cell	Electro Syn Cell	Electro Prod Cell
Electrical data				
Projected electrode area, min. [m^2] 1)	0.001	0.01	0.04	0.4
Projected electrode area, max. [m^2] 2)	-	0.2	1.04	16
Current density, max. [kA/m^2] 3)	4	4	4	4
Electrode gap range [mm] 2)	0.7-8	2-16	1-5	1-10
Standard electrode gap [mm]	4	8	5	4
Dimensions				
Height [mm]	120	306	550	1030
Width [mm]	70	182	238	1040
Length [mm] 4)	> 33	> 38	> 43 5)	> 300 6), 7)
Pipe connections				
Connections	female 1/8” NPT	female 1/2” NPT	G1 1/2” (union 32mm)	Flanges 8)
Outer pipe diameter 10)	-	-	32mm	90mm
Electrolyte flow data				
Max number of separate flows (compartments) 9)	4	4	2	3
Electrolyte Flow per max. module, stack [L/min] 3, 11)	-	20-80	65-117	100-600
Electrolyte Flow per frame, Cell [L/min] 3, 11)	0.18-1.5	1-4	5-9	5-30
Electrolyte volume per frame, Cell [L] 2)	0.01	0.2	0.6	-
Flow rate in each cell [m/sec] 3)	0.05-0.4	0.03-0.12	0.2-0.38	0.05-0.4
Pressure drop in a module (water 25C) [kPa]	-	5-50	8-50	0.5-16
Max working temperature 2, 3)	-	-	-	-
Materials 9)				
Flow frame materials, standard	PTFE	PP, PVDF	PP, PVDF	PP, PVDF
Sealing, gasket materials, standard	EPDM, FPM (Viton)			
Ion exchange/selective membranes, diaphragms	Nafion, other various types			
End plate materials (not in contact with media)	Stainless steel			
Electrode materials:	Stainless steel, Ti, Ni, Hastelloy, Nb, Ta, graphite, Zn, Sn, Fe, Pb, Pt foil, …			
Coated electrodes	Pt on Ti, DSA® for Cl_2 or O_2 evolution (Ir-, Ru-MMO), PbO_2, Boron Doped Diamond, …			
3 dimensional electrode materials	Graphite/carbon (felt, granulate, RVC), Ni foam, Cu foam, …			
GDE sheet materials	Catalyzed and uncatalyzed types with/without metal screens			

Remarks:

1) Area can be minimized/modified on request
2) Depends on configuration and choice of sealing and frame materials
3) Depends on application, configuration and choice of electrode materials etc.
4) Depends on configuration and stack size (excl. Pipe/ connectors)
5) Max length approx 280mm at 1.04m^2 stack size
6) Max length approx 1160mm for 2 compartment 16m^2 stack size
7) Max length approx 1120mm for 3 compartment 12m^2 stack size
8) DIN 2501 PN 10. Others on request
9) Depends on Cell type. Other materials on request
10) In general use piping with large openings (ID) in order to avoid back pressure and improve gas release
11) Max working pressure 0.5 bar (50 kPa). For higher pressure consult your local ElectroCell representative



LOCATION NO.	NONE	ITEM NO.	MFC30012	ITEMLIST	NONE

ElectroCell
Phone +45 9737 4499 · www.electrocell.com
Vennelystvej 1 · Dk-6880 Tarm · Denmark

Micro Flow Cell, PFTE
Cell configuration at delivery - 1 compartment
CORRESPONDING DRAWINGS: NONE

DATE	2013-09-13
Created by	TFC
SCALE	none
DWG. NO.	MFC30012

Rev. Consurn.:	- -	ISSUE	0

Prøvenr.			74297	101198	101199	101200	101201	101202	101203	101204	101205	101206	101207	101208	101209	101210	101211	137524	137525	137526	137527	137528	137529	137530	137531	137532	137533	137534	137535	137536	137537	137538	198533	198534	198535	198536	213197
Prøvemrk.			BE6-F2	BE6-F2	AAU1	AAU2	AAU3	AAU4	AAU5	AAU6	AAU7	AAU8	AAU9	AAU10	AAU11	AAU12	AAU13	timer	BE6-F2	AAU1 DSA	AAU2 DSA	AAU3 DSA	AAU4 DSA	AAU5 DSA	AAU6 DSA	AAU7 DSA	AAU8 DSA	AAU9 DSA	AAU10 DSA	AAU11 DSA	AAU12 DSA	AAU13 DSA	BE6_F2	AAU1 pose	AAU2 10. min	AAU3 20. min	AAU Mix
Udtaget iflg. Analyserapport			03-04-2023	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	03-05-2023*	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	07-06-2023	03-05-2023**	29-05-2023**	29-05-2023**	29-05-2023**	14-09-2023
Modtaget.			04-04-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	03-05-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	08-06-2023	31-08-2023	30-08-2023	30-08-2023	30-08-2023	14-09-2023
Prøvested.			By, DGU 114.2567	Grindsted, DGU	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted, Lab forsøg	Grindsted By	By, DGU 114.2567	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By	Grindsted By, DGU 114.2567 BE6	Grindsted By	Grindsted By	Grindsted By	Grindsted By
Runde			Indl. Analyse	Runde 1 (boring)	Runde 1 (Tedlarpos.)	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 1	Runde 2 (Micro flow cell)	Runde 2 (boring)	Runde 2 (Tedlarpos.)	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 2	Runde 3 (boring)	Runde 3 (Tedlarpos.)	Runde 3	Runde 3	Runde 3 (Grindsted-pakke A)
Anode						BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD	BDD			DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2	DSA-O2			BDD (stack)	BDD (stack)	BDD (stack)
Strømtæthed	mA/cm2					10	25	10	25	10	30	10	25	10	25	10	30	5			10	25	10	25	10	30	10	25	10	25	10	30			20	20	20
Opholdstid	sek.					16	16	19	19	90	90	16	16	19	19	90	90	18000			29	29	55	55	90	90	29	29	55	55	90	90			7	7	75
Adresse			Tårnvej 21	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Svinget 12	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21	Tårnvej 21
Ammonium+ammoniak, NH4+	1:2013+DS224:1975 Mod	mg/l	0,12	0,15	0,13	0,15	0,037	0,075	0,029	0,015	0,0048	0,033	0,029	0,035	0,023	0,012	<0,0040		0,19												0,014	0,015					
Mangan, Mn	DS/EN ISO 11885:2009	mg/l	0,067	0,080	0,068	0,066	0,068	0,069	0,067	0,063	0,060	0,069	0,066	0,072	0,067	0,063	0,060		0,088												0,064	0,067					
Calcium, Ca++	DS/EN ISO 11885:2009	mg/l	3,4	3,4	3,4	3,6	3,5	3,2	3,1	3,1	3,2	3,2	3,1	3,3	3,2	3,1	3,1		3,7												3,5	3,5					
Magnesium, Mg++	DS/EN ISO 11885:2009	mg/l	1,8	1,9	1,7	2,4	2,2	1,6	1,6	1,4	1,3	1,7	1,6	1,7	1,6	1,4	1,4		1,8												1,6	1,9					
Kalium, K+	DS/EN ISO 11885:2009	mg/l	1,2	1,0	0,83	1,0	0,96	0,81	0,76	0,77	0,79	0,76	0,76	0,84	0,78	0,72	0,71		1,0												0,95	0,97					
Natrium, Na+	DS/EN ISO 11885:2009	mg/l	140	130	130	140	130	130	130	130	130	130	130	130	130	120	130		140												140	140					
Jern, Fe	DS/EN ISO 11885:2009	mg/l	0,92	0,73	0,85	0,82	0,83	0,85	0,83	0,82	0,82	0,83	0,82	0,87	0,84	0,82	0,80		0,75												0,90	0,95					
Nitrit, NO2-	DS/ISO 15923-1:2013	mg/l	<0,0010	0,0013	<0,0010	0,0012	<0,0010	0,0011	<0,0010	0,058	0,091	<0,0010	<0,0010	<0,0010	<0,0010	0,072	0,089		0,0011												0,098	0,12					
Nitrat, NO3-	DS/ISO 15923-1:2013 + beregning	mg/l	<0,10	<0,10	<0,10	<0,10	0,10	0,23	0,11	0,14	0,35	0,14	0,15	0,11	0,17	0,15	0,36		<0,10												0,16	0,67					
Total phosphor, P	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018	mg/l	0,0090	0,018	0,016	0,017	0,019	0,016	0,019	0,021	0,019	0,016	0,020	0,016	0,021	0,014	0,017		0,011												0,020	0,019					
Hydrogencarbonat, HCO3	Granplot	mg/l	25	22	24	25	26	26	-	-	-	26	-	29	-	-	-		23												-	-					
Chlorid, Cl-	DS/ISO 15923-1:2013	mg/l	190	200	190	190	190	190	180	170	120	190	180	180	170	160	110		180												180	170					
Fluorid, F-	DS 218:1975,MOD	mg/l	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030	<0,030		<0,030												<0,030	<0,030					
Sulfat, SO4--	DS/ISO 15923-1:2013	mg/l	24	21	20	21	23	22	24	23	23	21	20	23	20	22	25		26												28	23					
Hydrogencarbonat, HCO3-	DS/EN ISO 9963-1:1996	mg/l	-	-	-	-	-	-	35	49	77	-	35	-	39	50	78		-												81	180					
Aggressiv kuldioxid, CO2	DS 236:1977	mg/l	117	127	124	121	117	123	118	94	66	123	112	116	112	97	54		120												75	45					
Inddampningsrest	DS 204:1980	mg/l	390	490	460	420	400	390	420	420	560	370	400	400	450	450	510		380												370	360					
Hydrogensulfid, H2S	DS 278:1976 + beregning	mg/l	0,037	0,079	0,017	0,013	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010	<0,010		0,069												<0,010	<0,010					
Methan, CH4	HS GC/FID	mg/l	5,3	6,4	4,3	1,6	0,94	2,6	1,3	0,46	0,11	3,1	1,4	2,9	1,5	0,52	0,11		4,0												0,16	0,043					
NVOC	DS/EN 1484:1997+SM 5310B:2014	mg/l	4,4	4,0	3,9	4,4	8,7	4,4	4,9	4,9	4,8	5,0	4,8	5,0	4,8	4,7	4,2		4,5												5,7	5,6					
Nikkel, Ni	DS/EN ISO 17294-2:2016	µg/l	3,9	4,1	3,9	3,9	3,9	3,9	3,9	4,2	5,0	3,7	3,8	3,8	3,8	4,1	4,6		3,9												4,5	3,9					
HS BTEXN	DS/EN ISO 10301:2000	-	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
Benzen	DS/EN ISO 10301:2000	µg/l	8,6	24	15	490	420	530	360	320	200	430	370	430	380	260	820		7,1	79	340	200	200	91	110	150	210	120	380	230	410	360	340	380	410	410	
Toluen	DS/EN ISO 10301:2000	µg/l	0,19	0,69	0,75	6,8	5,1	6,4	3,9	2,5	0,32	5,4	4,4	4,6	5,1	2,8	1,1		2,5	1,9	2,9	2,1	2,7	2,4	1,7	1,9	3,1	2,2	2,0	1,9	2,3	1,8	4,3	4,8	3,1	3,1	
Ethylbenzen	DS/EN ISO 10301:2000	µg/l	<0,020	1,0	0,48	1,6	1,0	1,4	0,80	0,41	0,063	1,3	1,0	0,97	1,1	0,58	0,18		1,5	0,69	0,59	0,39	0,54	0,40	0,31	0,34	0,66	0,42	0,43	0,37	0,51	0,39	1,8	0,58	0,66	0,68	
m/p-xylen	DS/EN ISO 10301:2000	µg/l	0,62	0,99	0,48	1,3	1,9	1,1	0,31	1,8	0,062	0,73	0,35	0,38	0,37	0,13	<0,020		1,2	0,59	0,15	0,031	0,050	<0,020	<0,020	<0,020	0,11	0,035	0,11	0,052	0,082	0,042	0,69	0,40	0,13	0,13	
o-xylen	DS/EN ISO 10301:2000	µg/l	1,6	2,5	1,4	1,9	1,7	2,1	0,87	0,39	0,36	1,3	0,73	1,0	0,85	0,35	0,042		2,3	1,4	0,54	0,24	0,34	0,24	0,21	0,17	0,50	0,25	0,35	0,20	0,27	0,19	2,3	1,0	0,67	0,63	
Xylener (o,-m- og p-xylen)	DS/EN ISO 10301:2000	µg/l	2,2	3,5	1,9	3,2	3,6	3,2	1,2	2,2	0,42	2,0	1,1	1,4	1,2	0,48	0,042		3,5	2,0	0,69	0,27	0,39	0,24	0,21	0,17	0,61	0,29	0,46	0,25	0,35	0,23	3,0	1,4	0,80	0,76	
Xylener (o,-m-, p-xylen og ethylbenzen)	DS/EN ISO 10301:2000	µg/l	2,2	4,5	2,4	4,8	4,6	4,6	2,0	2,6	0,49	3,3	2,1	2,4	2,3	1,1	0,22		5,0	2,7	1,3	0,66	0,93	0,64	0,52	0,51	1,3	0,71	0,89	0,62	0,86	0,62	4,8	2,0	1,5	1,4	
Naphtalen	DS/EN ISO 10301:2000	µg/l	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020		<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	0,085	0,025	
Kulbrinter i vand	GC/FID/pentan	-	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
Kulbrinter n-C6 - n-C10	GC/FID/pentan	µg/l	56	65	51	530	460	570	420	400	250	490	450	510	440	330	860		63	112	450	310	310	170	220	220	310	210	490	310	510	410	390	433	474	480	
Kulbrinter >n-C10 - n-C15	GC/FID/pentan	µg/l	<5,0	<5,0	<5,0	6,1	<5,0	7,0	<5,0	21	<5,0	15	<5,0	19	<5,0	18	<5,0		33	<5,0	15	52	16	48	18	47	27	13	17	50	19	39	9,3	18	17	18	
Kulbrinter >n-C15 - n-C20	GC/FID/pentan	µg/l	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0		<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	24	6,4	8,8	
Kulbrinter >n-C20 - n-C35	GC/FID/pentan	µg/l	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0		<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	<5,0	
Total kulbrinter (C6-C35)	GC/FID/pentan	µg/l	56	65	51	540	460	580	420	420	250	510	450	530	440	350	860		96	112	470	360	330	220	240	270	340	220	510	360	530	450	399	475	497	507	
HS Chlor. og nedbr.	DS/EN ISO 10301:2000	-	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
Trichlormethan (Chloroform)	DS/EN ISO 10301:2000	µg/l	<0,020	<0,020	<0,020	0,36	67	3,8	86	320	980	73	210	80	160	500	370		0,13	0,071	240	460	330	1000	440	2400	87	350	970	1400	1100	4000	<0,020	<0,020	120	110	
1,1,1-trichlorethan	DS/EN ISO 10301:2000	µg/l	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	0,023	<0,020	0,021	0,037	0,037	0,055	0,059	0,055		<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	0,039	0,038	
Tetrachlormethan	DS/EN ISO 10301:2000	µg/l	<0,020	<0,020	<0,020	<0,020	<0,020	<0,020	0,040	0,037	<0,020	0,021	0,037	0,035	0,039	0,045	0,043		<0,020	<0,020	0,073	0,080	0,087	0,096	0,067	0,12	0,077	0,090	0,047	0,081	0,067	0,099	<0,020	<0,020	0,050	0,053	
Trichlorethylen	DS/EN ISO 10301:2000	µg/l	0,89	1,2	0,61	1,0	0,92	1,1	0,84	0,49	0,026	0,88	0,77	0,98	0,82	0,46	0,13		1,0	0,83	0,68	0,36	0,54	0,31	0,26	0,26	0,77	0,42	0,37	0,23	0,38	0,27	0,99	0,48	0,55	0,57	
Tetrachlorethylen	DS/EN ISO 10301:2000	µg/l	2,2	2,6	1,7	2,5	2,1	2,5	2,0	1,9	0,077	2,2	2,1	2,3	2,3	1,5	0,63		1,2	1,8	1,6	1,0	1,4	0,95	0,64	0,68	1,5	1,2	0,70	0,65	0,98	0,62	2,4	1,6	1,8	1,9	
Chlorethan	DS/EN ISO 10301:2000	µg/l	0,23	0,13	0,25	0,29	0,36	0,47	0,64	1,0	0,37	0,55	0,88	0,97	1,3	1,6	1,2		<0,10	0,22	0,69	0,88	1,1	0,53	0,66	0,43	0,58	0,94	0,60	0,47	0,62	0,35	<0,10	1,2	1,3	1,4	
Vinylchlorid	DS/EN ISO 10301:2000	µg/l	930	690	970	1300	1100	1600	1200	870	180	1300	1200	1600	1100	530	580		710	1300	970	170	250	140	120	19	440	180	560	110	400	66	1000	1500	1000	1100	
1,1-dichlorethylen	DS/EN ISO 10301:2000	µg/l	0,26	0,25	0,17	0,27	0,26	0,42	0,25	0,11	<0,020	0,33	0,26	0,33	0,17	0,066	0,022		0,25	0,29	0,19	0,038	0,084	0,090	0,039	0,16	0,20	0,056	0,10	0,14	0,076	0,21	0,19	0,24	0,18	0,18	
trans-1,2-dichlorethylen	DS/EN ISO 10301:2000	µg/l	23	27	24	39	32	33	26	20	2,4	31	31	34	29	16	6,6		18	31	31	11	11	14	15	7,9	13	5,8	13	8,3	14	7,2	24	33	27	26	
cis-1,2-dichlorethylen	DS/EN ISO 10301:2000	µg/l	120	52	79	400	340	370	280	260	150	340	290	340	310	200	590		88	170	220	140	140	57	93	95	160	100	6,4	180	360	290	220	320	260	260	
1,2-dichlorethan	DS/EN ISO 10301:2000	µg/l	0,53	<0,020	<0,020	<0,020	89	38	87	96	86	100	99	110	100	84	98		5,8	5,8	78	52	56	54	40	39	57	39	100	51	100	78	17	21	92	98	
1,1-dichlorethan	DS/EN ISO 10301:2000	µg/l	0,079	0,10	0,060	0,085	0,11	0,12	0,16	0,38	0,077	0,17	0,34	0,30	0,45	0,45	0,40		0,068	0,081	0,11	0,088	0,10	0,094	0,095	0,097	0,14	0,11	0,098	0,088	0,12	0,082	0,067	0,075	0,26	0,28	
Dichlormethan	DS/EN ISO 10301:2000	µg/l	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	1,5	4,1	1,9	2,5	4,7	5,6	6,7	9,4	11		<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	1,0	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	<0,10	6,4	7,4	
Grindstedpakke A - Vand	LC-GC/MS/MS	-	:															:																			:
Acetylsulfaguanidin	LC/MS/MS	µg/l	<1,0															<0,10																			<10
Acetylsulfanilsyre	LC/MS/MS	µg/l	76															0,54																			<10
Aetallymal	GC/MS	µg/l	1,7															<0,10																			<1,0
Allyl-n-butylbarbityrat	GC/MS	µg/l	11															<0,10																			<1,0
5-allyl-5-isobutyl-barbitursyre (Butalbital)	GC/MS	µg/l	11															<0,10																			<1,0
5-allyl-5-(methylbutyl)-barbitursyre	GC/MS	µg/l	11															<0,10																			<1,0
Barbital	GC/MS	µg/l	14															<0,10																			<1,0
Butobarbital (N-butylethylbarbitursyre)	GC/MS	µg/l	5,1															<0,10																			<1,0
Butylbarbiturat	GC/MS	µg/l	15															<0,10																			<1,0
5,5-diallylbarbitursyre (Allobarbital)	GC/MS	µg/l	10															<0,10																			<1,0
N-N-diethylnicotinamid	GC/MS	µg/l	2,5															1,6																			1,1
Dipropenylamin	LC/MS/MS	µg/l	<1,0															<0,10																			<10
5-ethyl-5-sec-butylbarbitursyre (Butabarbital)	GC/MS	µg/l	7,9															<0,10																			<1,0
Ethylurethan	GC/MS	µg/l	-															27																			<1,0
Phthalylsulfathiazol	LC/MS/MS	µg/l	8,7															<0,10																			<10
Hexobarbital	GC/MS	µg/l	<1,0															<0,10																			<1,0
Isobutylbarbitursyre	GC/MS	µg/l	440															<0,10																			<1,0
Isopropylbarbitursyre	GC/MS	µg/l	12															<0,10																			<1,0
Meprobamat	GC/MS	µg/l	110															16																			1,3
Methoxyproprionitril	HS GC/MS	µg/l	<0,10															<0,10																			<0,1
N-methyldiethylbarbitursyre (Metharbital)	GC/MS	µg/l	<1,0															<0,10																			<1,0
Monoethylbarbitursyre	GC/MS	µg/l	7,8															<0,10																			<1,0
Pentobarbital	GC/MS	µg/l	61															<0,10																			<1,0
Amobarbital	GC/MS	µg/l	69															<0,10																			<1,0
Sulfanilamid	LC/MS/MS	µg/l	8,3															<0,10																			<10
Sulfaguanidine	LC/MS/MS	µg/l	82															<0,050																			<5,0
Sulfamethazin (Sulfadimidin)	LC/MS/MS	µg/l	73															0,13																			<10
Sulfamethiazol	LC/MS/MS	µg/l	6,5															<0,050																			<5,0
Sulfadiazin	LC/MS/MS	µg/l	1,9															<0,050																			<5,0
Sulfanilsyre	LC/MS/MS	µg/l	130															<0,10																			<10
Sulfacetamid	LC/MS/MS	µg/l	<1,0															<0,10																			<10
Sulfadoxin	LC/MS/MS	µg/l	<0,5															<0,050																			<5,0
Sulfamerazin	LC/MS/MS	µg/l	3,2															<0,050																			<5,0
Sulfanilylurinstof	LC/MS/MS	µg/l	6,9															<0,10																			<10
Sulfapyridin	LC/MS/MS	µg/l	<1,0															<0,10																			<10
Sulfathiazol	LC/MS/MS	µg/l	0,66															<0,050																			<5,0

*Korrekt for prøvetagning er 02-05-2023

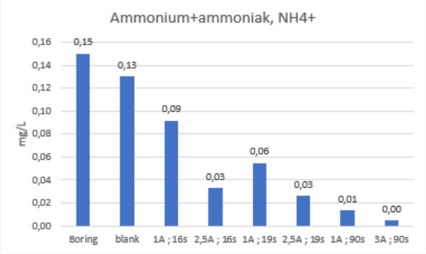
**Korrekt dato for prøvetagning er 29-08-2023

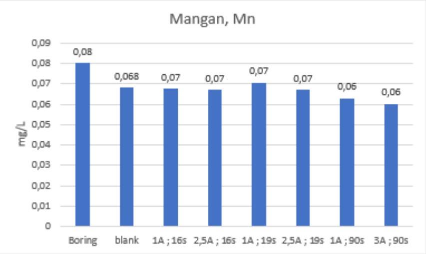
BILAG 6 - OVERSIGTSFIGURER TIL PRÆSENTATION AF DE EKSTERNE ANALYSEDATA

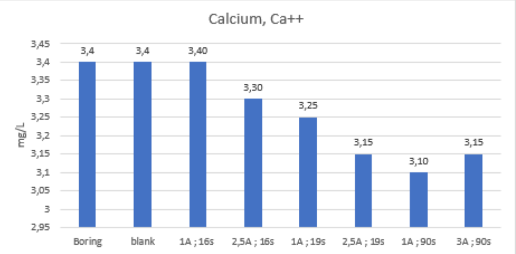
Resultater angivet som 0,00 referer til en koncentration under detektionsgrænsen.

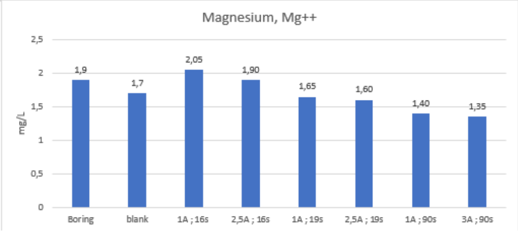
RUNDE 1

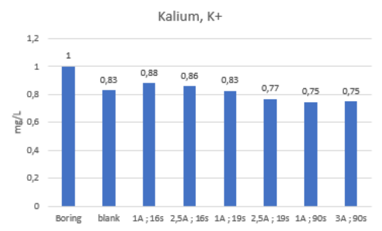
BORINGSKONTROL

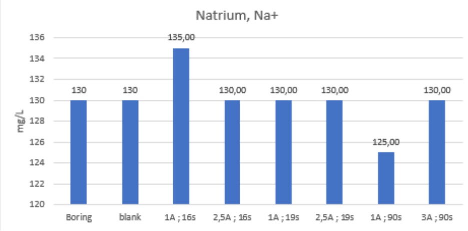


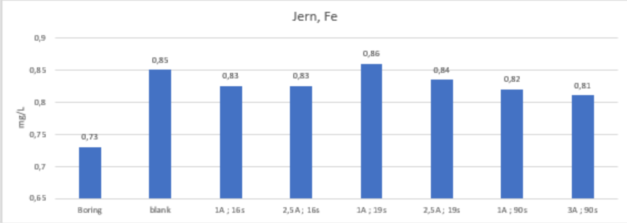


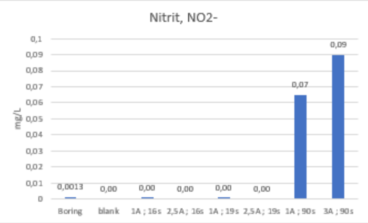


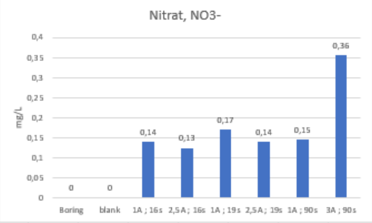


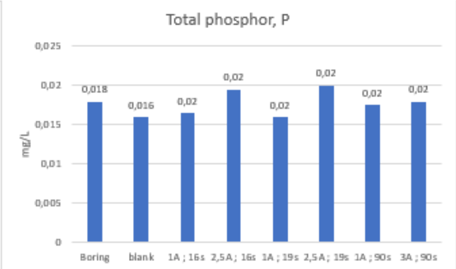


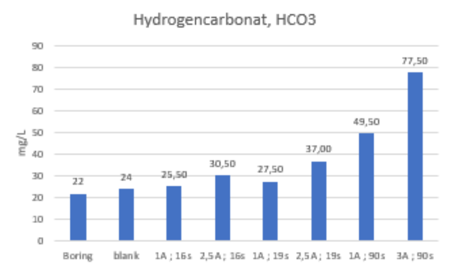


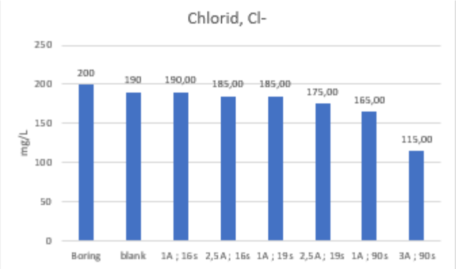


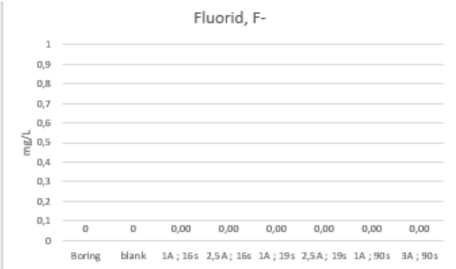


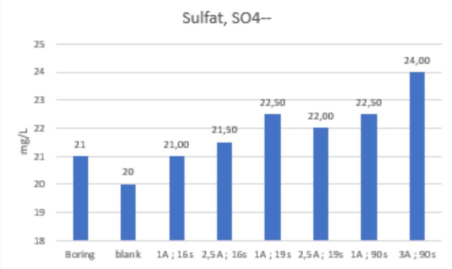


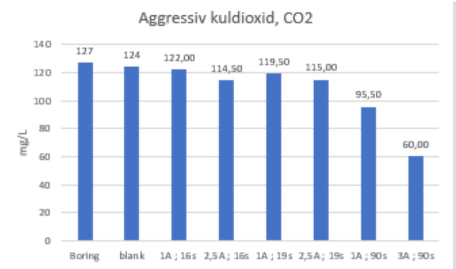


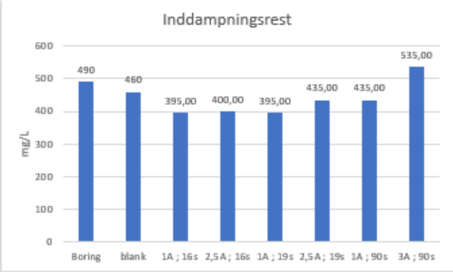


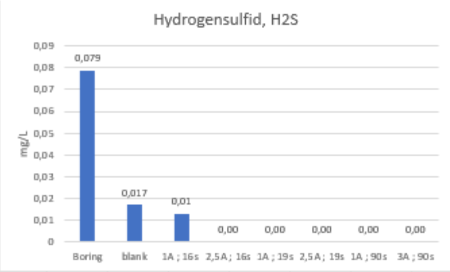


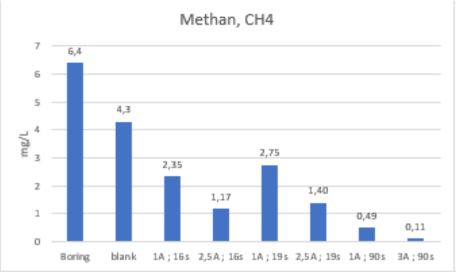


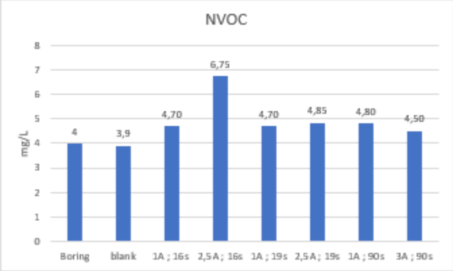


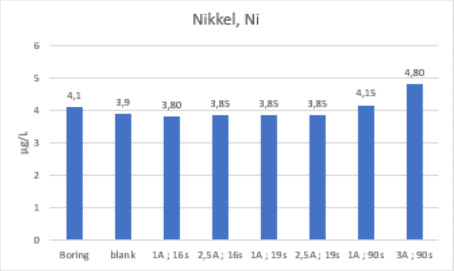



Inddampningsrest
mg/L
600
500
400
300
200
100
0
490
460
395,00
400,00
395,00
435,00
435,00
535,00
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

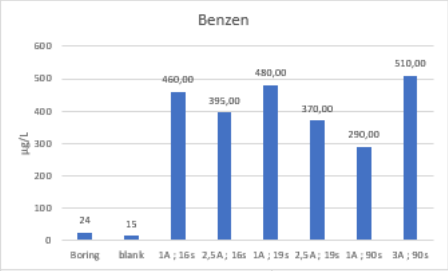

Hydrogensulfid, H2S
mg/L
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
0,079
0,017
0,01
0,00
0,00
0,00
0,00
0,00
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

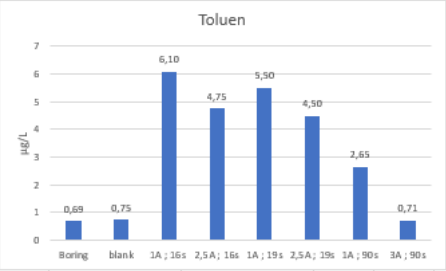

Methan, CH4
mg/L
7
6
5
4
3
2
1
0
6,4
4,3
2,35
1,17
2,75
1,40
0,49
0,11
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

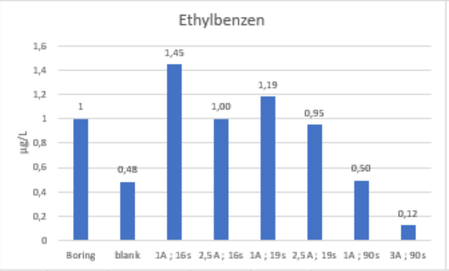

NVOC
mg/L
8
7
6
5
4
3
2
1
0
4
3,9
4,70
6,75
4,70
4,85
4,80
4,50
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

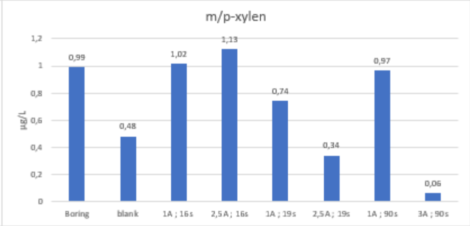

Nikkel, Ni
µg/L
6
5
4
3
2
1
0
4,1
3,9
3,80
3,85
3,85
3,85
4,15
4,80
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

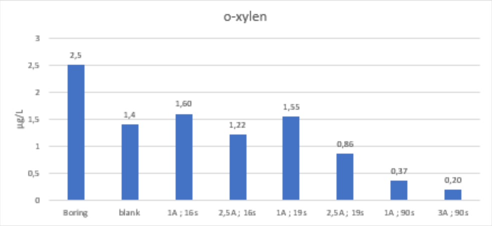
HS BTEXN

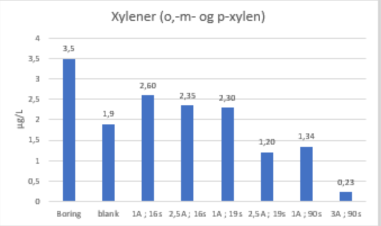

Benzen
µg/L
600
500
400
300
200
100
0
24
15
460,00
395,00
480,00
370,00
290,00
510,00
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

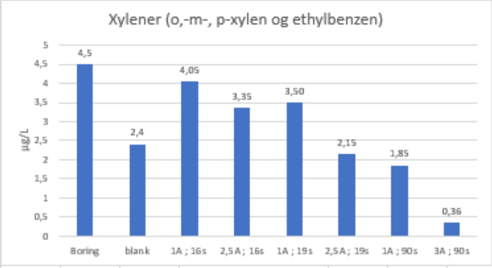

Toluen
µg/L
7
6
5
4
3
2
1
0
0,69
0,75
6,10
4,75
5,50
4,50
2,65
0,71
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

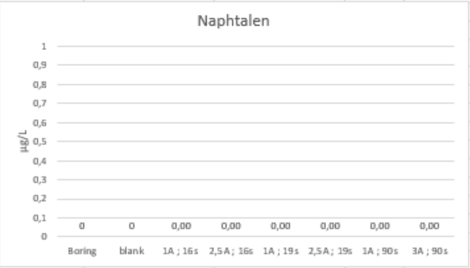

Ethylbenzen
µg/L
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
1
0,48
1,45
1,00
1,19
0,95
0,50
0,12
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s


m/p-xylen
µg/L
1,2
1
0,8
0,6
0,4
0,2
0
0,99
0,48
1,02
1,13
0,74
0,34
0,97
0,06
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

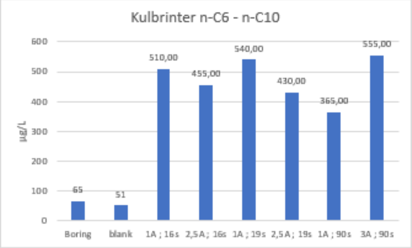

o-xylen
µg/L
3
2,5
2
1,5
1
0,5
0
2,5
1,4
1,60
1,22
1,55
0,86
0,37
0,20
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

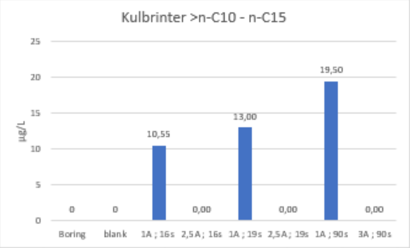

Xylener (o,-m- og p-xylen)
µg/L
4
3,5
3
2,5
2
1,5
1
0,5
0
3,5
1,9
2,60
2,35
2,30
1,20
1,34
0,23
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

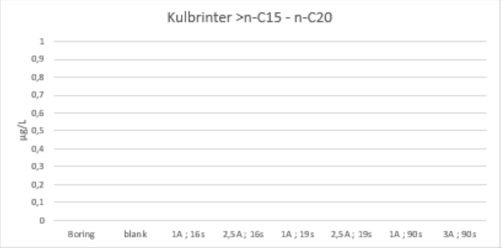

Xylener (o,-m-, p-xylen og ethylbenzen)
µg/L
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
4,5
2,4
4,05
3,35
3,50
2,15
1,85
0,36
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

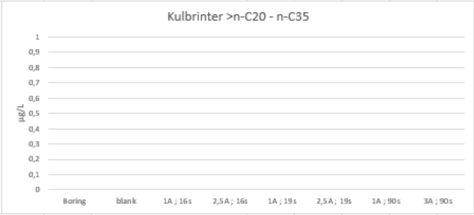

Naphtalen
µg/L
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
0
0,00
0,00
0,00
0,00
0,00
0,00
Boring
blank
1A ; 16s
2,5A ; 16s
1A ; 19s
2,5A ; 19s
1A ; 90s
3A ; 90s

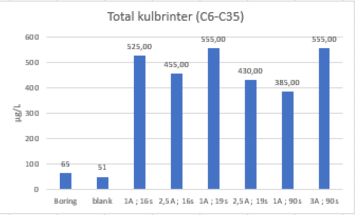
KULBRINTER I VAND



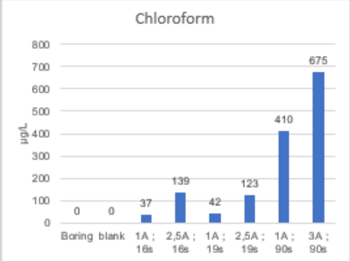


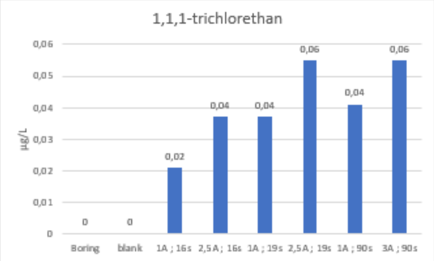


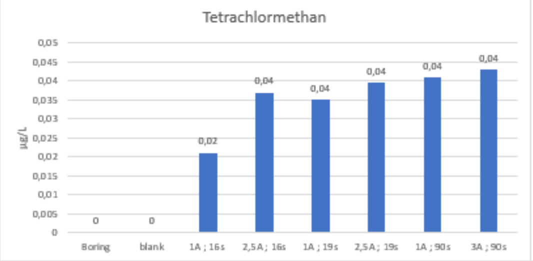


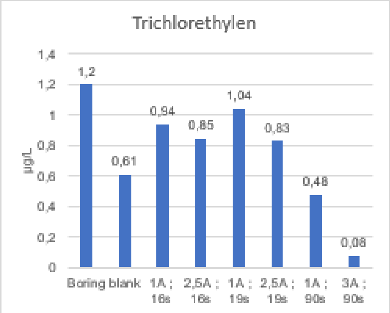


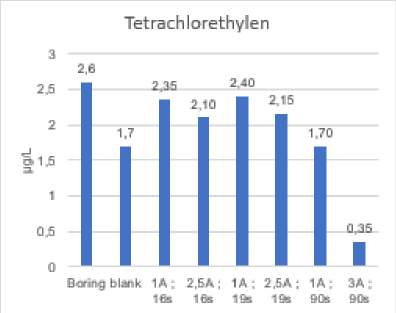
HS CHLOR. OG NEDBR.

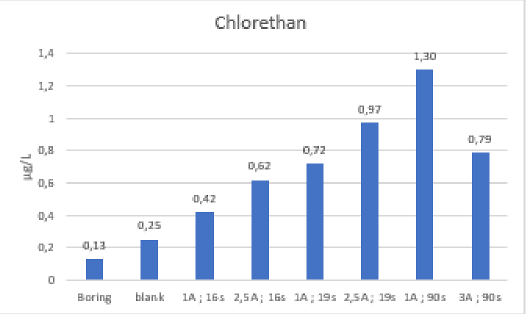


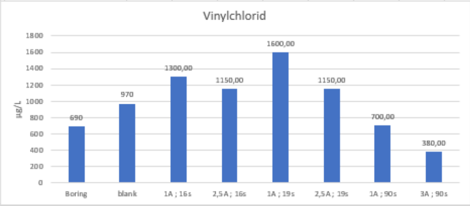


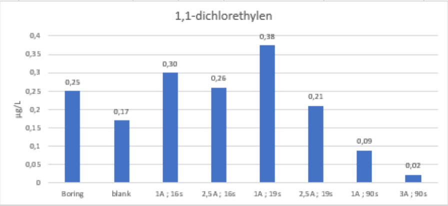


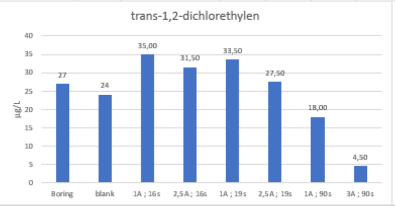


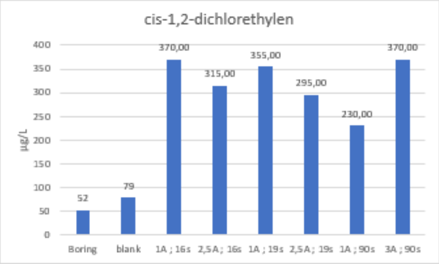


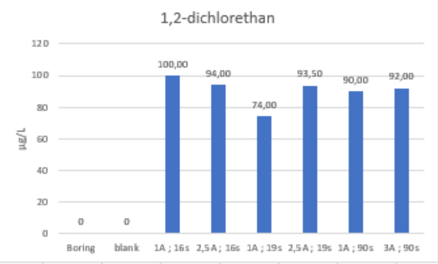


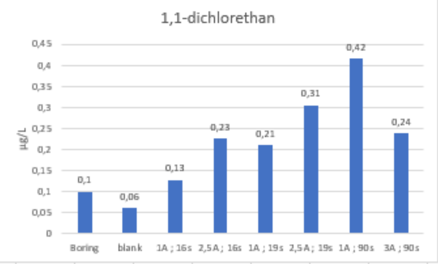


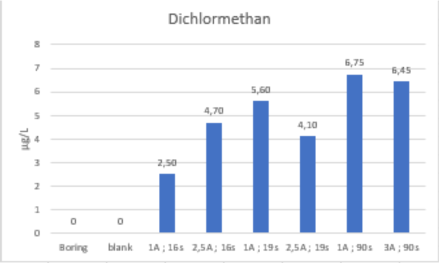






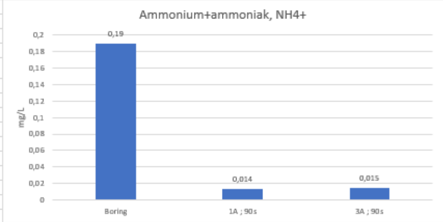


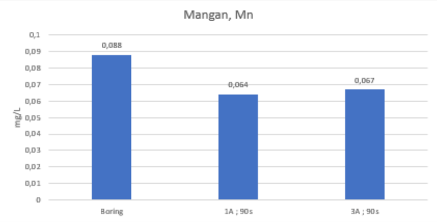


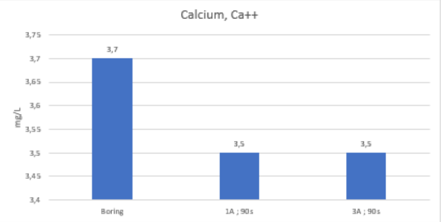


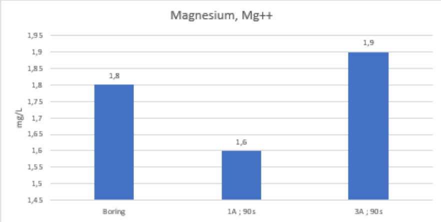
RUNDE 2

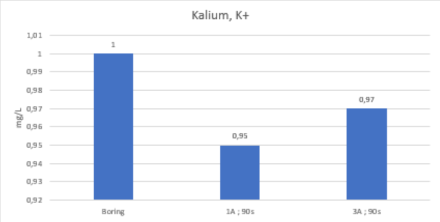
BORINGSKONTROL

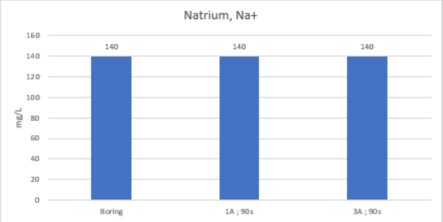


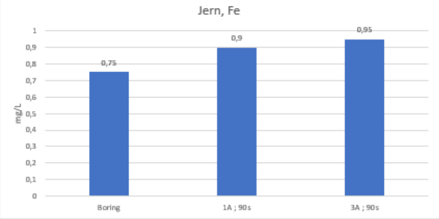


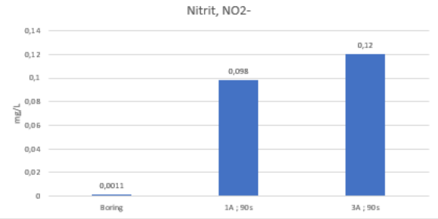


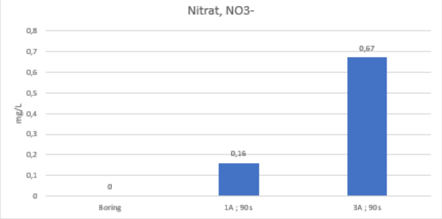


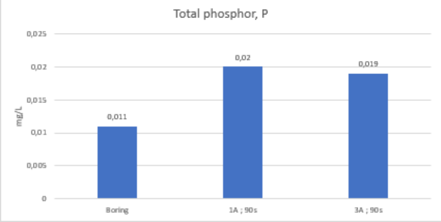


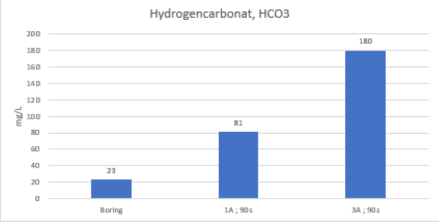


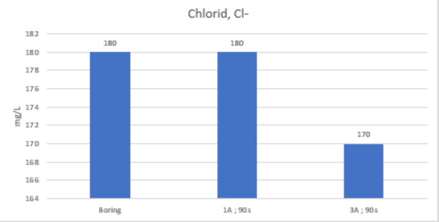


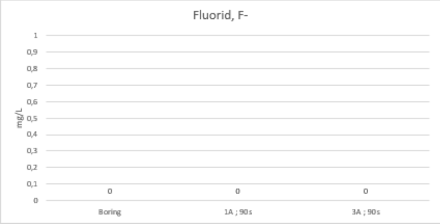


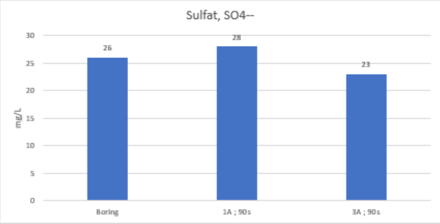


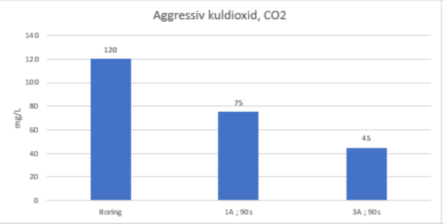


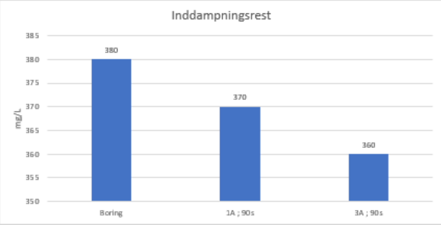


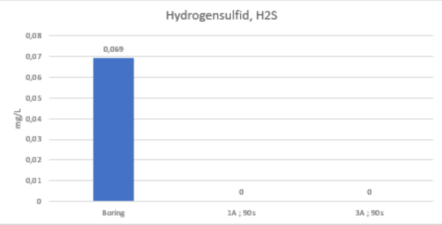


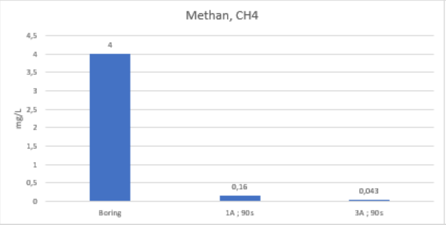

Fluorid, F-
mg/L
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Boring: 0
1A ; 90s: 0
3A ; 90s: 0

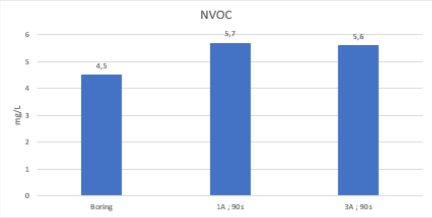

Sulfat, SO4--
mg/L
30
25
20
15
10
5
0
Boring: 26
1A ; 90s: 28
3A ; 90s: 23

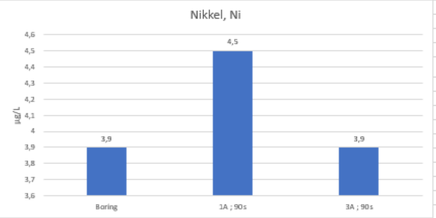

Aggressiv kuldioxid, CO2
mg/L
140
120
100
80
60
40
20
0
Boring: 120
1A ; 90s: 75
3A ; 90s: 45


Inddampningsrest
mg/L
385
380
375
370
365
360
355
350
Boring: 380
1A ; 90s: 370
3A ; 90s: 360

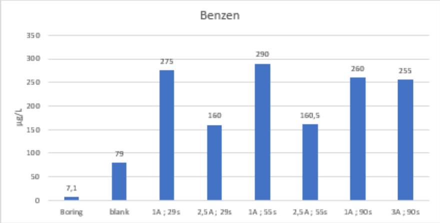

Hydrogensulfid, H2S
mg/L
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0,01
0
Boring: 0,069
1A ; 90s: 0
3A ; 90s: 0

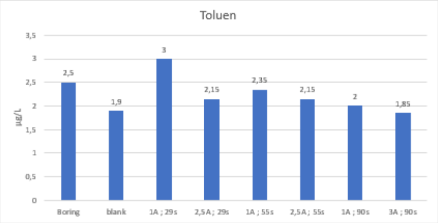

Methan, CH4
mg/L
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
Boring: 4
1A ; 90s: 0,16
3A ; 90s: 0,043

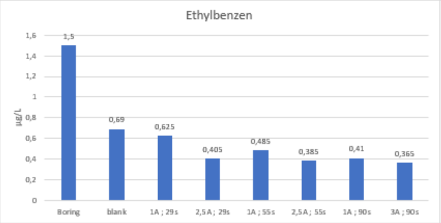

NVOC
mg/L
6
5
4
3
2
1
0
Boring: 4,5
1A ; 90s: 5,7
3A ; 90s: 5,6

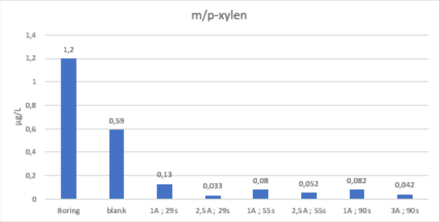

Nikkel, Ni
µg/L
4,6
4,5
4,4
4,3
4,2
4,1
4
3,9
3,8
3,7
3,6
Boring: 3,9
1A ; 90s: 4,5
3A ; 90s: 3,9

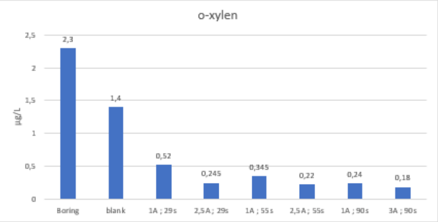
HS BTEXN

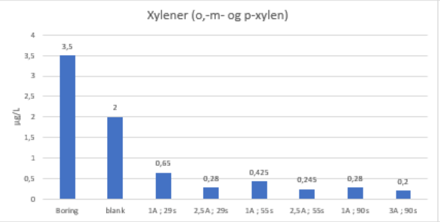

Benzen
µg/L
350
300
250
200
150
100
50
0
Boring: 7,1
blank: 79
1A ; 29s: 275
2,5 A ; 29s: 160
1A ; 55s: 290
2,5 A ; 55s: 160,5
1A ; 90s: 260
3A ; 90s: 255

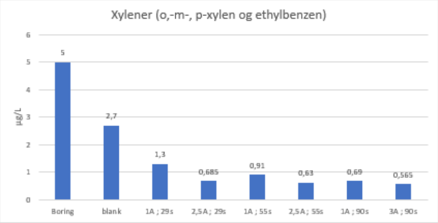

Toluen
µg/L
3,5
3
2,5
2
1,5
1
0,5
0
Boring: 2,5
blank: 1,9
1A ; 29s: 3
2,5 A ; 29s: 2,15
1A ; 55s: 2,35
2,5 A ; 55s: 2,15
1A ; 90s: 2
3A ; 90s: 1,85

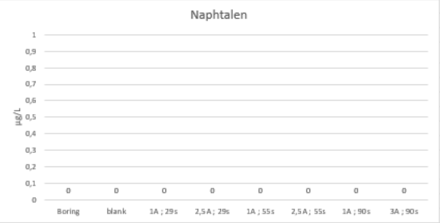

Ethylbenzen
µg/L
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
Boring: 1,5
blank: 0,69
1A ; 29s: 0,625
2,5 A ; 29s: 0,405
1A ; 55s: 0,485
2,5 A ; 55s: 0,385
1A ; 90s: 0,41
3A ; 90s: 0,365


m/p-xylen
µg/L
1,4
1,2
1
0,8
0,6
0,4
0,2
0
Boring: 1,2
blank: 0,59
1A ; 29s: 0,13
2,5 A ; 29s: 0,033
1A ; 55s: 0,08
2,5 A ; 55s: 0,052
1A ; 90s: 0,082
3A ; 90s: 0,042

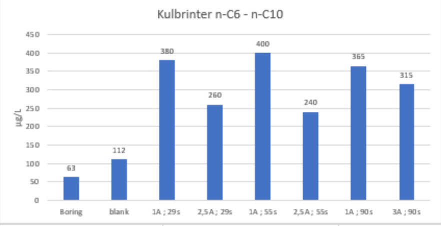

o-xylen
µg/L
2,5
2
1,5
1
0,5
0
Boring: 2,3
blank: 1,4
1A ; 29s: 0,52
2,5 A ; 29s: 0,245
1A ; 55s: 0,345
2,5 A ; 55s: 0,22
1A ; 90s: 0,24
3A ; 90s: 0,18

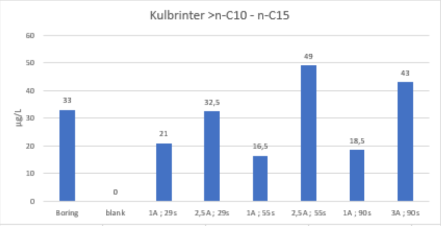

Xylener (o,-m- og p-xylen)
µg/L
4
3,5
3
2,5
2
1,5
1
0,5
0
Boring: 3,5
blank: 2
1A ; 29s: 0,65
2,5 A ; 29s: 0,28
1A ; 55s: 0,425
2,5 A ; 55s: 0,245
1A ; 90s: 0,28
3A ; 90s: 0,2

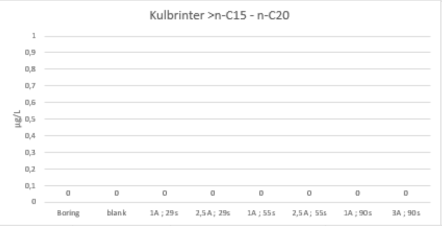

Xylener (o,-m-, p-xylen og ethylbenzen)
µg/L
6
5
4
3
2
1
0
Boring: 5
blank: 2,7
1A ; 29s: 1,3
2,5 A ; 29s: 0,685
1A ; 55s: 0,91
2,5 A ; 55s: 0,63
1A ; 90s: 0,69
3A ; 90s: 0,565

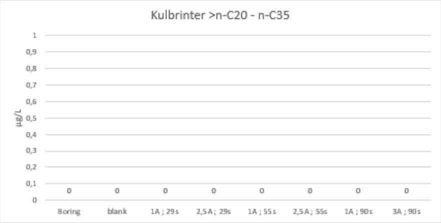

Naphtalen
µg/L
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Boring: 0
blank: 0
1A ; 29s: 0
2,5 A ; 29s: 0
1A ; 55s: 0
2,5 A ; 55s: 0
1A ; 90s: 0
3A ; 90s: 0

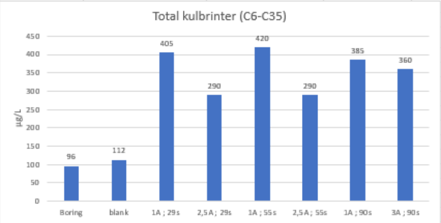
KULBRINTER I VAND


Kulbrinter n-C6 - n-C10

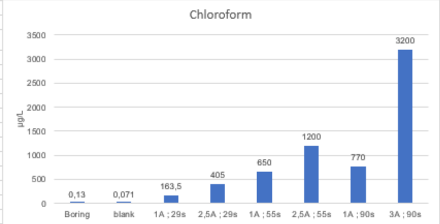

Kulbrinter >n-C10 - n-C15

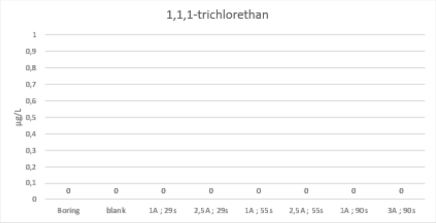

Kulbrinter >n-C15 - n-C20

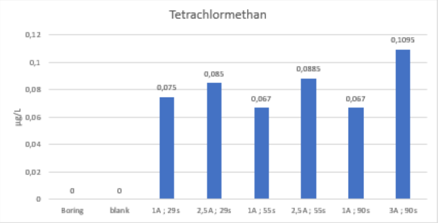

Kulbrinter >n-C20 - n-C35

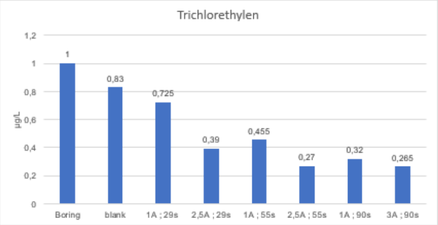

Total kulbrinter (C6-C35)

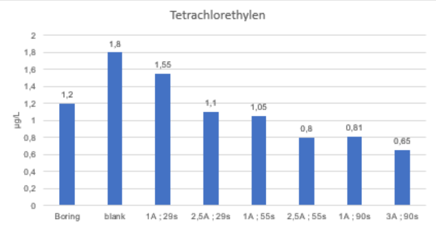
HS CHLOR. OG NEDBR.

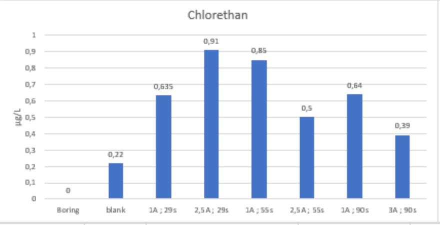

Chloroform

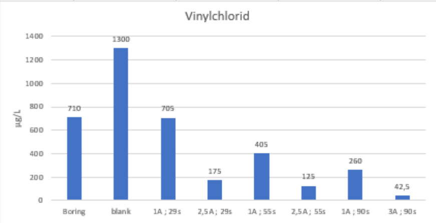

1,1,1-trichlorethan

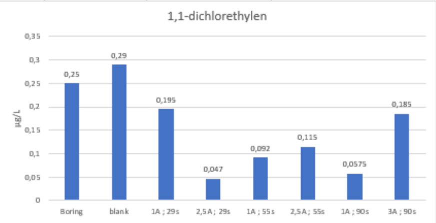

Tetrachlormethan

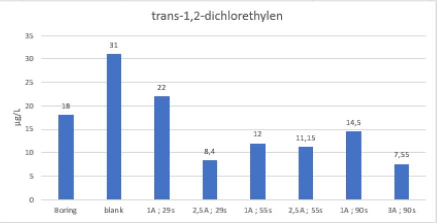

Trichlorethylen

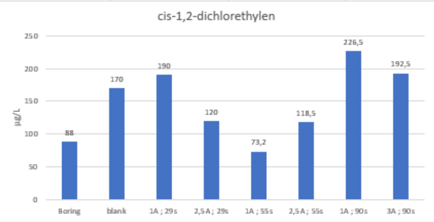

Tetrachlorethylen

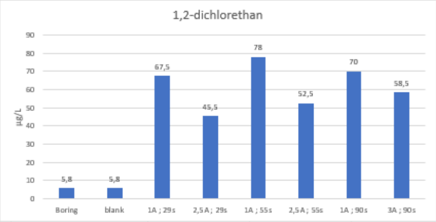

Chlorethan

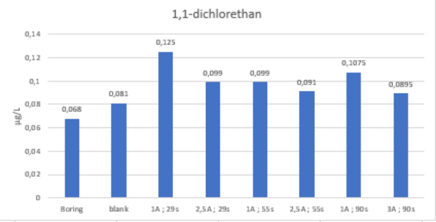

Vinylchlorid

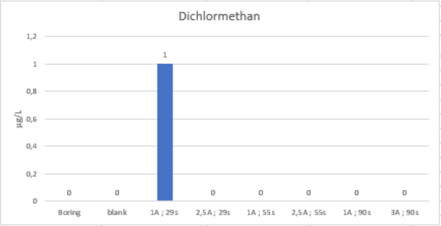

1,1-dichlorethylen


trans-1,2-dichlorethylen


cis-1,2-dichlorethylen

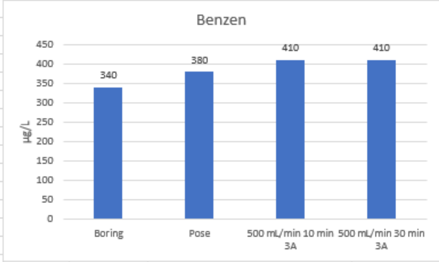

1,2-dichlorethan

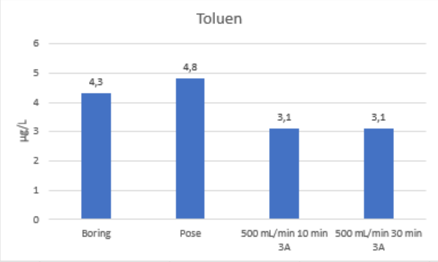

1,1-dichlorethan

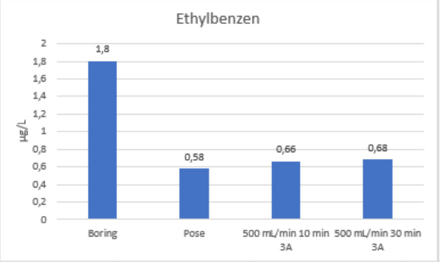


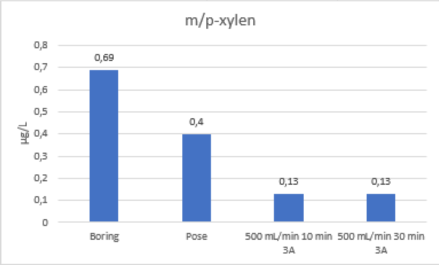
RUNDE 3

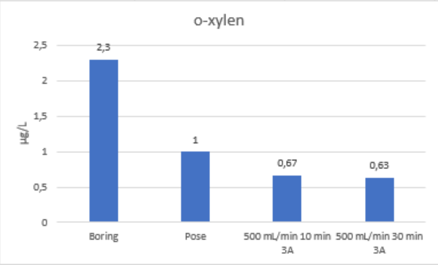
HS BTEXN

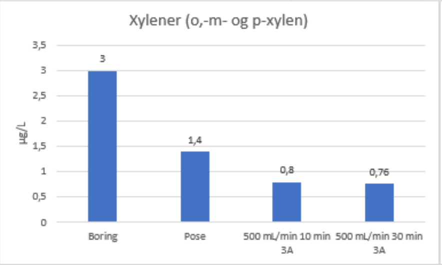


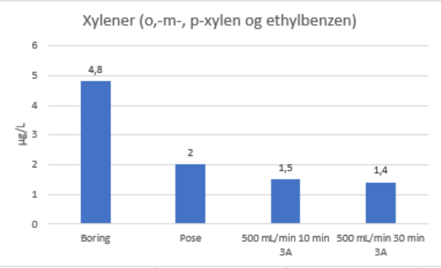


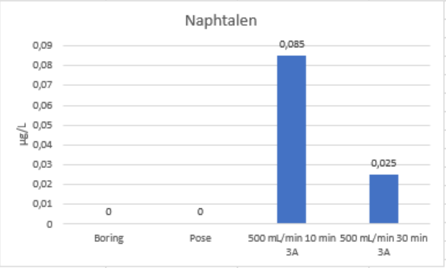




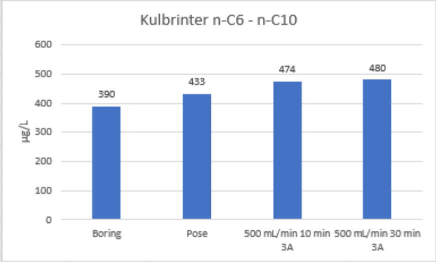


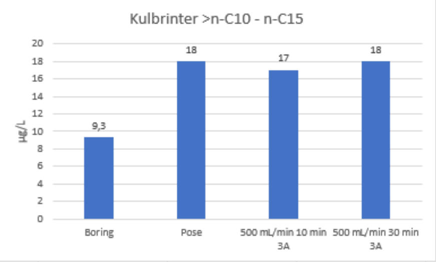


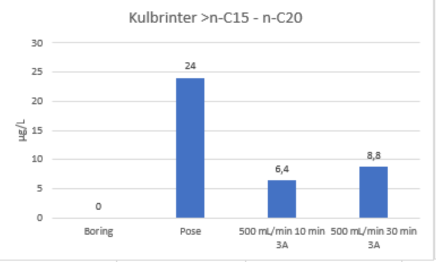


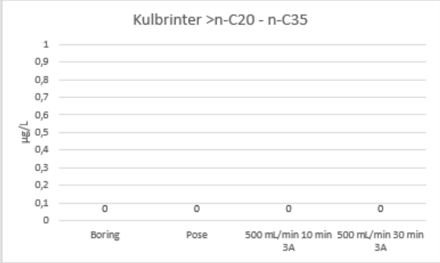


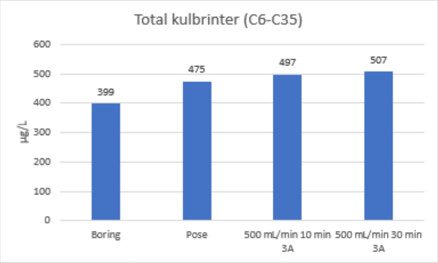
KULBRINTER I VAND



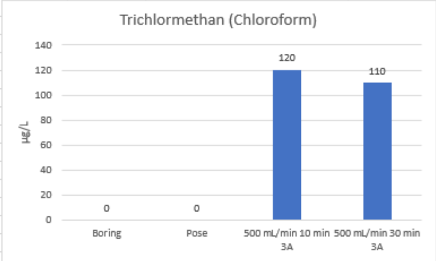


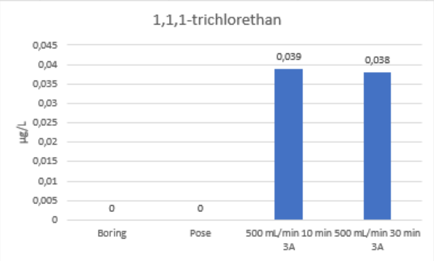


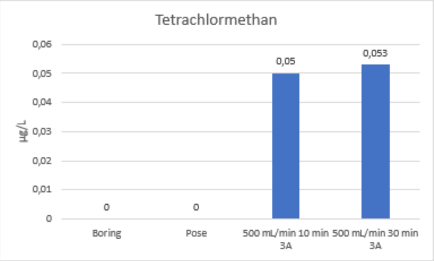


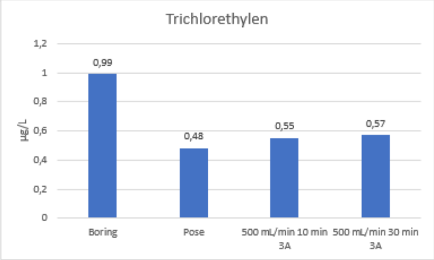


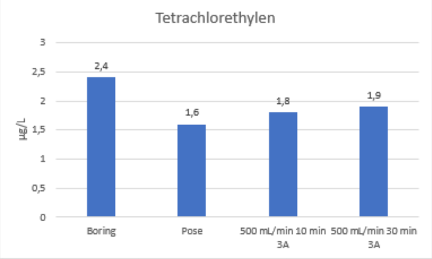
HS CHLOR. OG NEDBR.

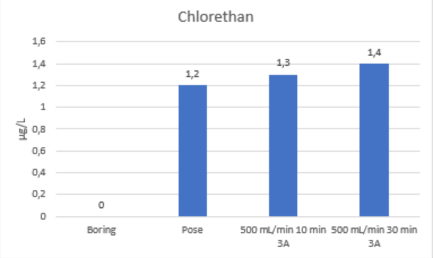


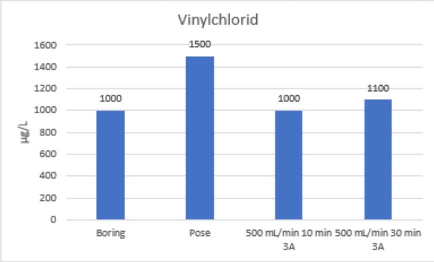


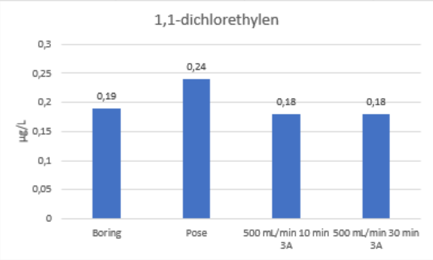


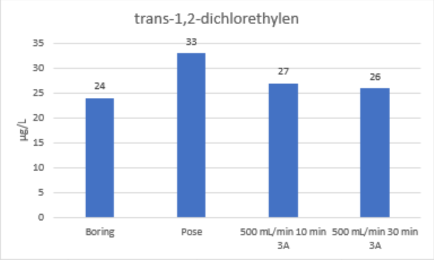


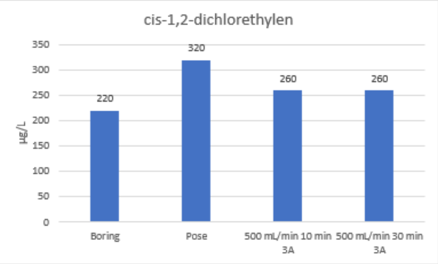


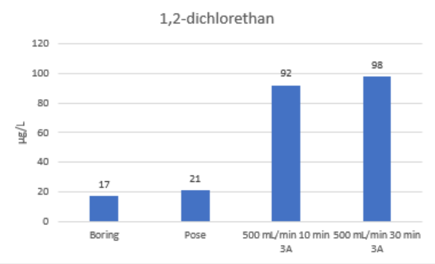


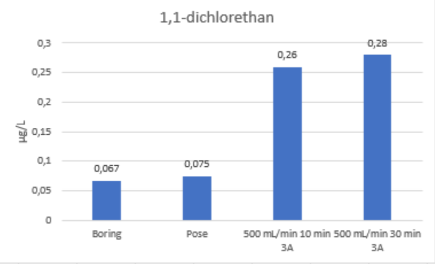


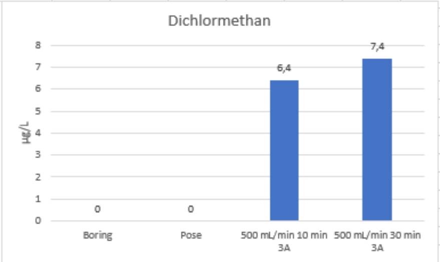











Dichlormethan
µg/L
8
7
6
5
4
3
2
1
0
0
0
6,4
7,4
Boring
Pose
500 mL/min 10 min 3A
500 mL/min 30 min 3A

BILAG 7 - INTERNE ANALYSERESULTATER AAU

Alle analyseresultater for vinylklorid og benzen i dette bilag stammer fra interne bestemmelser på GC-MS fra Aalborg Universitetet i Esbjerg. For at skabe transparens, er der i de tre første kolonner ”Prøve nr.”, ”prøve ID ALS” og ”dato modtaget ALS” direkte reference til de tilsvarende eksterne analyser hos ALS Denmark A/S. Analyserapporterne fra ALS Denmark A/S findes i bilag 3.

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L		Middelværdi µg/L	Standardafvigelse µg/L
101198		03-05-2023	Runde 1 (boring)	Figur 10 Figur 13				1385	1689	1537	215
101199	AAU1	03-05-2023	Runde 1 (blank Tedlar pose)	Figur 10 Figur 13				1392	1567	1480	124
101200	AAU2	03-05-2023	Runde 1	Figur 10 Figur 13	BDD	10	16	1154	1391	1273	168
101201	AAU3	03-05-2023	Runde 1	Figur 10 Figur 13 Figur 14 Figur 19	BDD	25	16	1908	1605	1757	214
101202	AAU4	03-05-2023	Runde 1	Figur 10 Figur 13	BDD	10	19	1349	1895	1622	386
101203	AAU5	03-05-2023	Runde 1	Figur 10 Figur 13 Figur 14 Figur 19	BDD	25	19	1029	1578	1304	388
101204	AAU6	03-05-2023	Runde 1	Figur 10 Figur 13	BDD	10	90	833	1063	948	163
101205	AAU7	03-05-2023	Runde 1	Figur 10 Figur 13 Figur 14 Figur 19	BDD	30	90	434	437	436	2

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L		Middelværdi µg/L	Standardafvigelse µg/L
137525		08-06-2023	Runde 2 (boring)	Figur 11 Figur 13				855	1024	940	120
137526	AAU1DSA	08-06-2023	Runde 2 (blank Tedlar pose)	Figur 11 Figur 13				1083	896	990	132
137527	AAU2DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	29	1472	1357	1541	177
137533	AAU8DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	29	1560	1776		
137528	AAU3DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	25	29	1097	1027	1688	737
137534	AAU9DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	25	29	2143	2486		
137529	AAU4DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	55	897	1028	1470	678
137535	AAU10DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	55	2389	1566		
137530	AAU5DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	25	55	809	921	922	169
137536	AAU11DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	25	55	797	1161		
137531	AAU6DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	90	845	905	1015	267
137537	AAU12DSA	08-06-2023	Runde 2	Figur 11 Figur 13	DSA-O2	10	90	1414	895		
137532	AAU7DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	30	90	508	394	432	55
137538	AAU13DSA	08-06-2023	Runde 2	Figur 11 Figur 13 Figur 19	DSA-O2	30	90	390	435		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Benzen µg/L	Middelværdi µg/L	Standardafvigelse µg/L
137525		08-06-2023	Runde 2 (boring)	Figur 17				405		
137526	AAU1DSA	08-06-2023	Runde 2 (blank Tedlar pose)	Figur 17				435		
137527	AAU2DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	29	521	519	2
137533	AAU8DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	29	518		
137528	AAU3DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	25	29	448	454	9
137534	AAU9DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	25	29	460		
137529	AAU4DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	55	392	422	42
137535	AAU10DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	55	451		
137530	AAU5DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	25	55	353	377	34
137536	AAU11DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	25	55	401		
137531	AAU6DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	90	403	431	40
137537	AAU12DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	10	90	459		
137532	AAU7DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	30	90	327	343	22
137538	AAU13DSA	08-06-2023	Runde 2	Figur 17	DSA-O2	30	90	359		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L			Middelværdi µg/L	Standardafvigelse µg/L
198533		31-08-2023	Runde 3 (boring)	Figur 18 (a)				1035	1080	1195	1057	226
198533		31-08-2023	Runde 3 (boring)	Figur 18 (a)				758	1395	881		
198534	AAU1 pose	30-08-2023	Runde 3 (blank Tedlar pose)	Figur 18 (a)				1025	1026	974	979	98
198534	AAU1 pose	30-08-2023	Runde 3 (blank Tedlar pose)	Figur 18 (a)				1103	818	929		
			Runde 3	Figur 18 (a) Figur 19	BDD (stack)	2 x 30	75	335	378	318	346	25
			Runde 3	Figur 18 (a) Figur 19	BDD (stack)	2 x 30	75	361	322	364		
			Runde 3	Figur 18 (a) Figur 19	BDD (stack)	2 x 30	37	475	576	567	543	66
			Runde 3	Figur 18 (a) Figur 19	BDD (stack)	2 x 30	37	524	643	472		
			Runde 3	Figur 18 (a)	BDD (stack)	2 x 45	75	187	202	167	193	15
			Runde 3	Figur 18 (a)	BDD (stack)	2 x 45	75	205	206	188		
			Runde 3 (blank Tedlar pose)	Figur 18 (a)				844	890	901	869	154
			Runde 3 (blank Tedlar pose)	Figur 18 (a)				686	1135	759		
			Runde 3	Figur 18 (a) Figur 19	DSA-O2 (stack)	2 x 30	75	336	329	264	300	29

[redacted]	[redacted]	[redacted]	Runde 3	Figur 18 (a) Figur 19	DSA-O2 (stack)	2 x 30	75	275	305	293		
[redacted]	[redacted]	[redacted]	Runde 3	Figur 18 (a) Figur 19	DSA-O2 (stack)	2 x 30	37	403	476	517	551	103
[redacted]	[redacted]	[redacted]	Runde 3	Figur 18 (a) Figur 19	DSA-O2 (stack)	2 x 30	37	645	664	603		
[redacted]	[redacted]	[redacted]	Runde 3	Figur 18 (a)	DSA-O2 (stack)	2 x 45	75	212	228	213	205	16
[redacted]	[redacted]	[redacted]	Runde 3	Figur 18 (a)	DSA-O2 (stack)	2 x 45	75	191	196	187		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Benzen µg/L		Middelværdi µg/L	Standardafvigelse µg/L
198533		31-08-2023	Runde 3 (boring)	Figur 18 (b)				422	392	384	31
198533		31-08-2023	Runde 3 (boring)	Figur 18 (b)				374	348		
198534	AAU1 pose	30-08-2023	Runde 3 (blank Tedlar pose)	Figur 18 (b)				336	324	347	22
198534	AAU1 pose	30-08-2023	Runde 3 (blank Tedlar pose)	Figur 18 (b)				376	350		
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 30	75	106	104	101	5
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 30	75	96	96		
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 30	37	196	168	181	12
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 30	37	184	176		
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 45	75	50	50	48	2
			Runde 3	Figur 18 (b)	BDD (stack)	2 x 45	75	46	46		
			Runde 3 (blank Tedlar pose)	Figur 18 (b)				374	345	358	25
			Runde 3 (blank Tedlar pose)	Figur 18 (b)				330	384		
			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 30	75	86	84	85	1

			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 30	75	84	84		
			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 30	37	180	165	173	16
			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 30	37	155	190		
			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 45	75	50	50	51	2
			Runde 3	Figur 18 (b)	DSA-O2 (stack)	2 x 45	75	52	52		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L			Middelværdi µg/L	Standardafvigelse µg/L
[redacted]	[redacted]	[redacted]	Processtabilitet	Figur 20	BDD (stack)	2 x 30	0	737	662	786	728	62
[redacted]	[redacted]	[redacted]	Processtabilitet	Figur 20	BDD (stack)	2 x 30	1800	213	225	234	224	11
[redacted]	[redacted]	[redacted]	Processtabilitet	Figur 20	BDD (stack)	2 x 30	3600	252	256	260	256	4
[redacted]	[redacted]	[redacted]	Processtabilitet	Figur 20	BDD (stack)	2 x 30	5400	223	249	194	222	28
[redacted]	[redacted]	[redacted]	Processtabilitet	Figur 20	BDD (stack)	2 x 30	7200	236	223	272	244	25

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L			Middelværdi µg/L	Standardafvigelse
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (a), (c) og (e)	[redacted]	[redacted]	[redacted]	851	790	716	746	75
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (a), (c) og (e)	[redacted]	[redacted]	[redacted]	636	775	705		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	10	12	645	683	720	657	52
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	10	12	649	567	676		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	30	12	657	731	758	684	49
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	30	12	672	647	636		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	10	25	571	509	542	498	51
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	10	25	465	441	459		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	30	25	383	364	369	365	13
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	MP Celle BDD	30	25	357	345	371		

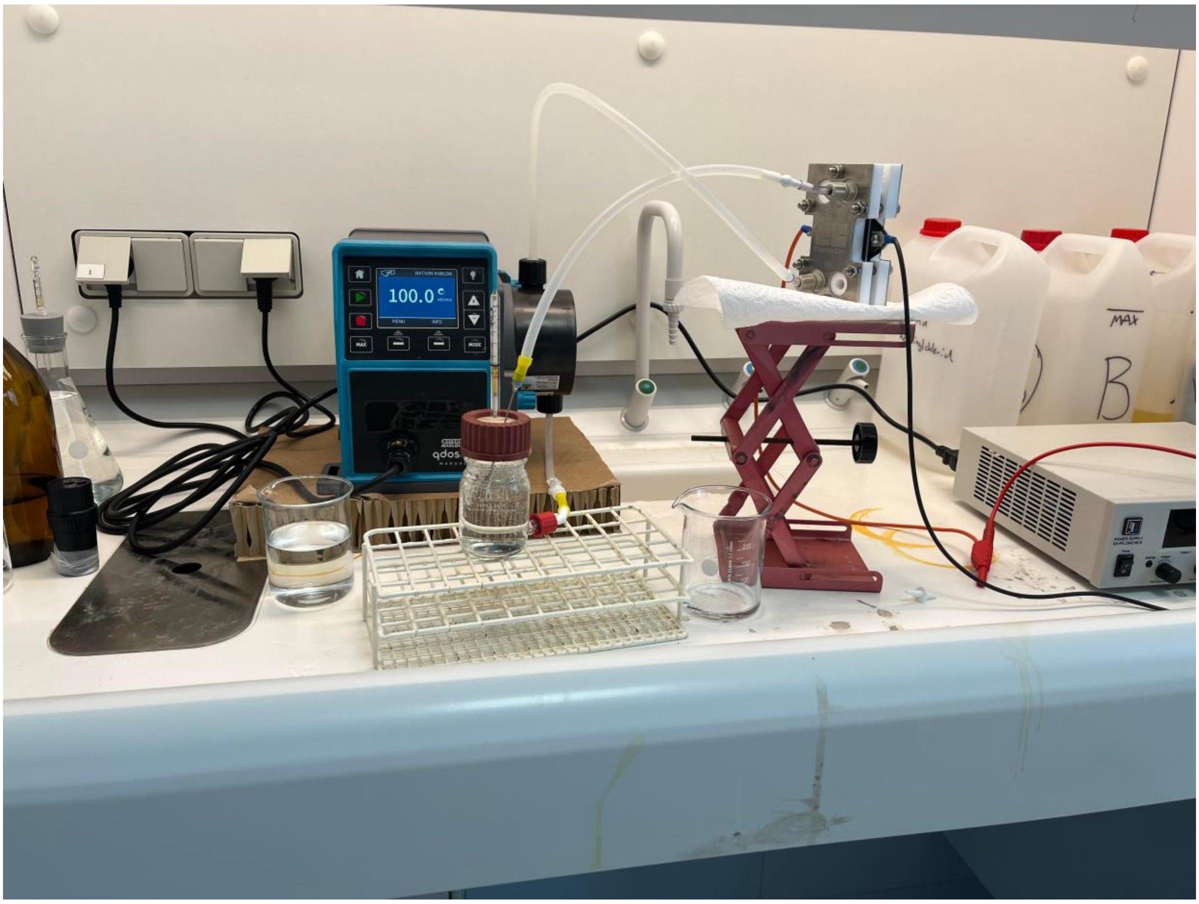
Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Vinylklorid µg/L			Middelværdi µg/L	Standard afvigelse
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (a), (c) og (e)	[redacted]	[redacted]	[redacted]	791	980	653	888	141
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (a), (c) og (e)	[redacted]	[redacted]	[redacted]	1028	907	968		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	10	2	741	704	701	842	160
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	10	2	1091	824	1061		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	30	2	753	854	817	771	55
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	30	2	726	767	711		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	10	4	790	669	759	756	52
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	10	4	820	733	767		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	30	4	717	656	643	672	58
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (a), (c) og (e)	Micro Flow celle BDD	30	4	579	740	696		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Benzen µg/L		Middelværdi µg/L	Standardafvigelse
			Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (b), (d) og (f)				114	114	121	8
			Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (b), (d) og (f)				130	124		
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	10	12	124	114	115	6
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	10	12	112	110		
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	30	12	104	104	102	3
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	30	12	100	98		
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	10	25	96	94	92	4
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	10	25	88	88		
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	30	25	66	74	69	3
			Sammenligning af celletyper	Figur 21 (b), (d) og (f)	MP Celle BDD	30	25	68	68		

Prøve nr.	Prøve ID ALS	Dato Modtaget ALS	Runde	Figur i rapporten	Anode	Strømtæthed (mA/cm^2)	Opholdstid (sek)	Koncentration Benzen µg/L		Middelværdi µg/L	Standard afvigelse
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (b), (d) og (f)	[redacted]	[redacted]	[redacted]	70	66	68	2
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper (Tedlar pose blank)	Figur 21 (b), (d) og (f)	[redacted]	[redacted]	[redacted]	66	68		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	10	2	68	68	68	1
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	10	2	66	68		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	30	2	66	66	65	1
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	30	2	64	64		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	10	4	66	68	64	4
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	10	4	60	62		
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	30	4	58	60	60	2
[redacted]	[redacted]	[redacted]	Sammenligning af celletyper	Figur 21 (b), (d) og (f)	Micro Flow celle BDD	30	4	62	60		

Electrolytic treatment of vinyl chloride contaminated groundwater

Ema Frankovic, Jesper Thygesen & Martin Sonne



February - May 2023

Aalborg University Esbjerg

AALBORG UNIVERSITY
STUDENT REPORT

Title page

Title: Electrolytic treatment of vinyl chloride contaminated groundwater

Topic: Process Modelling

Project-period: February - May 2023

Study-program: Chemical Engineering

Semester: 2.

Project-group: CE2-1-F23

Supervisors: Jens Muff

Number of pages: 101

Date of completion: 26.05.2023

Group members: 3

Signatures:

Jesper Thygesen

Jesper Thygesen

Martin Sonne

Ema Frankovic

Ema Frankovic

Abstract

This report focuses on electrochemical treatment of vinyl chloride contaminated ground water from Grindsted. Vinyl chloride contamination is a serious problem as vinyl chloride is carcinogenic and poses serious health concerns. The aim of this project is to investigate if vinyl chloride can be degraded using electrochemical oxidation in a pump-and-treat system. The effect of varying electrode material (boron-doped diamond (BDD) / Dimensionally Stable Anodes (DSA)), current (0.1/0.5 A), flowrate of the pump (100/200 mL/min pump setting) as well as time (0-30 minutes) was investigated. A literature study was first prepared, which aimed to investigate the Grindsted ground water site, chlorinated ethenes and their properties, electrochemical oxidation together with kinetics, reactor design and parameter considerations. The knowledge gained from this literature study was used to design laboratory scale experiments. The best configuration of the electrochemical cell was using BDD, 100 mL/min and 0.5 A to obtain 91% degradation of vinyl chloride in 30 minutes treatment time. GC-MS analysis performed on the gas, showed the amount of vinyl chloride in the produced gas was between 11-92% less than when the cell was inactive, meaning the cell is successfully able to degrade vinyl chloride and not just enhance evaporation. A model was made and used to estimate the amount of time needed for the vinyl chloride concentration to be degraded under the discharge limit, which the model predicted to be 135 minutes using the best configuration. Electrolysis is therefore an applicable treatment method for remediation of contaminated Grindsted water.

Preface

The following project was made by Ema Frankovic, Jesper Thygesen, and Martin Sonne as a 2ed semester project of the master's degree in chemical engineering at Aalborg University Esbjerg (AAUE) and is associated to a research project funded by Region of Southern Denmark. The project investigates the possibility of removing pollutants from contaminated water in Grindsted with electrochemistry, with special interest in vinyl chloride. This will be investigated by performing experiments in the laboratory to determine how current, electrode material, and flowrate affect degradation of vinyl chloride over time. The project period started on the 1st of February until the 26th of May, supervised by Jens Muff.

All laboratory work was performed in the laboratories on the 3rd floor in the chemical section of Aalborg University Esbjerg. Multiple experiments were performed in collaboration with laboratory technician Nicolai Præst Nielsen.

References are indicated with [number], referring to a source in the references found in section 10. Sources are placed at the end of a section unless directly referring to a number or other concrete knowledge. Equations are indicated with (number).

The project group would like to thank laboratory technician Nicolai Præst Nielsen, as well as the laboratory technicians Dorte Spangsmark and Linda Madsen for great assistance during the experimental work performed for this project, both in the form of performing and analyzing the experiments and samples, but also for coming up with different creative method to analyze the gas phase.

Table of Contents

1. Introduction 7

2. Problem Analysis 8

2.1 Grindstedværket 8
2.2 Chlorinated ethenes 12
2.3 Electrochemical oxidation 16
2.3.1 Reactions of EOTR 18
2.3.2 Indicators and Kinetics 21
2.3.3 Electrochemical oxidation modelling 24
2.3.4 Reactor design 25
2.3.5 Electrochemically induced degradation of vinyl chloride 29
3. Problem Statement 32

4. Project delineation 33

5. Materials and methods 35

5.1 Electrochemical cells used 35
5.2 Ground water sampling and characteristics 36
5.3 Determination of mass transfer coefficient 37
5.4 Analytical methods 38
5.4.1 Water phase 38
5.4.2 Vinyl chloride in the gas phase 39
5.4.3 Calculation of vinyl chloride in the gas phase 39
5.5 Experimental plan and setup 39
5.5.1 Removal of vinyl chloride in the water phase 41
5.5.2 Estimating stripping of vinyl chloride 41
6. Results and data analysis 43

6.1 Mass transfer coefficients results 43
6.2 Degradation of vinyl chloride in the water phase 56
6.2.2 Degradation of vinyl chloride efficiency 59
6.3 Stripping vs. Degradation 60
6.3.1 Determining evaporation of vinyl chloride with nitrogen 60
6.3.2 Determining evaporation of vinyl chloride with GC-MS 61
6.4 Vinyl chloride degradation modelling 64
6.5 Experiment based calculations and considerations 66
6.5.1 Model application with different parameters 66

6.5.2 Treatment time needed to reach the discharge limit ... 66
6.5.3 Scaling of flowrate, current and electrode area ... 67
7. Discussion ... 69

8. Conclusion ... 75

9. Further work ... 76

10. References ... 78

11. Appendix ... 83

Appendix 1 - Determining mass transfer coefficients ... 83
Appendix 2 - Results from ALS ... 96
Appendix 3 - Determination of the limiting current ... 98
Appendix 4 - GC-MS for analyzing for vinyl chloride in solution ... 99
Appendix 5 - Additional results from calculations and experiments ... 101

1. Introduction

Water is essential to life and as the population grows, the need for drinking water increases. Unfortunately, when chemicals are used there is a possibility of spills, leakage, improper disposal, etc. which can contaminate the water. Some common contaminants in the environment, with adverse effects on human health are gasoline, aromatic hydrocarbons, alcohols, ethers, ketones, chlorinated organic solvents, heavy metals [1], pesticides [2], [3], and per- and polyfluoroalkyl substances [4], [5]. Thus, harmful chemicals have been and probably continuously will be introduced to the environment.

This project focuses on contamination of groundwater with chlorinated solvents in the form of chlorinated ethenes, which include tetrachloroethylene (PCE) and trichloroethylene (TCE). Some common usage of these compounds includes paint, cleaning automotive parts, regenerating catalysts and dry cleaning [6]. Due to new information about toxicity and harmful impact of these compounds stricter environmental regulations were implemented, drastically decreasing the usage in the 1970's [6]. But the old methods of handling, storing, and using TCE and PCE had already contaminated the environment [7].

Under certain environmental conditions PCE and TCE will be biodegraded by specific microbial cultures [8]–[11]. But biodegradation is slow and often leads to accumulation of more harmful chlorinated intermediates in the form of cis-1,2-dichloroethylene (cis-DCE), trans-1,2-dichloroethylene (trans-DCE), 1,1- dichloroethylene (1,1-DCE) and vinyl chloride (VC) [12]–[14].

One site where these chlorinated intermediates in the form of vinyl chloride are found in the groundwater is a megasite in Grindsted (Denmark), where the contamination originates from historically poor industrial waste- and wastewater management. Region of Southern Denmark is responsible for the management of the megasite and want to study if/how electrolytic treatment of the groundwater could degrade the vinyl chloride into nontoxic components.

This study concerns the research of process parameters, such as electrode materials, current densities, applied potentials, and their effects on electrolytic treatment efficacy, as well as basic modelling of the process. Therefore, the problem analysis will contain information needed to understand the problem and carry out the experiments. This information includes a description of the contaminated site, description of the contaminant including degradation and properties, electrolysis in general and of chlorinated solvents, as well as different reactor designs.

2. Problem Analysis

2.1 Grindstedværket

Grindstedværket was founded in 1924 on a factory site in the north-eastern part of Grindsted. In the period from 1924 until the mid-1970s, the former Grindsted plant deposited solid and liquid waste from the production of vitamins and medicinal products in several places in and around Grindsted town, as well as in Kærgård Klitplantage. The four primary sources of pollution in Grindsted are the railway pit depot (Banegravsdepotet), the factory site (Fabriksgrunden), the drainage ditch (Afløbsgrøften) and the landfill south of the city (Lossepladsen), but only the pollution from the factory site is defined as a megasite, which is the focus of this remediation [15]. The location of these sites relative to each other can be seen in figure 1 [16].

Figure 1 - Overview map of the location of the four pollution sites in Grindsted caused by Grindstedværket [16].

The pollution on the factory site stems from loss of raw materials and chemicals, and consists mainly of solvents, sulphonamides and barbiturates [17]. Massive contamination of the upper groundwater reservoir has been found from the factory site to approx. 80 meters depth. The contamination has spread south-west with the groundwater and is under a large part of Grindsted town, heading towards Grindsted Å. The mobile pollutants are estimated to have been transported with the groundwater away from the factory site, so that the strongest contamination in the groundwater is now found somewhere between the factory site and Grindsted Å. The Technical University of Denmark has estimated that the stream is supplied annually with approx. 235 kg of vinyl chloride from the contaminated groundwater [18]. A model of this transport can be seen in figure 2 [19].

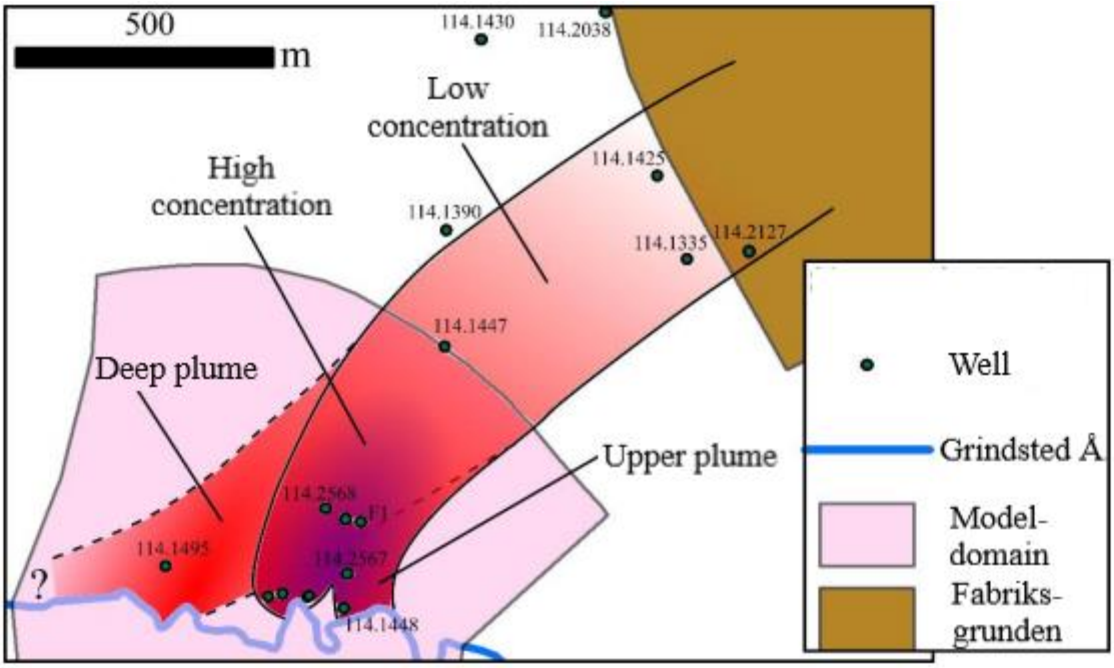


Figure 2 - Conceptual plan view of the spread of the pharmaceutical and chlorinated solvents and degradation products from 2012-2016. The plume is split into one close to the ground (solid line) and a deeper one (dotted lines) [19]

Vinyl chloride originates from the natural breakdown of chlorinated solvents that have been used on the factory site. This quantity gives rise to the quality criteria for vinyl chloride being exceeded by a factor of 100 in Grindsted Å. Along with vinyl chloride, a large number of other contaminants (see table 1) are supplied to the stream via the contaminated groundwater. Quality criteria for surface water have not yet been established for many of these substances [18].

An overview map of the location of selected wells north of Grindsted Å can be seen in figure 3. The area of Grindstedværkets soil contamination is shown with a red area and the wells with blue dots [20].

Figure 3 - An overview map of the location of selected wells north of Grindsted Å. The area of Grindstedværkets soil contamination is shown with a red area and the wells with red dots *[20]*.

Table 1 - Overview of chemical analysis results from wells carried out north of Grindsted Å and at the Grindsted plant. All detected substances are marked in bold. n.a. stands for "not analyzed". NVOC stands for "nonvolatile organic carbon" [20]–[23].

	Fabriks grund	**Fabriks grund**	**Centralt i fanen**	**Centralt i fanen**	**Centralt i fanen**
Well nr./Year	114.1334 17-10-2012	114.1425 15-10-2012	114.1447 18-04-2020	114.1495 13-04-2021	114.2567 11-03-2020
Depth (m)	20.5 - 30.5	55 - 62	53.5 - 54.4	42 - 43	8-10
Environmentally harmful substances (µg/L)					
Sulfanilic acid	<0.5	<0.5	**5.1**	**720**	**65**
Sulfamethazine	**8.4**	<0.5	**60**	**25**	**110**
Sulfanilamide	**6.2**	**1.8**	**280**	**480**	**37**
Sulfamethiazole	**0.62**	<0.05	**17**	**13**	**32**
Sulfathiazole	**9.5**	**0.08**	**21**	**13**	**3.6**
Sulfaguanidine	**16**	<0.5	**490**	**300**	**0.5**
Meprobamate	**7.1**	**0.54**	**80**	**37**	**61**
Barbital	**1.3**	<0.5	**23**	**14**	**15**
Amobarbital	**3.0**	<0.5	**7.1**	**2.5**	**43**
PCE	<0.02	**6.3**	**1.5**	**0.04**	**48**
TCE	<0.02	**0.59**	**4.7**	**0.65**	**22**
cis-DCE	**0.06**	**0.6**	**280**	**540**	**1400**
VC	<0.02	<0.02	**2700**	**2400**	**7100**
Benzene	**0.04**	**1.4**	**230**	**220**	**520**
Toluene	<0.02	<0.02	**2.2**	**2.9**	**5**
Ethylbenzene	<0.02	<0.02	**1.1**	**1.2**	**0.64**
Xylenes	**0.02**	<0.02	**1.0**	**2.0**	**2.3**
Inorganic compounds (mg/L)					
Chloride	**34**	n.a.	n.a.	**220**	**140**
Nitrate	< 0.3	n.a.	n.a.	<0.1	**0.06**
Sulfate	**68.0**	n.a.	n.a.	**120**	**32**
Dissolved iron	**13**	n.a.	n.a.	**56**	**5.4**
Ammonium	**1.55**	n.a.	n.a.	**2.1**	**0.18**
NVOC	**1.4**	n.a.	n.a.	**8.9**	**4.9**

The contamination chemistry in the groundwater plume from the Grindsted plant, based on the water samples shown (Table 1), is characterized by a content of large amounts of barbiturates, sulfonamides, sulfanilic acid, PCE, TCE, cis-DCE, VC and chloride [20].

2.2 Chlorinated ethenes

Chlorinated ethenes, also known as chlorinated solvents, such as tetrachloroethylene (TCE), trichloroethylene (PCE), and chloroform are common solvents used in different industries, however there are various health concerns related to their usage. The term chlorinated solvents conceptually refer to both aliphatic and aromatic compounds that are chlorinated, however due to common usage of the phrase, it has been more directly applied to aliphatic chlorinated compounds. Due to spills, leaks, and problematic waste handling and being intermediates in natural degradation pathways of other chlorinated ethenes, aliphatic chlorinated compounds are widespread in the environment [24]. The chlorinated ethenes are quite volatile, but they can often be found in the subsurface in different phases: dissolved in the groundwater or the soil moisture, in the soil vapor, sorbed to geologic materials in both the saturated and unsaturated layers of the subsurface, and as undissolved solvent as a separate phase liquid. Chlorinated ethenes are dense non-aqueous phase liquids (DNAPL), which increases the difficulty of their removal, as they can permeate through saturated layers, leaving globules and pools throughout the geologic matrix. DNAPLs in the subsurface will slowly dissolve into the groundwater, meaning the DNAPLs could take decades to deplete [24]. The chlorinated ethenes are slowly biodegraded by reductive dechlorination by different microorganisms. However, the reductive dechlorination of TCE and PCE, will eventually lead to an accumulation of vinyl chloride, which is more toxic and carcinogenic than TCE and PCE. This is due to each successive step of reductive dechlorination being slower than the previous step. The biodegradation pathway for TCE and PCE is seen in figure 4. Cometabolism is the process of using a secondary microorganism to produce an enzyme that aids in the degradation of chlorinated ethenes, allowing for degradation directly to carbon dioxide, however the process is severely limited by large demands for oxygen and co-substrate, and is non-viable as a remediation technique [25].

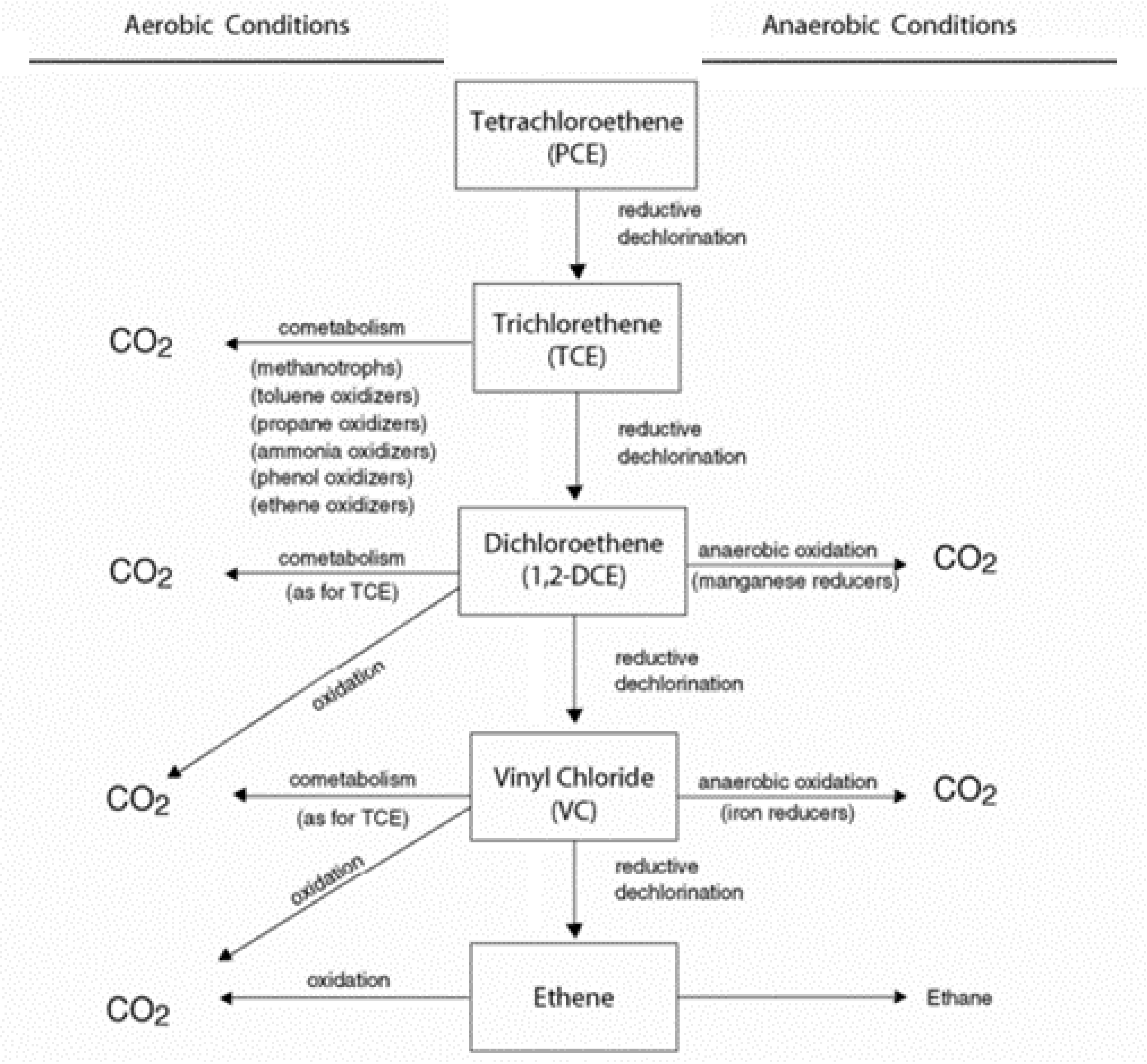
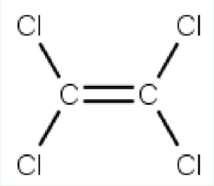
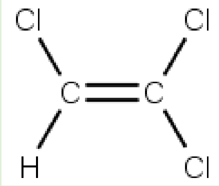
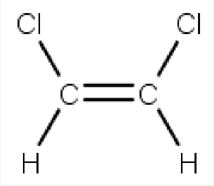
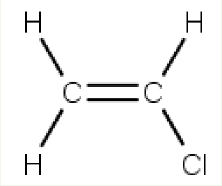


Figure 4 - Biological degradation pathways starting from PCE [25]

The organisms that are responsible for the biodegradation are however non-ubiquitous, meaning the process does usually not occur naturally. This predominantly affects the degradation of dichloroethene (DCE), leading to an accumulation of it instead of vinyl chloride [25].

The properties and parameters of chlorinated ethenes are important to understand, as it affects how well they travel through the subsurface. Especially their solubility in water, partition coefficient for octanol/water and distribution coefficient for air/water. K_{ow}, the octanol/water coefficient reflects the polarity of the compounds, while K_{oc} can somewhat reflect the sorption to the soil. Table 2 shows the properties for TCE, PCE, cis-DCE and VC at 25 °C.

Table 2 - Property table for chlorinated solvents and degradation products at 25℃ [26]–[34]

Properties at 25 °C	**PCE**	**TCE**	**Cis-DCE**	**VC**
Chemical structure				
Molar weight (g/mol)	165.83	131.39	96.94	62.5
Absolute viscosity (cP)	1.932	0.566	0.444	-
Density (kg/L)	1.63	1.47	1.27	0.92
Melting point (°C)	-22.7	-87.1	-81.47	-153.8
Boiling point (°C)	121.2	86.7	60.2	-13.4
Flash point (°C)	-	-	6	-78
Vapor pressure (kPa)	2.415	9.900	27.000	354.600
Water solubility (mg/kg)	206	1280	3512	1100-8800
Henry's volatility constant (dimensionless)	0.72	0.39	0.17	1.1
Log K_{ow}	2.88	2.53	1.86	1.38
K_{oc}	200-237	101	49	57
LC_{50} (mg/L) 48h Daphnia	8.5	2.2	6.8	196

Vinyl chloride is susceptible to evaporation when it is present in aqueous media, meaning the water solubility is very hard to determine accurately, thus it is possible to find values for vinyl chloride solubility that ranges from 1100-8800 mg/kg. Vinyl chloride is less likely to stay in the groundwater and soil compared to TCE, PCE and cis-DCE. The increased water solubility compared to TCE and PCE also enables it to have much higher mobility in the groundwater [29].

Hydrolysis and dehydrogenation should be avoided for chlorinated solvents, as they are unable to fully degrade the solvent, which means an increased amount of cis-DCE and VC, thus increasing the long-term toxicity. Under heavily reducing conditions it is possible for reductive dechlorination to occur, which can be catalyzed by reactive metals in both organic- and inorganic compounds, of which inorganic compounds can commonly be found in the soil matrix [26]. The use of H_2/O_2 mixed redox catalytic systems for full degradation of PCE has been detailed by S. Gao et al., with successful field results [35].

Different advanced redox processes have been applied for the remediation of chlorinated solvents, with most focusing on the degradation of TCE and PCE, however if the natural biodegradation is incomplete, the main contaminant is likely to be VC [25].

Typically, vinyl chloride is not the main pollutant in groundwater systems, with it primarily being present as a degradation product from incomplete degradation of TCE or PCE. Thus, literature on degradation of vinyl chloride in an aqueous media is limited. Generally, when working with ground water contamination, either containment, in-situ treatment or pump and treat methods are applied. In pump and treat, different treatment train components are used depending on what the specific contamination is [36]. Air strippers, granular activated carbon (GAC) filters, ion exchange and chemical treatments are often applied. Less commonly used is flocculation and filtration, which are commonly used in the wastewater treatment trains [37]. Due to the low K_{ow} and K_{oc} of vinyl chloride, it can be expected that the efficiency of GAC filters is likely to be low [38]. The use of air stripping could work, but there might be issues with storing the vinyl chloride. Thus, other methods of degradation, such as electrochemical oxidation should be investigated as possible treatment methods.

2.3 Electrochemical oxidation

Electrochemistry studies chemical reactions involving electron transfer, with oxidation as electron loss and reduction as electron gain. Redox reactants are separated, and the electrons produced flow through an external circuit to create an electric current. This current can be used as an energy source, and the reaction rate is inversely proportional to the current. The free energy change is inversely proportional to the cell voltage [39].

Advanced oxidation processes (AOPs), which are based on the generation of diverse reactive oxygen species (ROS), such as sulfate- or hydroxyl radical, have recently been shown to be effective methods for removing persistent contaminants from water [40]. These techniques are known as electrochemical advanced oxidation processes when AOPs are paired with electrochemistry (EAOPs). These technologies rely on the electro generation of hydroxyl radicals. EAOPs can be effectively applied to contaminated solutions with chemical oxygen demands (COD) ranging from 0.1 to 100 g/L [41].

Electrochemical oxidation uses an electric current or potential difference between two electrodes to create hydroxyl radicals or other oxidizing species, depending on the anode material and electrolyte [42]. The process can be direct or indirect, seen in figure 5, where direct oxidation refers to oxidation or reduction on the electrode surface and indirect oxidation refers to oxidation by ROS [43].

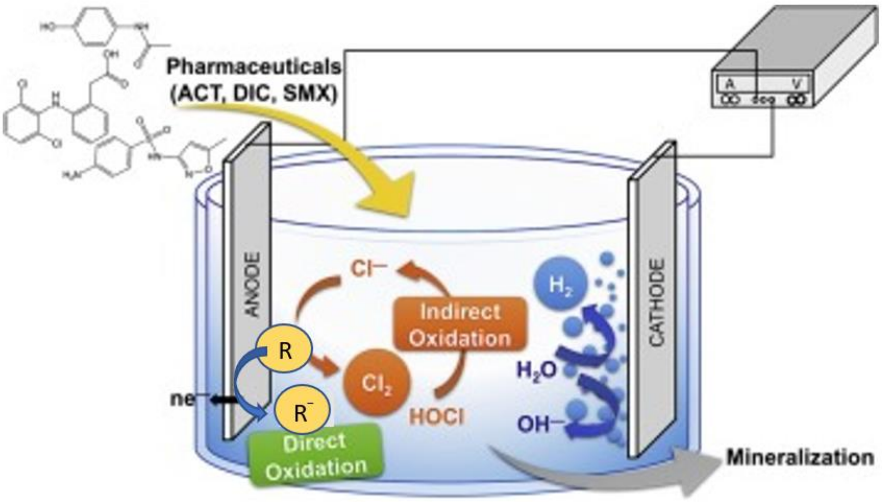


Figure 5 - Direct and indirect oxidation [44]

Without any other molecules present than the removed electron, contaminants are oxidized after adhering to the anode surface in a process of direct electrolysis, creating an adsorbed organic radical.

Anodic oxidation has various advantages, including the elimination of the need for chemicals and the generation of fewer secondary pollutants [44]. Electrochemical mineralization is a process that uses electrical energy to transfer oxygen from water molecules to the organic pollutant, resulting in the complete degradation of the organic compound into carbon dioxide, water, and inorganic minerals. This process is called electrochemical oxygen transfer reaction (EOTR). In some cases, fully mineralizing pollutants may not be the most effective treatment strategy, as it could require excessive energy to break down harmless short-length oxidation products, such as carboxylic acids [39].

Electrochemical oxidation (EO) technology does not involve the use of chemicals. As the electron is considered a safe, clean, and highly effective reagent, the oxidation of organic pollutants merely necessitates electrical energy. EO can treat a wide range of contaminants and handle volumes ranging from microliters to millions of liters, without being particularly selective. Operating parameters can be tailored to minimize power loss [39].

The problem with anodic electrolysis of organics at a fixed potential below oxygen evolution is a loss of catalytic activity due to the creation of a polymer film on the anode surface (poisoning). The extent of deactivation depends on the anode's adsorption characteristics, organic molecule concentration, and composition. Poorly adsorbing anodes show less poisoning, but high concentrations of organics and aromatic compounds such as phenol, chlorophenols, nitrophenols, and aniline make it worse. Poisonous compounds can only be oxidized at high anode potentials with simultaneous oxygen evolution, allowing anode surface regeneration during oxidation [45]. By performing oxidation in the area of water outflow, organics can be oxidized electrochemically on the anode surface by EOTR or by indirect electrolysis, in which redox reagents are electrochemically generated in-situ in solution as a chemical reactant to oxidize the organics [39]. Panizza et al. [46] discovered that the polymetric film that causes electrode fouling cannot be removed using organic solvents or polarization in the potential area of water discharge to revive a $TiRuSnO_2$ electrode. However, the activity of the PBO_2 and BDD (boron-doped diamond) electrodes can be restored by anodic polarization in the potential zone of water discharge, because using these electrodes causes the generation of hydroxyl radicals, which oxidize the polymeric coating on the surface.

2.3.1 Reactions of EOTR

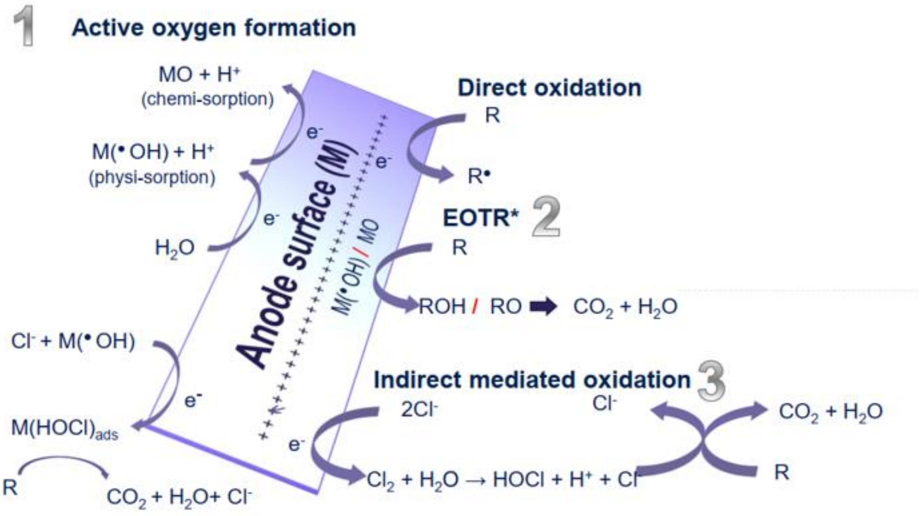


Figure 6 - Scheme of EO of organics by EOTR [47]

The EOTR reaction chain, Figure 6, begins with the discharge of water molecules, in acid or alkali solution, at the anode which forms a hydroxyl radical, seen in equation 1, where MO_x represents a metal oxide anode [39], [45].

$$MO_x + H_2O \rightarrow MO_x(\cdot OH) + H^+ + e^- \tag{1}$$

The adsorbed hydroxyl radicals may interact with the oxygen already present at the anode, with oxygen potentially transitioning from the adsorbed hydroxyl radical to the oxide anode's lattice, generating the so-called higher oxide, as seen in equation 2 [39], [45]:

$$MO_x(\cdot OH) \rightarrow MO_{x+1} + H^+ + e^- \tag{2}$$

To selectively oxidize or convert organic compounds, an effective anode must have a high rate of oxygen transition into the oxide lattice (equation 2), exceeding the rate of hydroxyl radical formation (equation 1). This requires a low concentration of active sites on the anode surface and a high concentration of "oxygen vacancies" within the oxide lattice. On the other hand, for the full mineralization of organic compounds, the anode surface should have a high concentration of hydroxyl radicals. This can be achieved by ensuring a high rate of hydroxyl radical formation, with an effective anode possessing a significant number of active sites for hydroxyl radical adsorption and a low concentration of "oxygen vacancies" within the oxide lattice [45].

Active anodes, like ruthenium-titanium, iridium dioxide and ruthenium dioxide, promote partial oxidation reaction because they have a low oxygen evolution overpotential, which results in the formation of intermediate oxidation products. Overpotential refers to the discrepancy between the potential required for an electrolytic reaction to occur experimentally and the potential predicted by thermodynamics. Non-active anodes, like antimony-doped tin oxide, lead dioxide, or boron-doped diamond (BDD), have a higher oxidation power due to their ability to promote complete oxidation reactions. These anodes can directly oxidize organic compounds to carbon dioxide and water, without producing intermediate oxidation products [39].

Active electrodes have a higher oxidation state on the surface and can interact more with the hydroxyl radical that is adsorbed at the surface by further oxidation, which forms higher oxides, as seen in equation 3. MO_x/MO_{x+1} is demoted chemisorbed active oxygen and operates as a mediator in the partial oxidation or conversion of organics on active anodes [39], [45].

$$R + MO_{x+1} \rightarrow RO + MO_x \tag{3}$$

Non-active anodes are said to be a weak electrode, as the interaction of hydroxyl radicals produces physisorbed (adsorption by van der Waals force) active oxygen, which can aid in the full mineralization of organics to carbon dioxide, as seen in equation 4 [39], [45].

$$R + MO_x(\cdot OH) \rightarrow MO_x + CO_2 + H_2O + H^+ + e^- \tag{4}$$

Both physisorbed and chemisorbed active oxygen undergo a competitive oxygen evolution side reaction, producing dioxygen, which results in lower anodic process efficiency and energy loss, as seen in equation 5 and equation 6 respectively [39], [45].

$$MO_x(\cdot OH) \rightarrow \frac{1}{2}O_2 + H^+ + e^- + MO_x \tag{5}$$

$$MO_{x+1} \rightarrow MO_x + \frac{1}{2}O_2 \tag{6}$$

Pollutants are oxidized in the bulk of the solution by oxidants electrochemically produced on the anode in indirect electrolysis, seen in figure 6. The most commonly used oxidant for wastewater treatment is active chlorine, produced from chloride in the solution in forms like gaseous chlorine, hypochlorous acid or hypochlorite ions depending on pH, by the reactions seen in equations 7-9 [48].

$$2Cl^- \rightarrow Cl_2 + 2e^- \tag{7}$$

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-, \quad K = 4.4 \cdot 10^4\ (25°C) \tag{8}$$

$$HOCl \rightleftharpoons H^+ + OCl^-, \qquad pK_a = 7.4\ (25°C) \tag{9}$$

Table 3 shows a direct relationship between the anode's oxidation potential (which represents the initiation potential for oxygen evolution) and the overpotential for oxygen evolution, as well as the adsorption enthalpy of hydroxyl radicals on the anode's surface. In other words, the higher the O_2 overvoltage for a particular anode material, the greater its oxidation capacity. Meaning that active anodes may be preferred in situations where partial oxidation products are desired, while non-active anodes may be preferred when complete oxidation is desired [49].

Table 3 - Oxidation power of different electrode materials [49]

Electrode material	Oxidation potential (V)	Overpotential O_2 evolution (V)	Adsorption enthalpy of $MO_x(\cdot OH)$	Oxidation power of the anode
RuO_2-TiO_2	1.4-1.7	0.18	Chemisorption of OH radical ↑ Physisorption of OH radical	↓
IrO_2-Ta_2O_5 (DSA)	1.5-1.8	0.25		
Ti/Pt	1.7-1.9	0.3		
Ti/PbO_2	1.8-2.0	0.5		
Ti/SnO_2-Sb_2O_5	1.9-2.2	0.7		
p-Si/BDD	2.2-2.6	1.3		

The cathode is significant in water treatment as it can directly reduce pollutants or generate H_2 through cathodic reactions. The cathode material is also crucial in promoting mediated decontamination through cathodic H_2O_2 electro generation via oxygen reduction reactions in both acidic (equation 10) and alkaline (equation 11) media [48].

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2 \tag{10}$$

$$O_2 + H_2O + 2e^- \rightarrow HO_2^- + OH^- \tag{11}$$

Performing anode oxidation with H_2O_2 at an acidic pH and in the presence of iron ions (either added or pre-existing in the effluent) leads to EF technology through Fenton's reaction (equation 12) occurring in the solution bulk and generating homogeneous ·OH [48].

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \cdot OH + OH^- \tag{12}$$

2.3.2 Indicators and Kinetics

The purpose of establishing indicators is to optimize operating parameters. Current efficiency and specific energy consumption will be explained [39].

Current efficiency (CE) measures the portion of the charge used to oxidize a compound compared to the total charge transmitted during electrolysis. It helps determine whether all electrons in the circuit come from targeted organic oxidation or if there are side reactions. CE can be measured as instantaneous current efficiency (ICE), as seen in equation 13, and as general current efficiency (GCE), as seen in equation 14 [39]. GCE represents an average value of the current efficiency by taking COD between t equal to 0 and t. ICE represents the amount of current applied and the amount necessary for the reaction [39], [50].

$$ICE = \frac{COD_t - COD_{t+\Delta t}}{8I\Delta t} FV \tag{13}$$

$$GCE = \frac{COD_0 - COD_t}{8 \cdot I \cdot t} \cdot F \cdot V \tag{14}$$

Where: I (A) is the current intensity, F is the Faraday`s constant of 96.485 C/mol t (s) is time, and V (L) is the electrolyte volume [39].

Energy consumption, E_{sp}, is a measure of the energy efficiency of electrochemical oxidation, which is the amount of energy consumed in kWh for the removal of 1 kg of COD. This value is calculated based on the average cell voltage, U(V), that is required to achieve the desired current intensity, as seen in equation 15 [39].

$$E_{sp} = \frac{tUI}{V\Delta COD} \tag{15}$$

Where t (h) is the time of electrolysis, I (A) is the current intensity, V (L) is the volume, and ΔCOD is the change in COD.

The kinetics of an electrochemical process depend on the mass transfer and electron transfer kinetics. Figure 7 shows electrochemical reduction as a 3-step process. First the oxidized species is brought to the surface of the electrode (mass transport) after which a reduction will occur (electron transfer), following with the reduced species returning to the bulk (mass transport). The same kinetics applies to electrochemical oxidation [47].

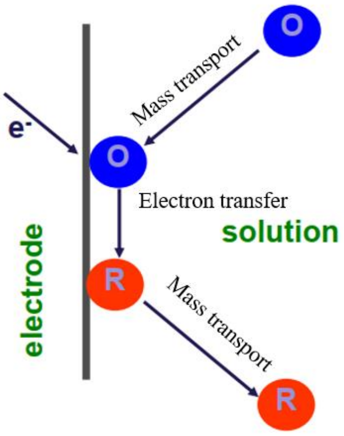


Figure 7 - Mass transport and electron transfer [47]

The current efficiency of organic mineralization is considered to take only two parallel reactions into account: the main EOTR reaction (equation 16) and the side reaction of oxygen evolution (equation 17), where hydroxyl radicals act as intermediates in both instances [39].

$$xBDD(\cdot OH) + R \rightarrow xBDD + mineralization\, products + yH^{+} + ye^{-} \tag{16}$$

$$BDD(\cdot OH) \rightarrow BDD + \frac{1}{2}O_2 + H^{+} + e^{-} \tag{17}$$

Because of these initial assumptions the indirect oxidation is not considered. Additional assumptions are the negligible adsorption of organic compounds at the electrode surface, the constant value of the diffusion coefficient, and that the rate of mineralization is independent of the chemical nature of the organics. Following these assumptions the limiting current density (i_{lim} (A/m^2)) is given by equation 18 [39].

$$i_{\text{lim}} = nFk_mC_{org} \tag{18}$$

Where n is the number of electrons that are involved in the mineralization, F is the Faraday constant, k_m (m/s) is the mass transport coefficient and C_{org} is the concentration (mol/m^3)

If the mineralization of the generic organic compound is compared using COD (mol O_2/m^3) it is possible to obtain equation 19 [39].

$$i_{lim}(t) = 4Fk_mCOD(t) \tag{19}$$

Where 4 represents the exchanged electrons per mole of O_2 needed to oxidize the organic compounds [39].

Kapalka et al. [49] identified 2 different operating regimes under galvanostatic conditions, based on the applied current density. The expressions are based on a specified electrolysis process characteristic parameter α, which is the ratio between the applied and the limiting current.

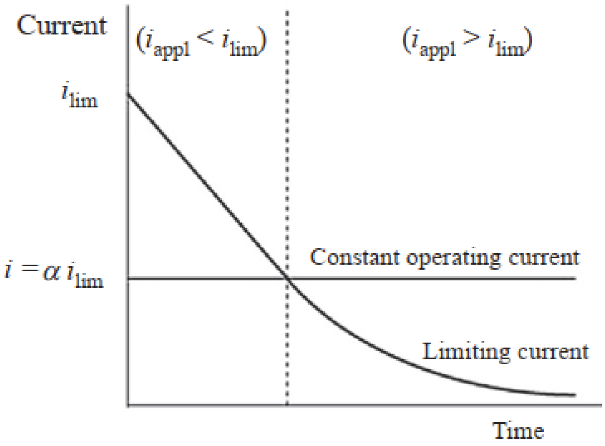


Figure 8 - Current-time curve [49]

Looking at figure 8 when ($i_{\text{appl}} < i_{\text{lim}}$) the current controls the electrolysis process, leading to the formation of organic intermediates during oxidation. The ICE is 100%, and COD decreases linearly with time. This behavior continues until a critical point, t_{cr}, is reached, which can be seen in equation 20 [49].

$$t_{cr} = \frac{1-\alpha}{\alpha} \cdot \frac{V_r}{A \cdot k_m} \tag{20}$$

Where A is the anode surface (m^2) and V_r is the reservoir volume (m^3). α is the characteristic parameter and is the ratio of the applied and the limiting current given by equation 21. Where A is the anode surface (m^2) and V_r is the reservoir volume (m^3). α is a characteristic parameter and is the ratio of the applied and the limiting current given by equation 21 [49].

$$\alpha = \frac{I_{applied}}{I_{\text{lim}}^{0}} \tag{21}$$

Looking at figure 8 when ($i_{\text{apply}} > i_{\text{lim}}$), mass transport controls the electrolysis, causing complete mineralization of organic compounds to CO_2. Secondary reactions, including oxygen evolution start, leading to reduced current efficiency. Consequently, the ICE falls below 100%, while COD removal decreases exponentially [49].

2.3.3 Electrochemical oxidation modelling

Kapalka et. al presents a single parameter model, that can describe the behavior of the EOTR in an electrochemical cell, utilizing the mass transfer coefficient [49]. The mass transfer coefficient is used to find the limiting current and critical time as seen in equation 19 and 20. Due to the different regimes, two functions are used to determine the rate constant, one for the current limited (equation 22), and one for the mass transfer limited (equation 23).

$$r_{EOTR,current\ lim} = COD_0^{\left(1-\frac{A\cdot k_m}{V_r}\cdot t\right)} \tag{22}$$

$$r_{EOTR,mass\ lim} = \alpha \cdot COD_0 \cdot e^{\left(-\frac{A\cdot k_m}{V_r}\cdot t+\frac{1-\alpha}{\alpha}\right)} \tag{23}$$

The COD_0 is the initial COD concentration (mol O_2/m^3). This model can only predict the direct EOTR, and is likely to deviate from the experimental results, due to the lack of evaporation and indirect oxidation. The evaporation term can be expected to be a first order reaction, and thus the two rate equations can be combined to equation 24.

$$r_{EOTR+evaporation} = \alpha COD_0 \cdot e^{\left(-\frac{A\cdot k_m}{V_r}-k_{evap}\right)\cdot t+\frac{1-\alpha}{\alpha}\left(1+\frac{k_{evap}\cdot V_r}{A\cdot k_m}\right)} \tag{24}$$

With k_{evap} being the rate constant for the evaporation, which needs to be determined experimentally, based off an evaporation study and first order rate constant determination.

Muff et al. proposed an expanded model with an added first order chemical oxidation contribution for the mass transfer limited regime seen in equation 25 [51].

$$r_{EOTR+indirect} = \alpha COD_0 \cdot e^{\left(-\frac{A\cdot k_m}{V_r}-k_{chem}\right)\cdot t+\frac{1-\alpha}{\alpha}\left(1+\frac{k_{chem}\cdot V_r}{A\cdot k_m}\right)} \tag{25}$$

k_{chem} being the rate constant for the indirect bulk chemical oxidation. The chemical rate constant is then found by fitting the model to the experimental data with a least squares regression using a fitting parameter S, as seen in equation 26.

$$S = \sum_{i=0}^{n}\left(COD_{i,experimental} - COD_{i,combination}\right)^2 \tag{26}$$

A combined EOTR+indirect+evaporation model can then also be constructed, as seen in equation 27, by adding the evaporation term to the EOTR+indirect model. This however will predict a different rate constant for the chemical oxidation.

$$r_{EOTR+indirect+evapo} = \alpha COD_0 \cdot e^{\left(-\frac{A\cdot k_m}{V_r}-k_{chem}-k_{evap}\right)\cdot t+\frac{1-\alpha}{\alpha}\left(1+\frac{k_{chem}\cdot V_r}{A\cdot k_m}+\frac{k_{evap}\cdot V_r}{A\cdot k_m}\right)} \tag{27}$$

2.3.4 Reactor design

There are several important factors that must be considered when designing an electrochemical process; anode and cathode material, use of a catalyst, shape of the electrode material (rod, mesh, foam) where for example foams have higher surface area. The current intensity applied is important as well as the order of the redox zones in flow-through reactors which is determined by the sequencing of the electrodes. The composition of organic pollutants must be considered as well as pH and oxygen which are all case-sensitive parameters. Electroactive species in alkaline medium can be more easily oxidized than that in acid medium. The oxidation of water to oxygen is commonly regarded as an undesirable side-reaction during the removal of contaminants because it significantly reduces process efficiency [52].

Table 4 shows important factors which determine electrolysis performance.

Table 4 - Factors determining electrolysis performance [52]

Factor	**Remarks**
Electrode potential and current density	Control the reactivity and reaction rates, determining the efficiency of the process
Potential and current distribution	Determine the spatial distribution of the reactant consumption and hence should be as homogeneous as possible
Mass transport regime	High mass transport coefficient leads to a greater uniformity of pollutant concentration in the reaction layer near the electrode surface, usually resulting in higher efficiency
Electrochemical cell design	Cell dimensions, the presence or absence of a separator, the geometry of the electrodes, and the interelectrode distance as well as the operation mode (batch or flow) are some of the crucial parameters that affect the figures of merit of electrochemical treatment
Electrolysis medium	Supporting electrolyte nature and concentration, pH, temperature, and matrix composition (i.e., presence of radical scavengers, chelating substances, and natural organic matter)
Electrode materials	Electrode material should be cheap, exhibiting physicochemical and mechanical stability in the electrolysis medium and high activity toward oxidation of organics and low activity toward side reactions (e.g., O_2 evolution)
Current input	Continuous, pulsed, or alternating current to favor current and decontamination efficiency

Electrode material:

The electrode must have the following characteristics: high physical and chemical stability, resistance to erosion, corrosion, and the formation of passive layers, adequate electrical conductivity, high catalytic activity and selectivity; as well as low cost and durability (i.e., long service life) [52]. Table 5 shows anode while table 6 shows cathode materials with their advantages and disadvantages.

Dimensionally stable anodes (DSA), Tin(IV)oxide (SnO_2), Lead dioxide (PbO_2), graphite, and BDD are chemically resistant and commonly used in wastewater treatment. Carbonaceous electrodes are popular for organic removal in 3D electrochemical reactors due to their low cost and high surface area. However, they have limited endurance at highly anodic potentials due to corrosion. Because of the substantial secondary contamination, the formation of extremely poisonous Pb^{2+} is a worry in the case of PbO_2 anodes. Nonetheless, Ti/PbO_2 has proven to be reasonably stable, however its performance and stability are dependent on the technique of manufacture. Ti/SnO_2 has been claimed to have a limited service life due to similar characteristics. BDD is the most efficient anode material for degrading refractory contaminants, generating a substantial amount of reactive •OH and leading to efficient water treatment [52].

DSA or mixed metal oxide (MMO) are classified as active and are resistant to corrosion during electrochemical processes. Active electrodes like DSA, IrO_2 or RuO_2 facilitate organic oxidation through the creation of a metal oxide (MO_{x+1}) with a high state of oxidation, which leads to selective oxidation. In contrast, non-active anodes like BDD directly oxidize organic molecules through adsorbed ·OH, allowing for full mineralization and making them ideal for wastewater treatment. These anodes can withstand high voltages before electrochemical reactions begin. However, BDD's high cost and mechanical resistance limit its large-scale use [39], [52], [53].

Bente Højlund Hyldegaard [54] found that when working in-situ, that due to the release of ferrous ions instead of oxygen, which provides strongly reducing circumstances, Fe anodes are best suited for the removal of chlorinated ethenes, attaining up to 99% trichloroethylene (TCE) elimination. Because oxygen's reduction potential (1.229 V vs. SHE) is greater than TCE's (0.42 V vs. SHE from TCE to cis-DCE), oxygen is reduced at the cathode rather than TCE. However, due to blockage of pores in porous matrices, Fe complex formation may pose a difficulty to the application of Fe anodes.

Table 5 - Different anode types with advantages and disadvantages (VOC - volatile organic compounds) [54]

Electrode material	Advantages	Disadvantages
Cast iron, Fe	- Instead of O_2, ferrous iron is released (corrosion); minimal VOC stripping - Reduction environment suitable for fast reduction is maintained - Easily acquired and in many different purities and costs	- Possible clogging and electrode coverage because of Fe complexes forming - Because of the low H+ production, elevated pH degrades the electrochemical zone. - Possible release of impurities embedded in Fe
Mixed metal oxide, MMO (DSA)	- Retains its structure and can be reused - dimensionally stable - Maintains the pH and oxidation-reduction potential of the water	- VOC stripping can increase due to low O_2 overpotential - generates oxidising conditions - The oxidation of chlorinated ethenes competes with O_2 evolution.
Graphite	- Generates hydroxyl radicals because of slow decomposition of H_2O_2	- Oxidizes chloride to chlorine gas
BDD	- Has affinity to produce hydroxyl radicals	- Removal of organics is in competition with hydroxyl radicals transformation to O_2

When choosing a cathode material, it is important to know whether polarity reversal is going to be applied [55]. Polarity reversal is a process in which the polarity of the electrodes in an electrochemical system is periodically reversed, such that the anode becomes the cathode, and the cathode becomes the anode. This technique is commonly used in electrochemical wastewater treatment processes to enhance the efficiency of the treatment process and reduce the buildup of scale and fouling on the electrodes. Polarity reversal can help to prevent the accumulation of reaction products and electrode surface passivation, by alternately generating and reversing the charge on the electrodes, which promotes the removal of contaminants and helps to maintain the activity of the electrodes over time [56].

Table 6 - Different cathode types with advantages and disadvantages [54]

Cathode material	Advantages	Disadvantages
Iron, Fe	- Better at removing chlorinated ethene than MMO - Pb coated Fe is better than coated Ni, Al, C, Cu - low cost	- Slower hydrodechlorination than noble metals; high H_2 overpotential
Mixed metal oxide, MMO	- Low cost	- Interacts with H_2 on its surface to create oxides, resulting in less H_2 for hydrodechlorination.
Carbon, C	- High porosity and surface area - Better than Fe, Cu, Al in chlorinated ethane removal	- Not suitable in the field - fragile
Graphite	- Produces H_2O_2 and hydroxyl radical - Safe and cheap material	- Limited activity so slow formation of H_2
Copper, Cu	- Better at removing chlorinated ethane than Fe and Al - Low cost	- Includes precipitation and electrode coverage - Slower hydrodechlorination because of higher H_2 evolution overpotential than noble metals
Nickel, Ni	- Lower H_2 overpotential which supports higher hydrodechlorination than, C, Cu, Al and Fe	- Accumulation of H_2 bubbles on the surface

Electrode spacing, sequence and current density:

Increasing the electrode spacing raises electrical resistance and cell voltage, adversely affecting the removal. In general, electrode sequencing impacts species distribution, which can affect oxidation rate and water quality. Proper sequencing can ensure sufficient oxidizing species for contaminant reaction while minimizing consumption from reduction reactions [57].

Increasing current density generally leads to greater pollutant removal in the low current density range, where mass transport of organics to the anode surface does not limit the EO process. In the high current density range, where the process is mass transport controlled, increasing current density enhances O_2 evolution but decreases current efficiency (CE) and increases energy costs. The decrease in CE is due to less of the overall energy being used to degrade organics. The efficiency of the process is affected by the variation of current density, but also by the production of strong oxidants at the anode surface which is controlled by other operating conditions and anode properties [52].

2.3.5 Electrochemically induced degradation of vinyl chloride

When chlorinated ethenes pass through electrochemical zones, they undergo both reduction and oxidation processes. These processes involve complex mechanisms, such as direct and indirect abiotic reduction and oxidation, which can lead to the formation of various transformation products [52]. In addition to these processes, the presence of specific microbial degraders in the system can also stimulate biotic reduction and/or oxidation. Overall, the electrochemical treatment of chlorinated ethenes is a multi-step process that may involve a combination of abiotic and biotic reactions [54].

Abiotic reduction of chlorinated ethenes can occur directly when they receive electrons from the cathode surface or indirectly through hydrogen produced during water electrolysis. The use of metals with low H_2 overpotential, such as nickel or palladium, can enhance the process of indirect abiotic reduction. Factors such as cathode material and current intensity affect the degree of indirect reduction. Abiotic oxidation depends on low oxygen overpotential and stability [52], [54]. Figure 9 shows the dominant biotic reduction, abiotic reduction, and abiotic oxidation pathways for PCE, TCE, DCEs and VC. Thus, the pathways shown are the most likely to occur for each compound. Similarly, it is important to note that the different degradation methods have different underlying chemistries, which means there are likely different optimal conditions and reaction rates for each method and compound [54].

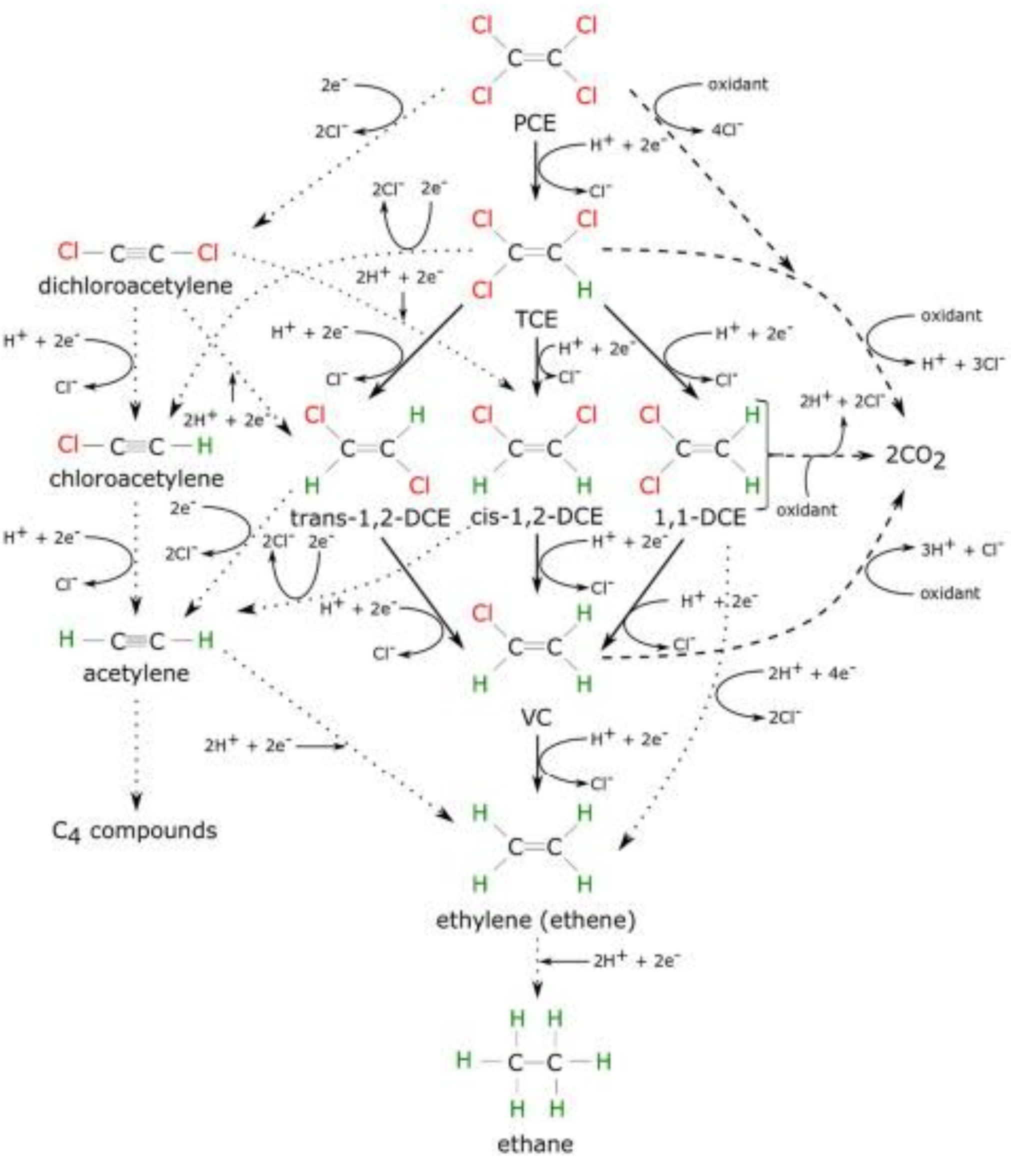


Figure 9 - Electrochemically induced degradation pathways for the chlorinated ethenes, biotic reduction (solid arrows), abiotic reduction (dotted arrows) and abiotic oxidation (dashed arrows) [54]

The standard electrode potentials in table 7 indicate the tendency of a reaction. Contaminants can be reduced at potentials lower than their own potential, like PCE transformed via hydrogenolysis at <0.592 V vs. SHE. Alternatively, oxidation can occur at potentials higher than the contaminant species, such as TCE undergoing abiotic oxidation at >0.540 V vs. SHE. Higher reaction potentials lead to greater energy yield, increasing the likelihood of the reaction [54].

Table 7 - reduction and oxidation potential for chlorinated ethane [54]

	Abiotic			**Biotic**	
Chlorinated ethane	Hydrogenolysis (V vs. SHE)	Elimination (V vs. SHE	Oxidation (V vs. SHE)	Hydrogenolysis (V vs. SHE)	Oxidation (V vs. SHE)
PCE	0.592	0.631		0.43	
TCE	0.509-0.530	0.599	0.540	0.42	
Cis-DCE	0.407	0.568		0.31	0.7
Trans-DCE	0.428	0.589			0.7
1,1-DCE	0.423				0.7
VC	0.481			0.38	0.5

Table 7 shows the reduction and oxidation potentials from which trends can be extrapolated:

1. The probability of abiotic reduction of chlorinated ethenes via elimination is higher than that of hydrogenolysis.
2. Abiotic reduction of PCE and TCE is more probable than that of the chlorinated intermediates.
3. Chlorinated intermediates are more susceptible to oxidation than reduction.
4. Abiotic reduction of chlorinated ethenes is more likely than biotic reduction, due to the lowered redox potential for these reactions.

The proposed pathways for VC degradation are a biotic reduction to ethylene or an abiotic oxidation to CO_2, thus a full mineralization. The abiotic reaction potential for VC is not specified, however a voltage above 1.0 V is for certain able to oxidize the VC, however it might also be close to the oxidation potential of the electrodes, reducing the efficiency of the degradation. This project centers around VC and employs a pump and treat approach for electrochemical oxidation. Given VC's highly volatile nature, there is a lack of research regarding pump and treat of VC as bringing it to the surface from the contaminated ground is dangerous, as well as inconsistent since the VC will evaporate quickly, affecting the validity of the results. All the research done on chlorinated solvents involves in-situ ways of treatment as well as focusing more on the PCE, TCE and cis-DCE instead of VC. Consequently, numerous unexplored elements will need to be considered and tested. The problem statement will delve into the key aspects that require attention.

3. Problem Statement

Production of vitamins and medicinal products at Grindstedværket from 1924 until the mid-1970s, has resulted in several contaminated sites in and around Grindsted, due to deposited solid and liquid waste from the production. The pollution on the factory site will be the focus of this project and stems from loss of raw materials and chemicals, and consists mainly of solvents, sulphonamides and barbiturates. This has resulted in a massive contamination of the upper groundwater reservoir at the factory site to approx. 80 meters depth.

Biodegradation of chlorinated ethenes is slow and often leads to accumulation of more harmful chlorinated intermediates. This is also the problem in Grindsted where vinyl chloride is spreading with the groundwater to Grindsted Å. Region of Southern Denmark is responsible for the management of the site and want to study if/how electrolytic treatment of the groundwater could degrade the vinyl chloride into nontoxic components. The goal of this work will therefore be to remove vinyl chloride from groundwater using electrolysis in a pump and treat system. This report will investigate this based on the following problem formulation:

"How efficient is electrolytic treatment of Vinyl Chloride contaminated groundwater?"

The problem formulation will be answered by carrying out experiments in a closed recirculated flow where the contaminated water from Grindsted is passed through a sandwich packed cell. This setup is used to study the influence of process parameters such as electrode materials, flowrate, applied current and modelling of the process efficiency. The investigation of the problem formulation was done based on the following objectives, answered through laboratory investigations:
Objectives:

- Establish a closed setup to be able to evaluate degradation vs stripping of vinyl chloride.
- Determine mass transfer coefficients at different flows.
- Study treatment with different electrode materials, currents, and flowrates.
- Model the performances and compare to experimental data.

The main goal of this problem formulation is to get knowledge of electrolysis of VC, before a pilot test will be performed by the Region of Southern Denmark in collaboration with AAU Esbjerg.

4. Project delineation

There are different contextual considerations to adapt to when working in a pump and treat system compared to an in-situ system. As the operational conditions are more controlled, the electrodes do not need to be as resilient to degradation, and thus the system can be optimized more heavily towards the degradation efficiency. There are numerous parameters that are likely to influence the efficiency of the system, such as the flowrate, applied current, electrode material, electrode spacing, and electrode sequencing. The general evaporation of vinyl chloride is likely to be quite high, which can cause uncertainty in the results of any experiments if not accounted for. Because of the high evaporation of vinyl chloride, an evaporation study was performed by the laboratory technicians at AAU to observe the evaporation of vinyl chloride in the electrochemical cell, as well as in storage. The system was closed for this study, however due to headspace in the reservoir, the vinyl chloride could continuously evaporate. Thus, any headspace should be avoided by overfilling the bottles. During the study 86% and 98% of vinyl chloride evaporated during 1 and 3 hours respectively. A half-life of approximately 20-30 min was calculated which is a value similar to the 26 and 27 min the government of Canada and New Jersey department of environmental protection estimated [58], [59]. It is important to be aware of the high volatility of vinyl chloride, which means different experimental precautions must be made.

Aside from the headspace the applied current is likely to increase the temperature of the sample, which would increase the rate of evaporation. Similarly, since the applied current will lead to a formation of hydrogen, oxygen and CO_2 gases, there will be an increased surface area in these gas bubbles as they move through the system. This would then allow for a higher rate of evaporation. Investigating the evaporation during operation is vital, as it is needed to be able to determine if the vinyl chloride is degrading or simply evaporating more when a current is applied.

As the collection and quantification of vinyl chloride is likely to be a significant part of the experimental work, several assumptions were made.

The following assumptions were made prior to experimentation:

- If the VC is not found in gases collected or in the solution, it is degraded, meaning the system is effectively closed.
- The difference in volume when collecting with a measuring cylinder compared to the gas bag is negligible. Different methods for collecting the gas have no significant difference in gas volume. This is important, due to the different methods being used for collecting the gas.

- The concentration of VC in the gas phase can be determined based on CO_2 in the air, assuming there is a concentration of 412 ppm CO_2 in the atmosphere [60].
- CO_2 and VC have the same response factor in the GC-MS.
- It is assumed that the gas production increases linearly with time.

5. Materials and methods

5.1 Electrochemical cells used

During this project two different cells from Electrocell (Denmark) were tested. The two cells are the micro flow cell and an electro MP cell. A picture of these cells can be seen in figure 10 and specification of the cells can be seen in table 8. During this project the micro flow cell will be referred to as the small cell, while the electro MP cell will be referred to as the big cell in the remainder of this report.

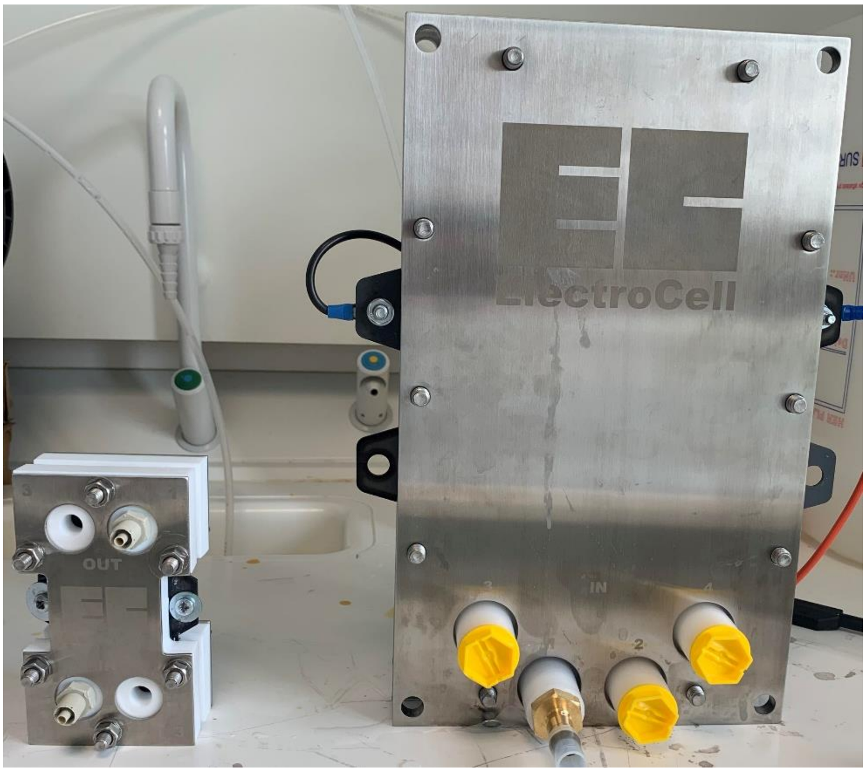


Figure 10 - Picture of the micro flow cell (left) and the electro MP cell (right)

Table 8 - Cell specifications

	Small cell	**Big cell**
Electrode area, min [m^2]	0.001	0.01
Electrode area, max [m^2]	0.001	0.2
Current density max [A/cm^2]	0.4	0.4
Electrode gab [mm]	4	8
Height [mm]	120	306
Width [mm]	70	182
Length [mm]	>33	>38
Electrolyte flow per frame [L/min]	0.18 - 1.5	1 - 4
Electrolyte volume per frame [L]	0.01	0.2
Flowrate in each cell [m/s]	0.05 - 0.4	0.03 - 0.12

During this project three different frames (3, 4 and 10 mm in width) for the small cell were used, to find the most comparable setting to the big cell, which will be used for pilot scale experiments. These frames will for the rest of this project be referred to as spacers 1, 2, and 3 respectively as seen in table 9.

Table 9 - Overview of different spacers used for the small cell

	Spacer 1	**Spacer 2**	**Spacer 3**
Width [mm]	3	4	10

The cathode and anode used were made of the same materials during all experiments. The electrode materials used were either DSA or BDD delivered by Electrocell, unfortunately no datasheet could be obtained for these electrode materials. A sketch of the cell can be seen in figure 11, where frame is also referred to as the spacer.

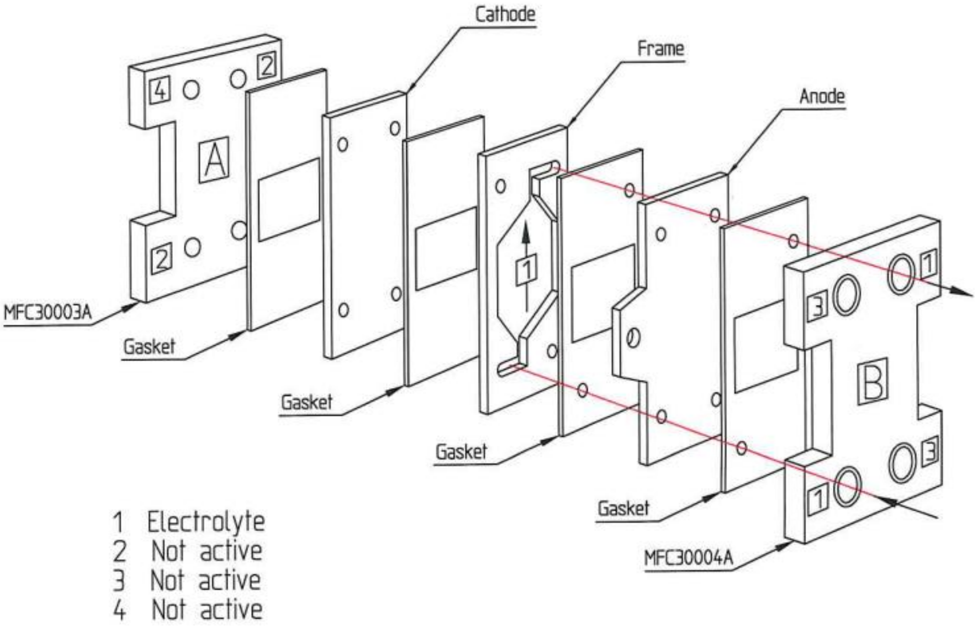


Figure 11 - Sketch of the cell

5.2 Ground water sampling and characteristics

All groundwater used in this project was collected from well 114.2567 in the contaminated area in Grindsted. The specific location of this well can be found in section 2.1. All samples were collected on 03/04/2023 by the laboratory technicians, by pumping the water up with a submersible pump into multiple brown 1 L bottle. To avoid headspace in the samples, the bottles were overfilled. After sampling the bottles were transported back to the laboratory and kept at 4°C.

Since the characteristics of the water can change from last time the waters were tested (2020), seen in table 1. A water sample was therefore sent to ALS for testing and can be seen in table 10.

Table 10 - Overview of chemical analysis results from well 114.2567. NVOC stands for "nonvolatile organic carbon"

Well nr./ Sample date	**114.2567** **11-03-2020**	**114.2567** **03-04-2023**
Depth (m)	8-10	8-10
Environmentally harmful substances (µg/L)		
Sulfanilic acid	65	130
Sulfamethazine	110	73
Sulfanilamide	37	8.3
Sulfamethiazole	32	6.5
Sulfathiazole	3.6	0.66
Sulfaguanidine	0.5	82
Meprobamate	61	110
Barbital	15	14
Amobarbital	43	69
PCE	48	2.2
TCE	22	0.89
cis-DCE	1400	120
VC	7100	930
Benzene	520	8.6
Toluene	5	0.19
Ethylbenzene	0.64	<0.020
Xylenes	2.3	2.2
Inorganic compounds (mg/L)		
Chloride	140	190
Nitrate	<0.10	<0.10
Sulfate	32	24
Dissolved iron	5.4	0.92
Ammonium	0.18	0.12
NVOC	4.9	4.4

Due to time limitation of this project, only the concentration of vinyl chloride obtained at the AAU Esbjerg laboratory will be shown in this report after treatment.

5.3 Determination of mass transfer coefficient

To be able to model the expected efficacy of the system, the mass transfer coefficient and limiting current must be determined. The method utilizes the limiting current and is centered on maximizing the rate of an electrochemical reaction until it is restricted by mass transport. This restriction is signified by a plateau in the current (referred to as the limiting current) when plotted against the applied potential. To determine the limiting current solutions of ferrocyanide ($Fe(CN)_6^{4-}$) and ferricyanide ($Fe(CN)_6^{3-}$) in 2:1 M ratio respectively, in a supporting electrolyte of sodium hydroxide

(NaOH) with a concentration of 0.5 M are made. The concentration of ferro/ferri cyanide was varied from 0 - 2.4 mM as well as the potential from -0.2 - 1 V using a potentiostat (µAUTOLAB Type 3). A blue cap flask with a tap containing the ferrocyanide and ferricyanide solution in sodium hydroxide was used, with increasing concentrations of ferrocyanide and ferricyanide added while constant stirring was applied. The flowrate was altered using a Watson Marlow qdos30 manual pump, with different flowrates tested. The pump and electrochemical cell with BDD electrodes were connected in a closed-loop system. The potentiostat connectors were connected to the cell to measure the limiting current using the NOVA program. The solution was left to stir for 5 minutes between each concentration increase, to ensure complete mixing. Different flowrates were tested to investigate if a linear correlation could be found. A sketch of the setup can be seen in figure 12.

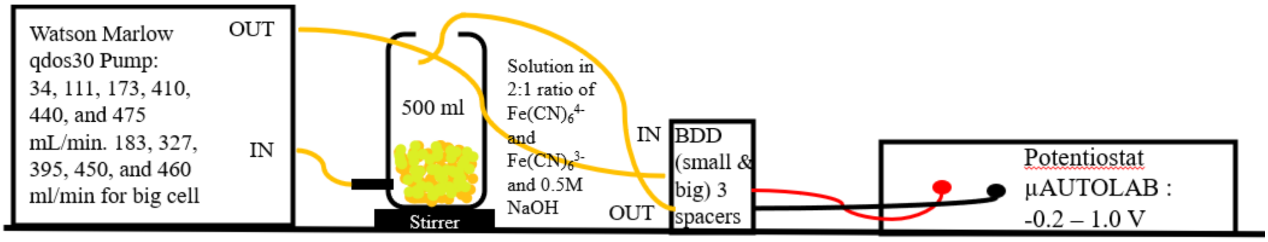


Figure 12 - Mass transfer coefficient determination

5.4 Analytical methods

In this section analytical methods performed on the water and gas phase will be described.

5.4.1 Water phase

Right after opening the brown bottle with contaminated water at 4 ℃, the initial concentration of VC was determined with GC-MS, by adding 12 mL of contaminated water to a closed test tube, as well as 1.2 mL of 0.1 M isobrom in pentane. The column used in the GC-MS is an Elite 5 (Crossbond 5% diphenyl- 95% dimethyl polysiloxane), which is a capillary column with a length of 30 meters, 0.25 mm inner diameter, and 0.25 µm film thickness. The initial temperature was 50°C for 2 minutes followed by a 45℃/min ramp up to 140℃. The quantification method developed before these experiments can be seen in appendix 4. This method was repeated right after the experiment to determine the concentration after treatment.

After reaching room temperature the conductivity was determined with a CDM92 conductivity meter. This was done by submersing the conductivity meter electrode in the water sample. Special attention must be taken so the electrode does not touch the container. The same procedure was performed after the experiment.

5.4.2 Vinyl chloride in the gas phase

The gas produced during the experiment was analyzed using GC-MS like the water phase. The same column was used with an initial temperature of 60°C for 1.5 minutes followed by a 20°C/min ramp up to 100°C. This was done by manually injecting 300 μL of collected gas with a syringe. Since no method was developed for quantification of vinyl chloride section 5.4.3 will explain how the concentration of vinyl chloride was determined.

5.4.3 Calculation of vinyl chloride in the gas phase

The following section will focus on explaining the calculations performed to obtain the concentration of VC in the gas phase. As explained in the problem delineation one of the assumptions made was that CO_2 in the atmosphere can be used to determine VC concentration. The concentration of the CO_2 in the atmosphere is approximately 412 ppm, and assuming the response of this in the GC-MS would be the same for 412 ppm of VC, allows for an estimation of the amount of moles present in the gas, based on the total volume of the gas produced.

Another assumption made was that the amount of produced gas increases linearly over time. The volume of the produced gas was measured using a measuring cylinder, which is explained in section 5.5.2. Based on the measurements at 30 minutes, the gas at a given time was estimated based on the assumption of a linear gas production. The total amount of moles in the produced gas were calculated using the ideal gas equation at 25℃ and 1 atm. Using GC-MS response for both CO_2 in the atmosphere and VC in the collected gas, the ppm of VC can be calculated with equation 28.

$$VC_{ppm} = \frac{VC_{response} \cdot CO_{2_{ppm}}}{CO_{2_{atmo,response}}} \tag{28}$$

After which the moles of VC can be calculated, based on the total amount of moles in the gas, seen in equation 29:

$$VC_{moles} = n_{gasbag} \cdot VC_{ppm} \tag{29}$$

5.5 Experimental plan and setup

The experiment plan was developed in a trial-and-error phase of the research project. A summary of the experiments performed can be seen in table 11.

The experiments were based on two different electrodes materials, BDD and DSA supplied by Electrocell. The degradation performance was investigated for dependence on flowrate and current. The current applied was either 0.1 or 0.5 A, while the flowrate was either 100 or 200 mL/min. The time was mainly kept constant at 30 min, but to model degradation over time with the best cell configuration, 5, 10, and 20 min were also investigated. Due to evaporation of VC, experiments with the cell turned off (0 A) were also performed at 5, 10, 20, and 30 min. In addition, one experiment was performed with nitrogen and heat to investigate if the current was degrading the VC or simply increasing the evaporation. The experiments were performed in a randomized order, when possible, but due to the trial-and-error approach this was not possible for all experiments.

Table 11 - Overview of the experiments performed, all experiments were performed in random order with at least 2 replicas. Blank experiments were done with BDD material in the cell, but with the cell turned off.

Electrode material	Flowrate (mL/min)	Time (min)	Current (A)
BDD	100	30	0.1
BDD	100	30	0.5
BDD	200	30	0.1
BDD	200	30	0.5
DSA	100	30	0.1
DSA	100	30	0.5
Blank	100	30	0
Blank	100	20	0
Blank	100	10	0
Blank	100	5	0
BDD	100	20	0.5
BDD	100	10	0.5
BDD	100	5	0.5
Blank + heat + N_2	100	30	0

The desired outcome of these experiments was to degrade VC in the water phase, but to test if VC is degraded or simply evaporating, the gas must also be analyzed. The explanation of the experiments will therefore be split into two sections, removal of vinyl chloride in the water phase and vinyl chloride stripping.

5.5.1 Removal of vinyl chloride in the water phase

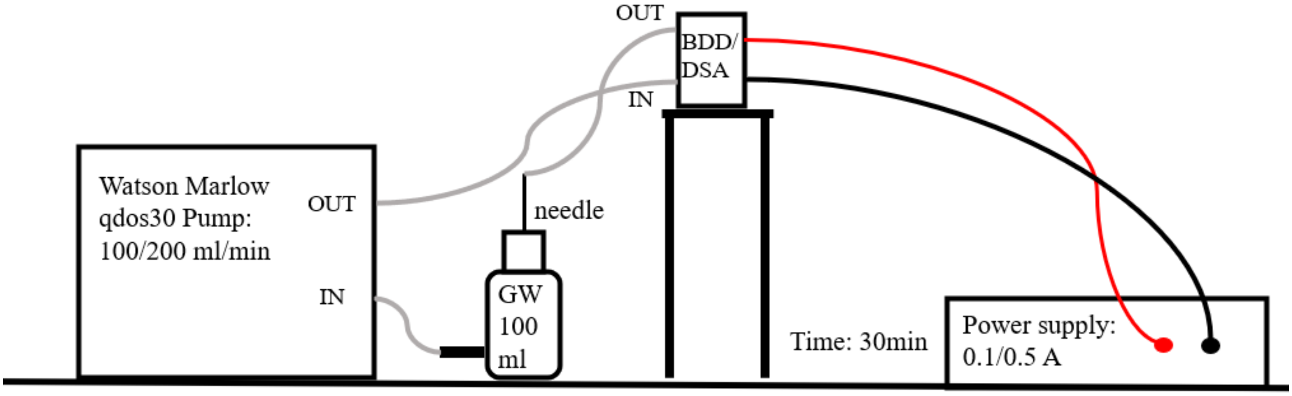


Figure 13 - General experimental set up, GW = Grindsted water

The main experiment of the project was regarding the electrochemical oxidation of vinyl chloride from a contaminated site. The experimental set up, seen in figure 13, consisted of a Watson Marlow qdos30 pump with a flowrate of 100 or 200 mL/min connected with low density polyethylene tubes, a Power Supply EA-PS 2342-06 B which provided a current of 0.1 or 0.5 A, the electrochemical cell with either BDD- or DSA electrodes, and a 100 mL flask which contained contaminated water at 4 ℃. The system was closed to ensure all VC passed through the cell. After measuring the starting concentration of vinyl chloride, the water is poured into a 100 mL flask, and some water is pumped through the system. The 100 mL flask was then filled almost to the top and closed with a cap. The cap is then punctured with a needle, which recirculated the water. The pump and power supply are started, and the experiment is run for 30 minutes, after which another sample is taken to the GC-MS and conductivity is measured.

To determine if the decrease in VC concentration in the water was due to the applied current or increased evaporation in the system, nitrogen gas and heating was applied for one experiment. The nitrogen gas and heat (30 ℃) were applied while the pump was running at a flowrate of 100 mL/min. If the vinyl chloride concentration is higher compared to when a current is applied, it can be qualitatively determined that the applied current is degrading the vinyl chloride.

5.5.2 Estimating stripping of vinyl chloride

As mentioned before VC evaporates quickly. The first idea was therefore to use a Dräger short term vinyl chloride tubes which would indicate the concentration of VC in the gas phase. Unfortunately, that was unsuccessful, and a gas bag (SKC FlexFoil sample bag) was used, figure 14. The gas bag was able to collect the VC from the gas phase and a concentration could be determined using GC-MS analysis of the gas.

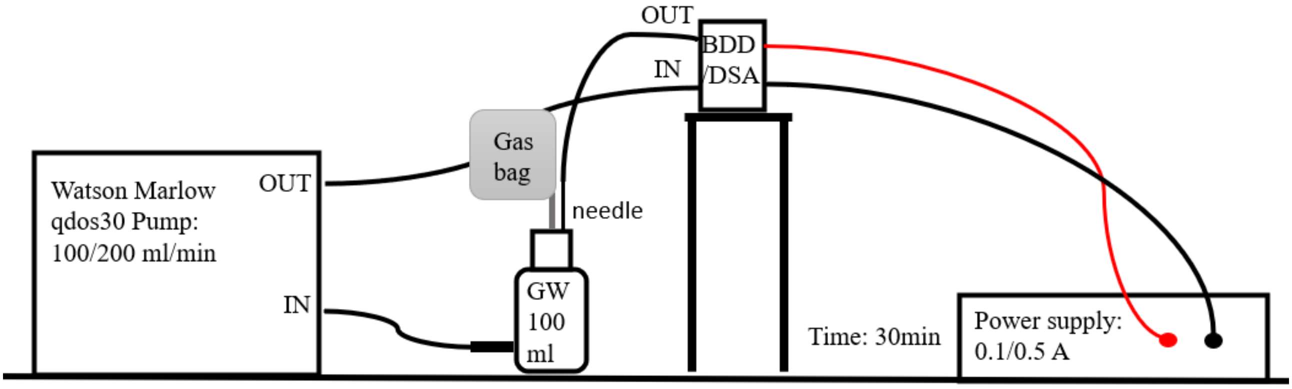


Figure 14 - Experimental set up using a gas bag, GW = Grindsted water

However, to determine the amount of gas produced, a measuring cylinder as seen on figure 15 was employed. Using this technique, the amount of gas produced during the electrolysis can be obtained and a gas sample can be taken and analyzed by the GC-MS. This experiment was performed with contaminated water as well as with Na_2SO_4, to estimate the amount of gas demineralized water produces compared to contaminated water. Due to the low conductivity of demineralized water, Na_2SO_4 was added to the system to determine the amount of gas produced with the given flowrate and current, without producing CO_2 as would be the case when using contaminated water.

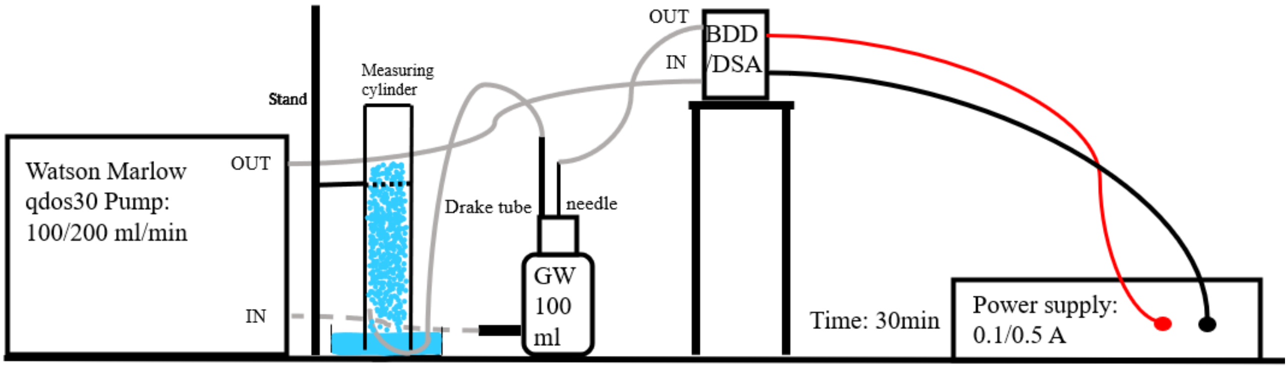


Figure 15 - Experimental set up with a measuring cylinder used to measure amount of gas produced, GW = Grindsted water

6. Results and data analysis

During this section, the effect of varying current and flowrate on the degradation time of vinyl chloride is investigated. This will be used to build a model to predict performance in the field. Since vinyl chloride is a volatile compound, the gas phase will also be analyzed to determine if vinyl chloride is degraded by the cell or if the cell only enhances evaporation. The vinyl chloride results will therefore be split into two parts: vinyl chloride in the water phase and stripping of vinyl chloride. All experiments are performed on Grindsted well water, unless specified otherwise.

6.1 Mass transfer coefficients results

During this section the effect of varying flowrate and spacers on the mass transfer coefficient for the small cell, will be investigated. These results will be compared to a bigger cell, which is intended to be used in the field. Therefore, this section aims to develop an understanding of which cell configuration of the small cell is most comparable to the bigger cell, as well as trying to predict the mass transfer coefficient at different flows, so every flowrate does not have to be tested in the field.

Determination of the mass transfer coefficient at flowrate of 34, 111, and 173 mL/min, can be seen in figure 16, 17, and 18. On the left the applied potential from -0.2-1.0 V can be seen vs the current in ampere colored by concentration of ferrocyanide from 0.4-2.4 mM. The right plot shows the limiting current in ampere as a function of concentration of ferrocyanide in mM. The limiting current is determined by taking the top of the peak for each concentration as seen in the left plot, indicated with dotted lines. The values from the left plot can then be used together with concentration of ferrocyanide to get the right plot, with the slope being the mass transfer coefficient.

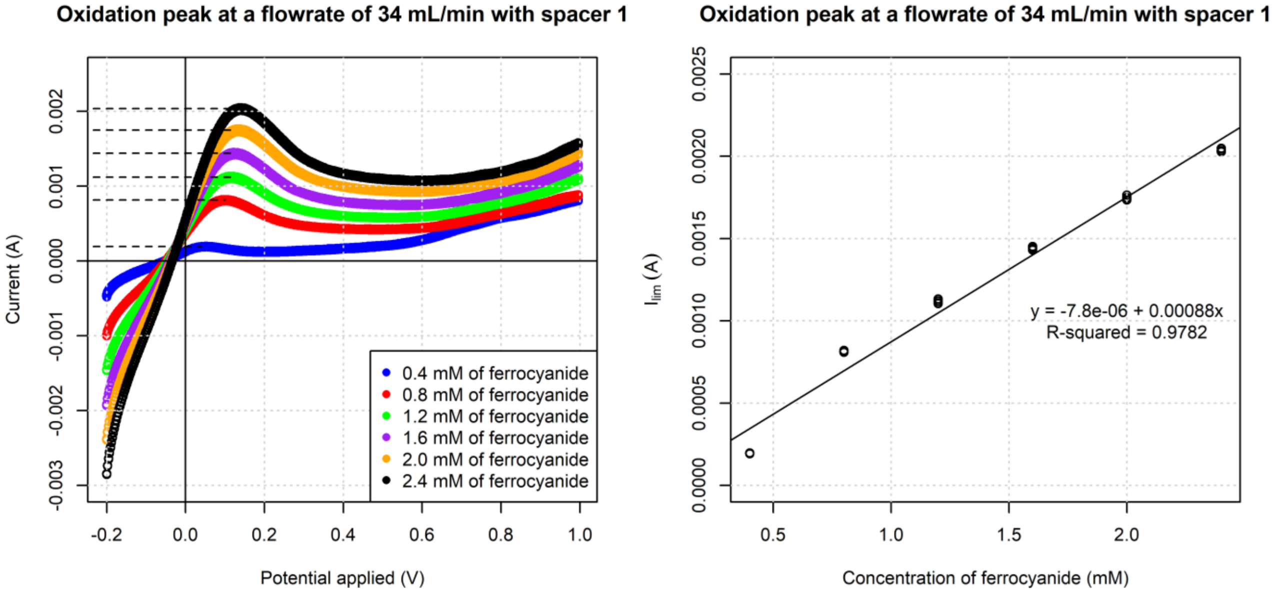


Figure 16 - Top peak at a flowrate of 34 mL/min

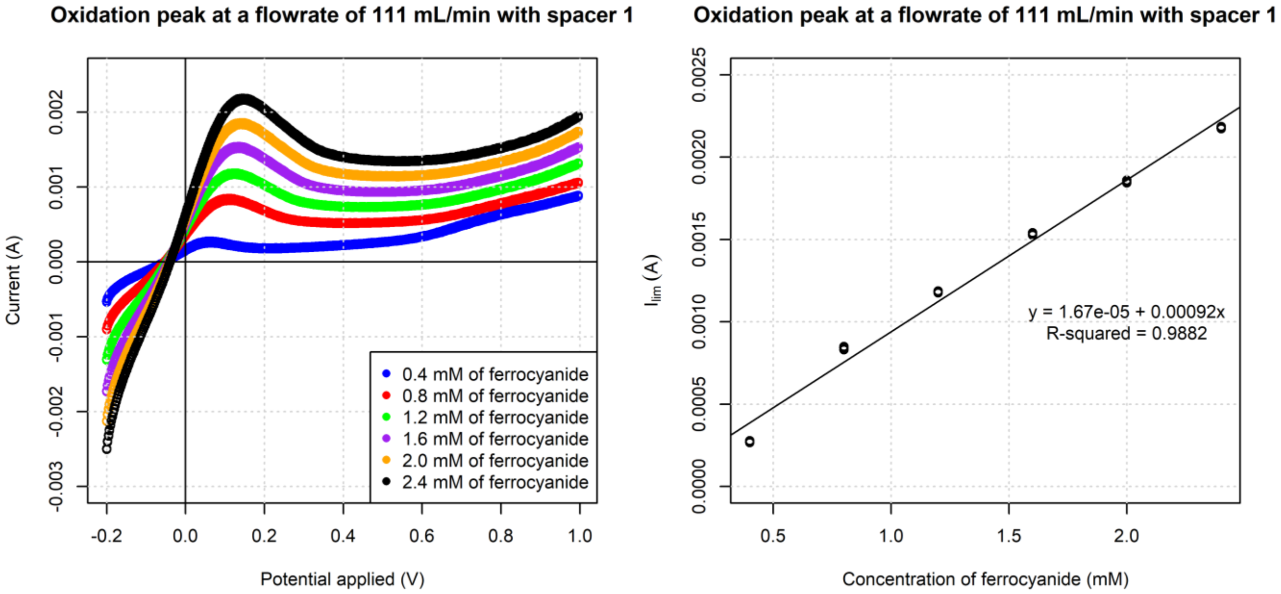


Figure 17 - Top peak at a flowrate of 111 mL/min

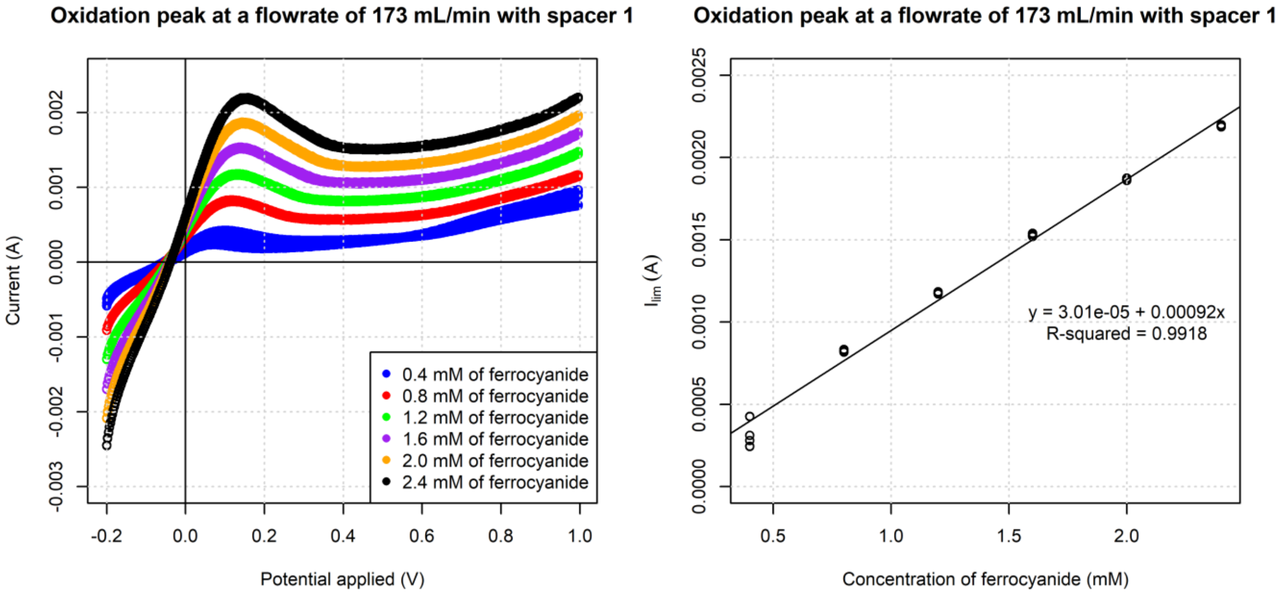


Figure 18 - Top peak at a flowrate of 173 mL/min

As it can be seen in figure 16-18 there is a good linear correlation between limiting current and concentration. However, there is a dip after the peak, where a plateau is desired when determining the limiting current. Therefore, the limiting current is also determined after the oxidation peak in figure 19-21 and the backscan in figure 22-24 to determine which method gives the best mass transfer coefficient.

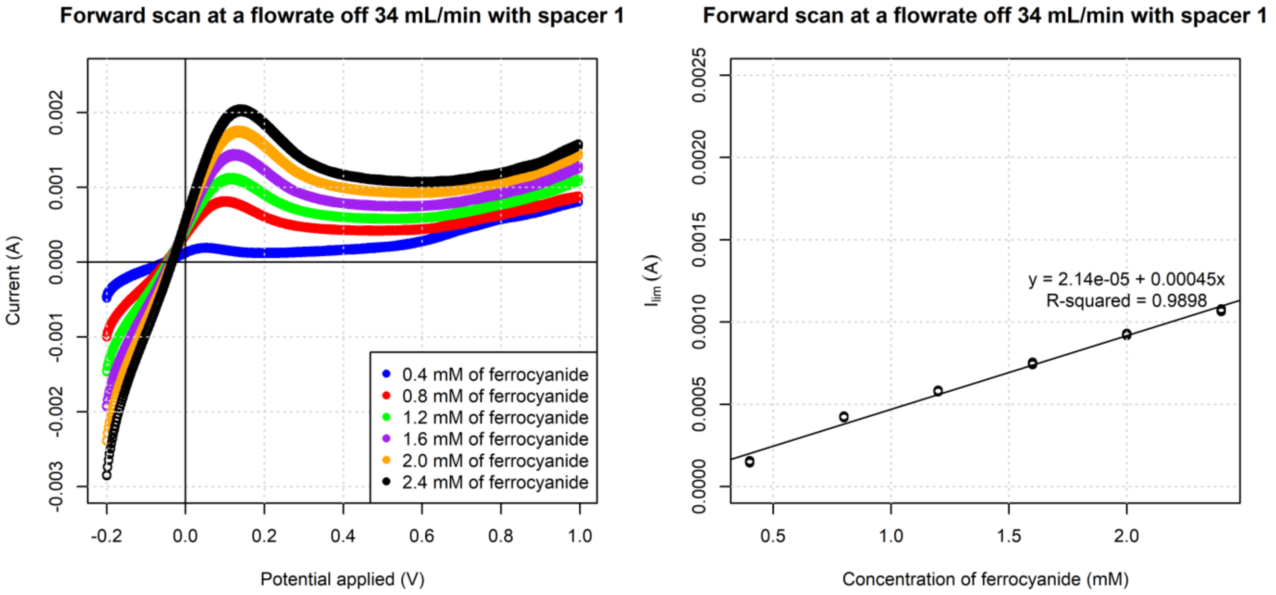


Figure 19 - Plateau of forward scan at a flowrate of 34 mL/min

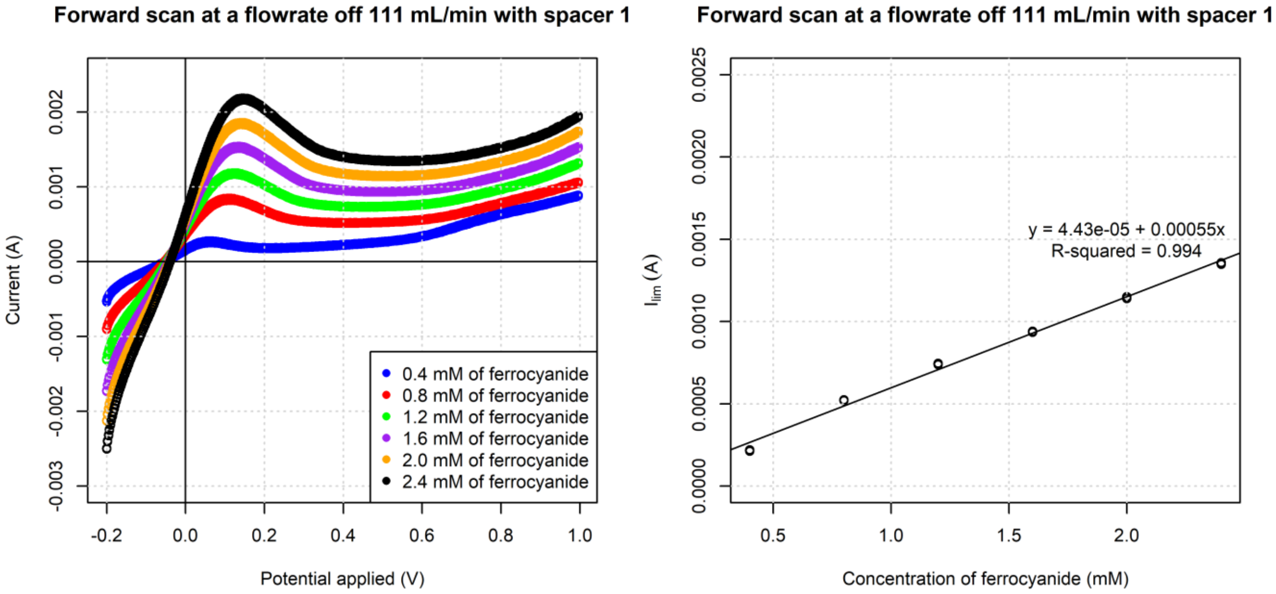


Figure 20 - Plateau of forward scan at a flowrate of 111 mL/min

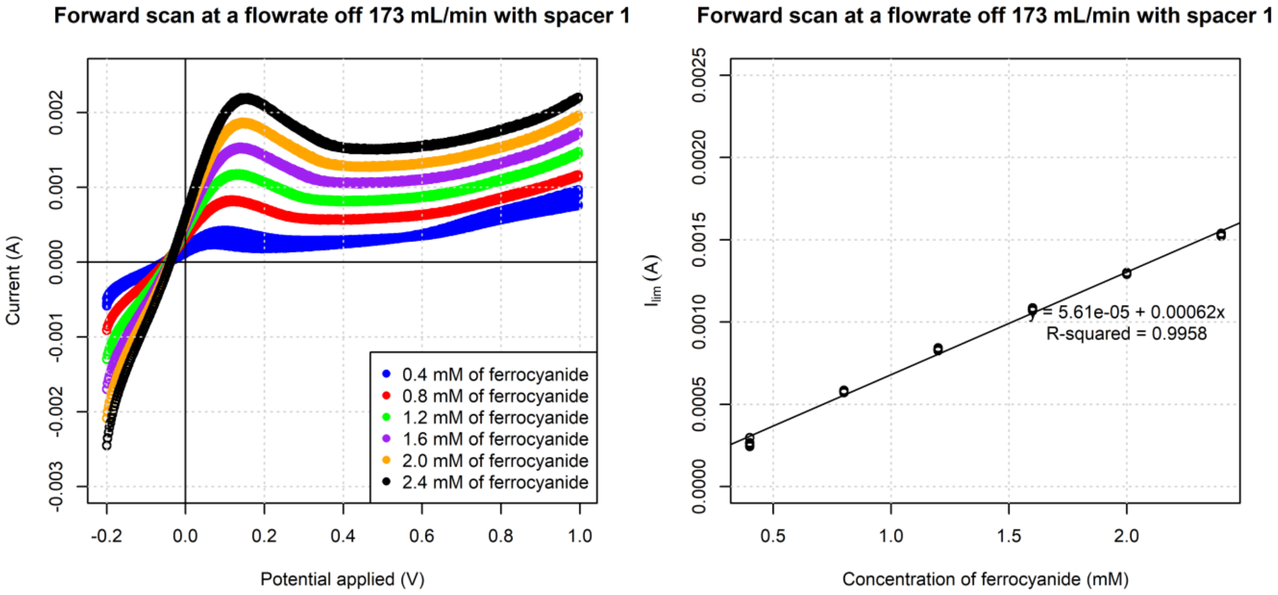


Figure 21 - Plateau of forward scan at a flowrate of 173 mL/min

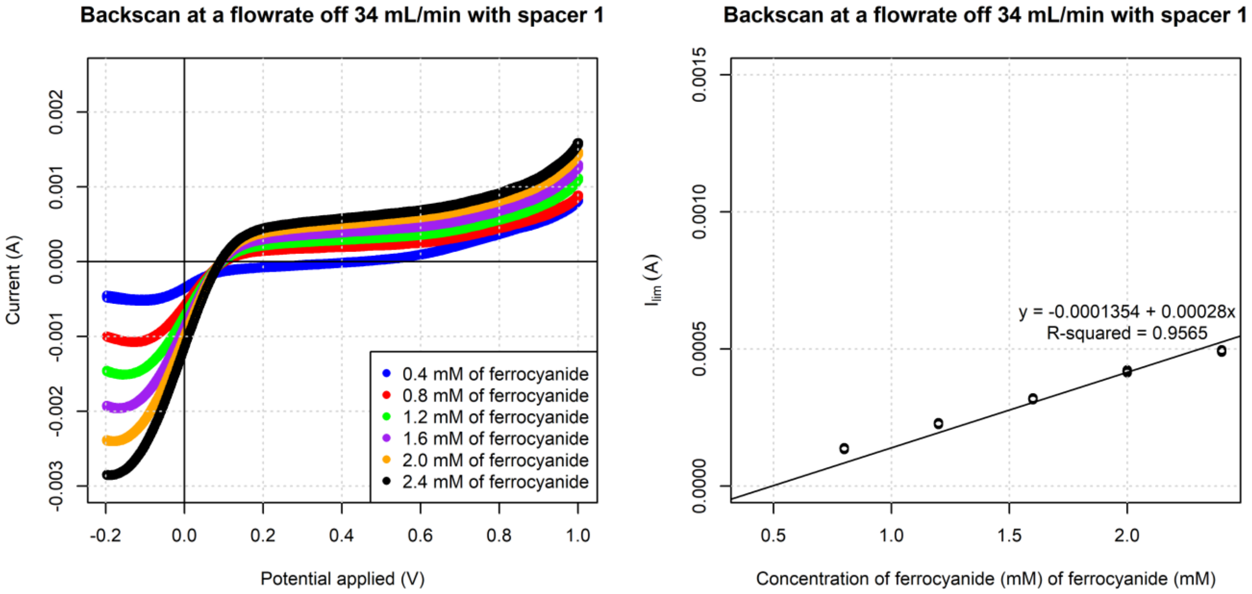


Figure 22 - Backscan at a flowrate of 34 mL/min

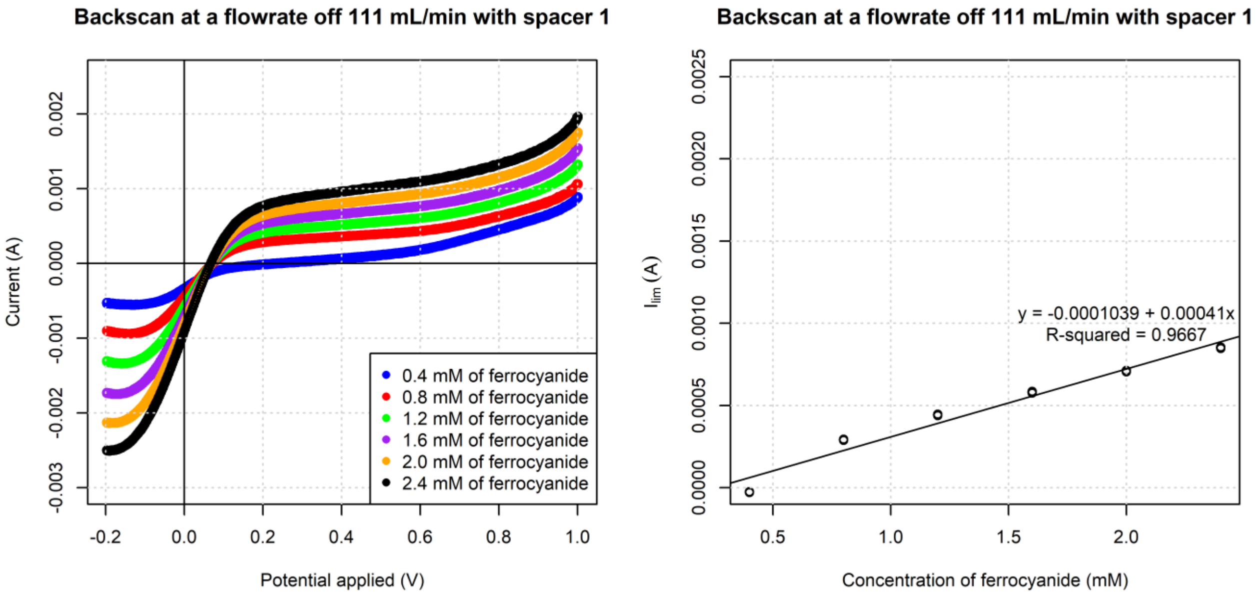


Figure 23 - Backscan at a flowrate of 111 mL/min

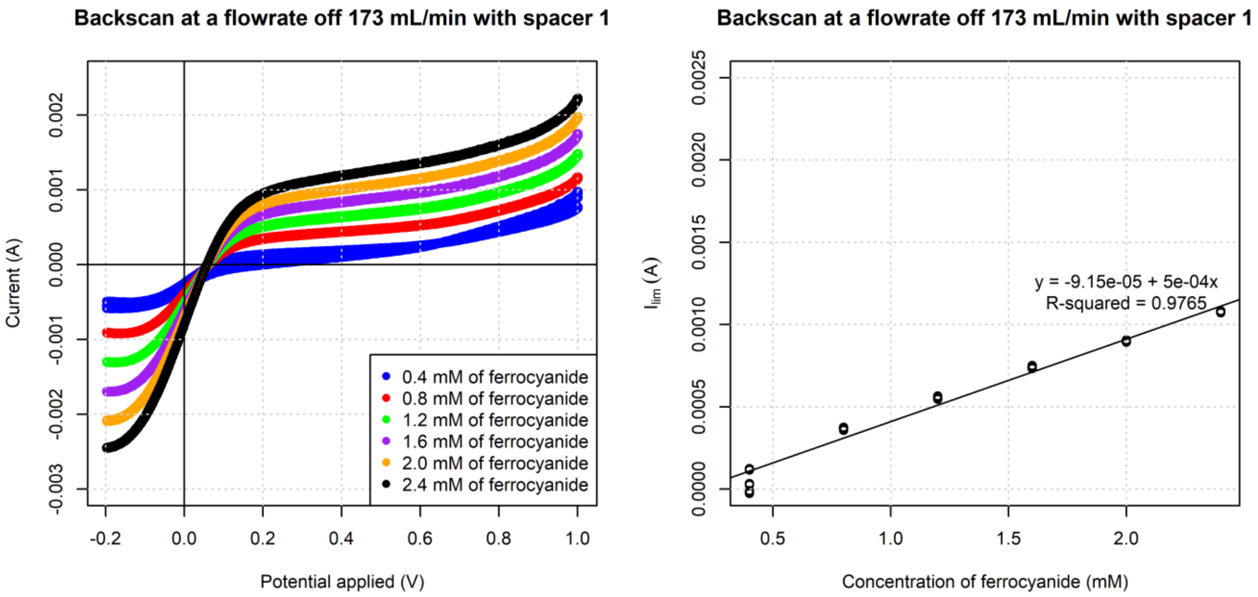


Figure 24 - Backscan at a flowrate of 173 mL/min

As with figure 16-18 there is a good linear correlation between limiting current and concentration of ferrocyanide in figure 19-24. The slope from figure 16-24 can now be used determine the mass transfer coefficient. The results can be seen in figure 25, where k_m is shown as a function of flowrate. The backscan is plotted as a red line, the forward scan is an orange line, and the oxidation peak is the purple line.

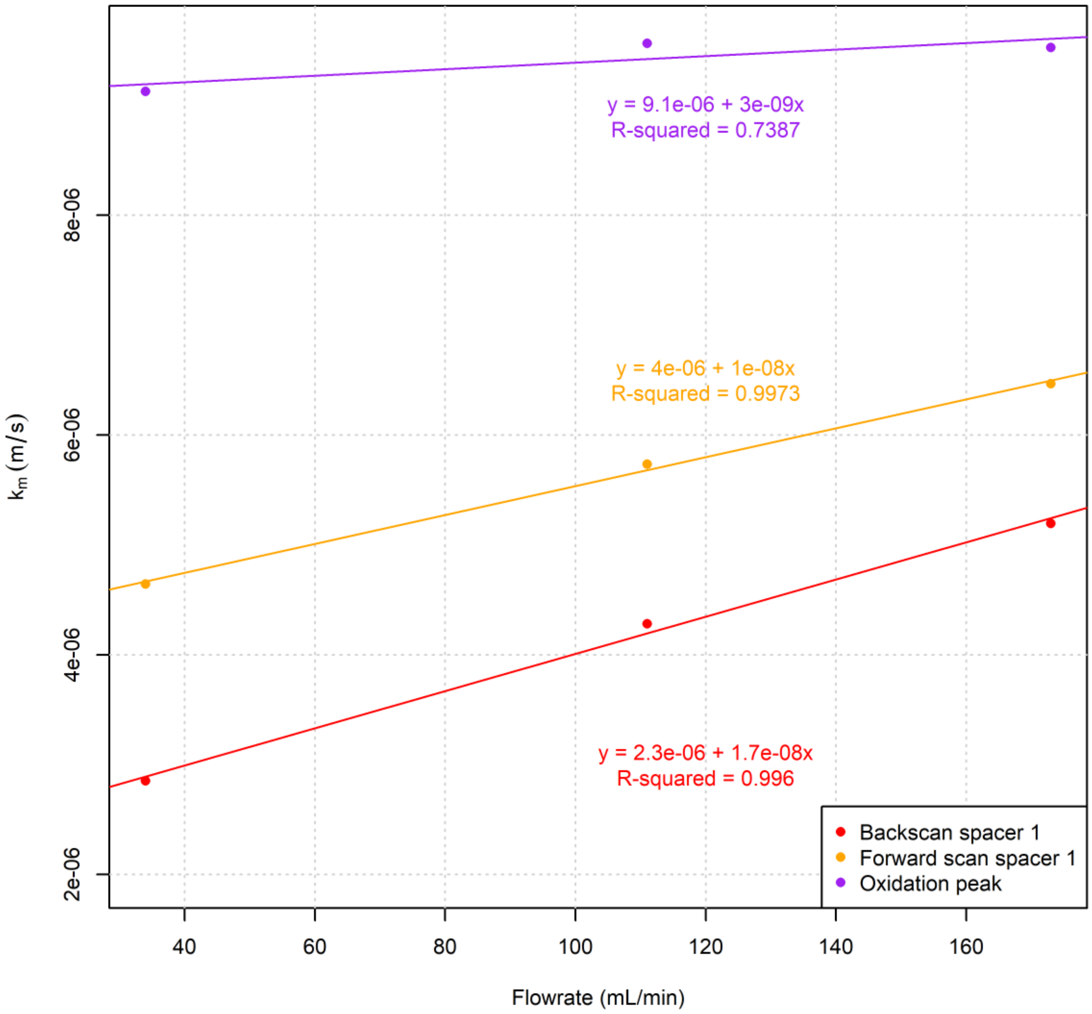


Figure 25 - k_m as a function of flowrate

Here it is seen that there is a good linear correlation between flowrate and k_m for the backscan and the forward scan. There is no linear correlation between the flowrate and k_m for the oxidation peak, which means that one of the other methods should be used.

These experiments were repeated with flowrates of 410, 440, and 475 mL/min and with 3 different spacers, to be able to compare the mass transfer of the small cell to the big cell that will be used during field testing. All these results looked similar to the plots shown in figure 16-24. Therefore, the plots of these results are shown in appendix 1, while the slope and R^2 are summed up in table 12.

Table 12 - Slope, intercept and R^2 for the small cell with three different spacers and a flowrate of 410, 440, and 475 mL/min

	Slope	Intercept	R^2
Forward scan 410 mL/min spacer 1	9.190e-04	6.002e-06	0.9995
Forward scan 440 mL/min spacer 1	9.566e-04	1.295e-06	0.9996
Forward scan 475 mL/min spacer 1	9.813e-04	4.659e-06	0.9998
Forward scan 410 mL/min spacer 2	6.717e-04	-2.968e-05	0.9990
Forward scan 440 mL/min spacer 2	6.857e-04	-2.873e-05	0.9989
Forward scan 475 mL/min spacer 2	7.062e-04	-3.539e-05	0.9989
Forward scan 410 mL/min spacer 3	6.414e-04	2.516e-06	1.0000
Forward scan 440 mL/min spacer 3	6.476e-04	3.927e-06	1.0000
Forward scan 475 mL/min spacer 3	6.540e-04	6.761e-06	1.0000
Backscan 410 mL/min spacer 1	8.492e-04	-3.211e-05	0.9995
Backscan 440 mL/min spacer 1	8.897e-04	-4.093e-05	0.9993
Backscan 475 mL/min spacer 1	9.152e-04	-3.299e-05	0.9997
Backscan 410 mL/min spacer 2	5.152e-04	-6.229e-05	0.9989
Backscan 440 mL/min spacer 2	5.334e-04	-5.285e-05	0.9993
Backscan 475 mL/min spacer 2	5.671e-04	-6.591e-05	0.9985
Backscan 410 mL/min spacer 3	4.854e-04	-4.033e-05	0.9999
Backscan 440 mL/min spacer 3	5.000e-04	-3.474e-05	0.9999
Backscan 475 mL/min spacer 3	5.169e-04	-3.087e-05	0.9998

Table 12 shows a good linear correlation between limiting current and concentration for all combinations. The slope from table 12 can now be used to determine the mass transfer coefficient. The results can be seen in figure 26, where k_m is shown as a function of flowrate. The forward scan with spacer 1 is colored red, forward scan with spacer 2 is colored orange, forward scan with spacer 3 is colored purple, backscan with spacer 1 is colored green, backscan with spacer 2 is colored blue, and backscan with spacer 3 is colored black.

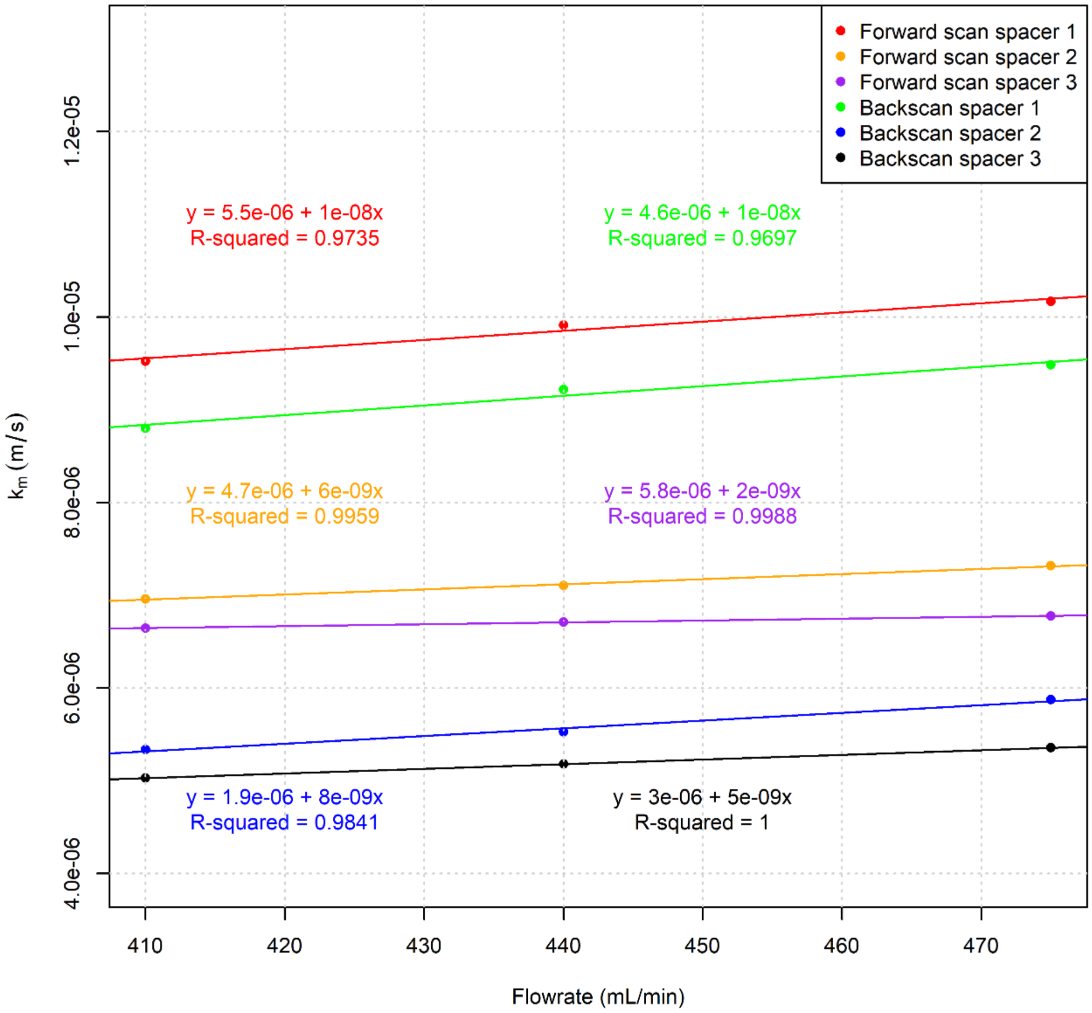


Figure 26 - k_m as a function of flowrate

As it can be seen from figure 26 there is a good linear correlation between flowrate and k_m. It can also be seen that the lines closest to each other are the backscan and forward scan with the same spacer. The slope of all lines is also similar, meaning that both the forward scan and backscan can be used to determine k_m as a function of flowrate.

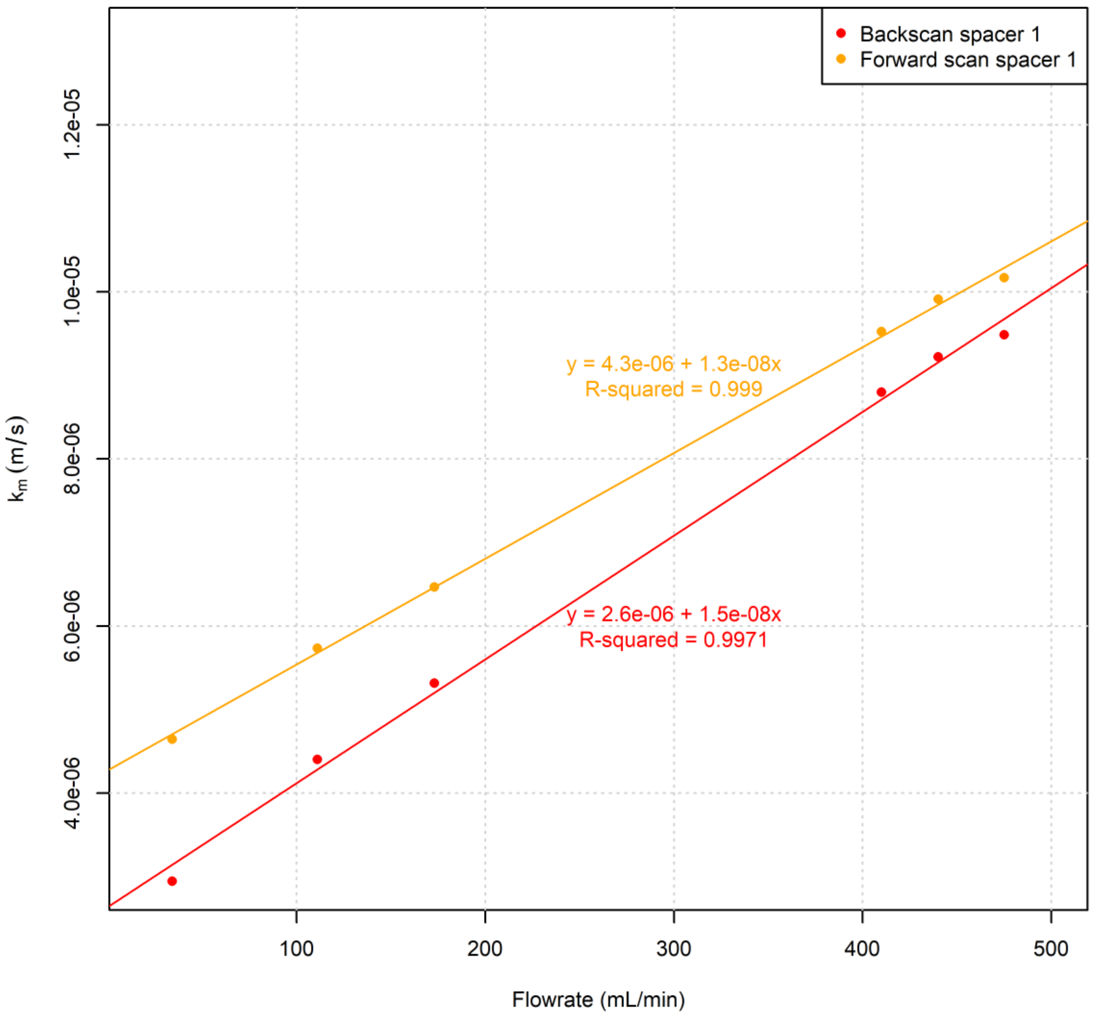


Figure 27 - k_m as a function of flowrate

Since the experiment with spacer 1 was carried out in the same manner, they can be compared as seen in figure 27. Here it is clear, that it is linear in the whole range that the pump can deliver, meaning the equations in the figure can be used to predict k_m.

The mass transfer experiment was repeated for the big cell to determine the mass transfer coefficient to see which type of spacer should be used to get the most compatible results. The mass transfer coefficient was determined at a flowrate of 183, 327, 395, 450, and 460 mL/min. The results for this experiment can be seen in figure 28-30 and table 13.

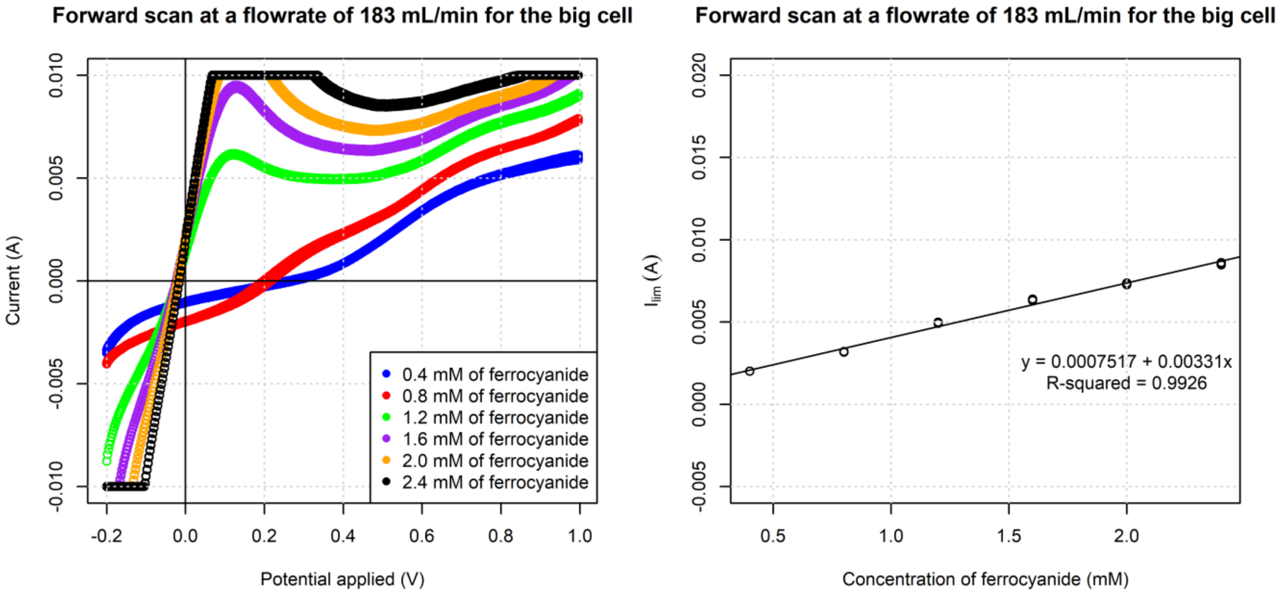


Figure 28 - Plateau of forward scan for the big cell at a flowrate of 183 mL/min

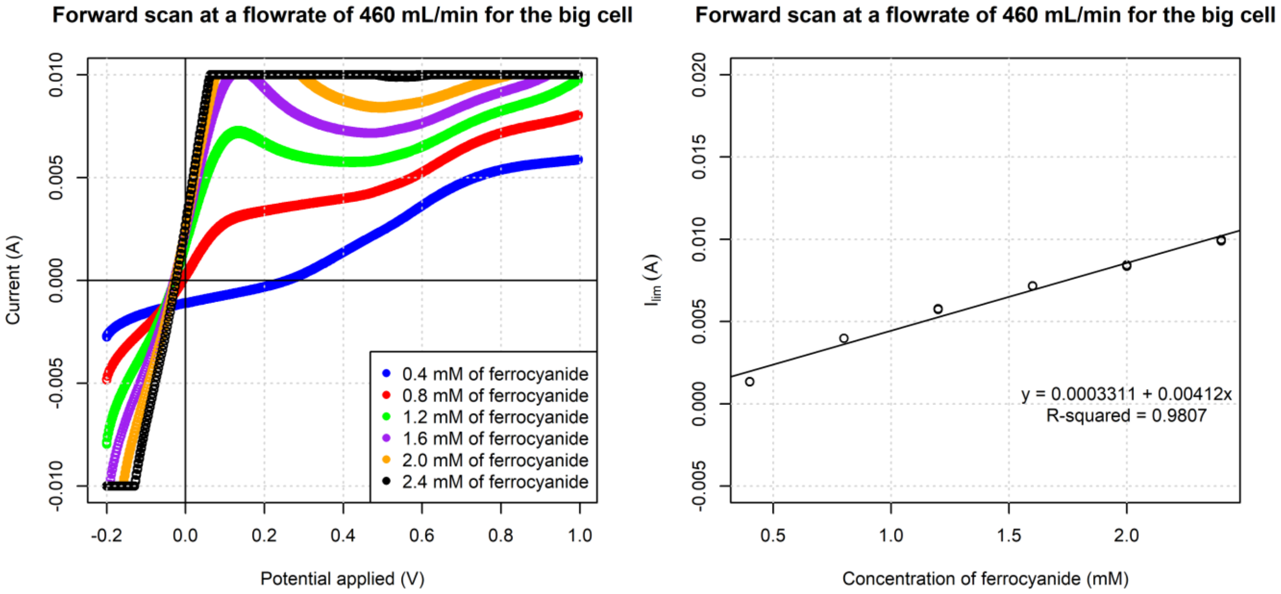


Figure 29 - Plateau of forward scan for the big cell at a flowrate of 460 mL/min

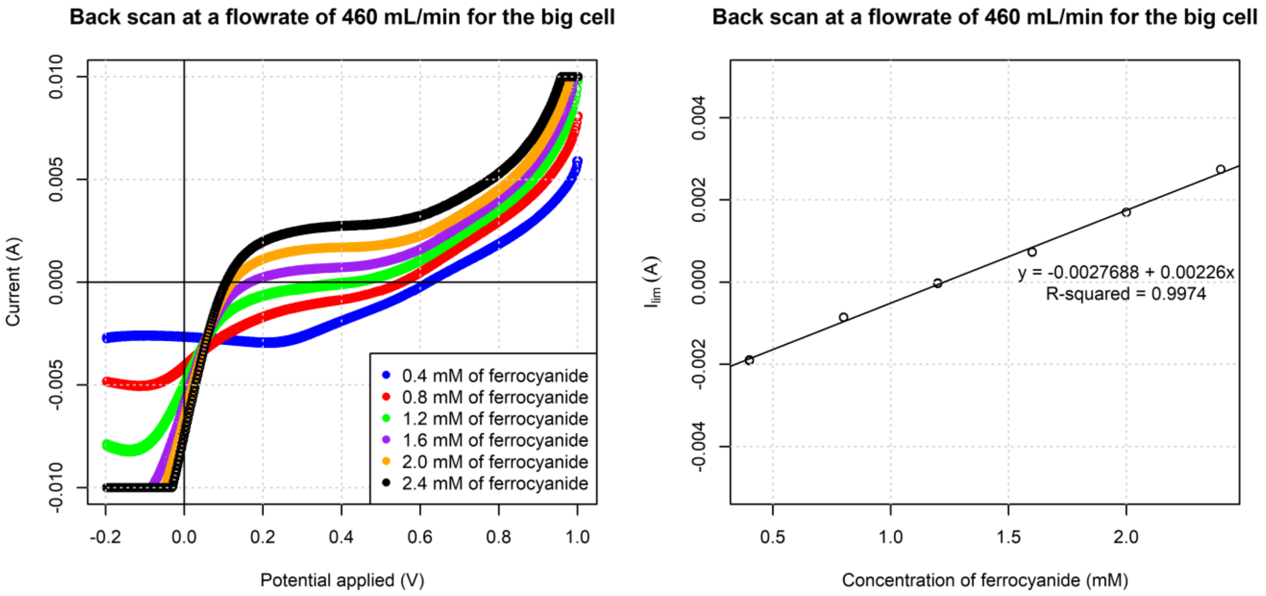


Figure 30 - Backscan for the big cell at a flowrate of 460 mL/min

The forward scan seen in figure 28 and 29 shows that the maximum current the equipment can measure was reached for concentration above 1.2 mM of ferrocyanide. As the flow increased more of the forward scan was unable to be measured. The amounts of ferrocyanide and ferricyanide added were already so small, that decreasing it even further was not an option. Although the maximum current was reached all of the forward scans showed a good linear correlation. Since it was previously determined that the plateau for the forward scan and backscan gave the best results, both were therefore analyzed anyway.

All results looked similar for the backscan as shown in figure 30. Therefore, the plots of these results are shown in appendix 1, whilethe slope and R^2 are summed up in table 13.

Table 13 - Slope, intercept and R^2 for the big cell with a flowrate of 183, 327, 395, 450, and 460 mL/min

	Slope	**Intercept**	R^2
Backscan 183 mL/min	0.001816	-0.003177	0.9947
Backscan 327 mL/min	0.002111	-0.003019	0.9948
Backscan 395 mL/min	0.002226	-0.002922	0.9947
Backscan 450 mL/min	0.002281	-0.002844	0.9973
Backscan 460 mL/min	0.002261	-0.002769	0.9974

Table 13 shows a good linear correlation between limiting current and concentration for all combinations of the backscan. The slopes from figure 28-30 and table 13 can therefore be used to determine the mass transfer coefficient. The results of this can be seen in figure 31, where k_m is shown as a function of flowrate.

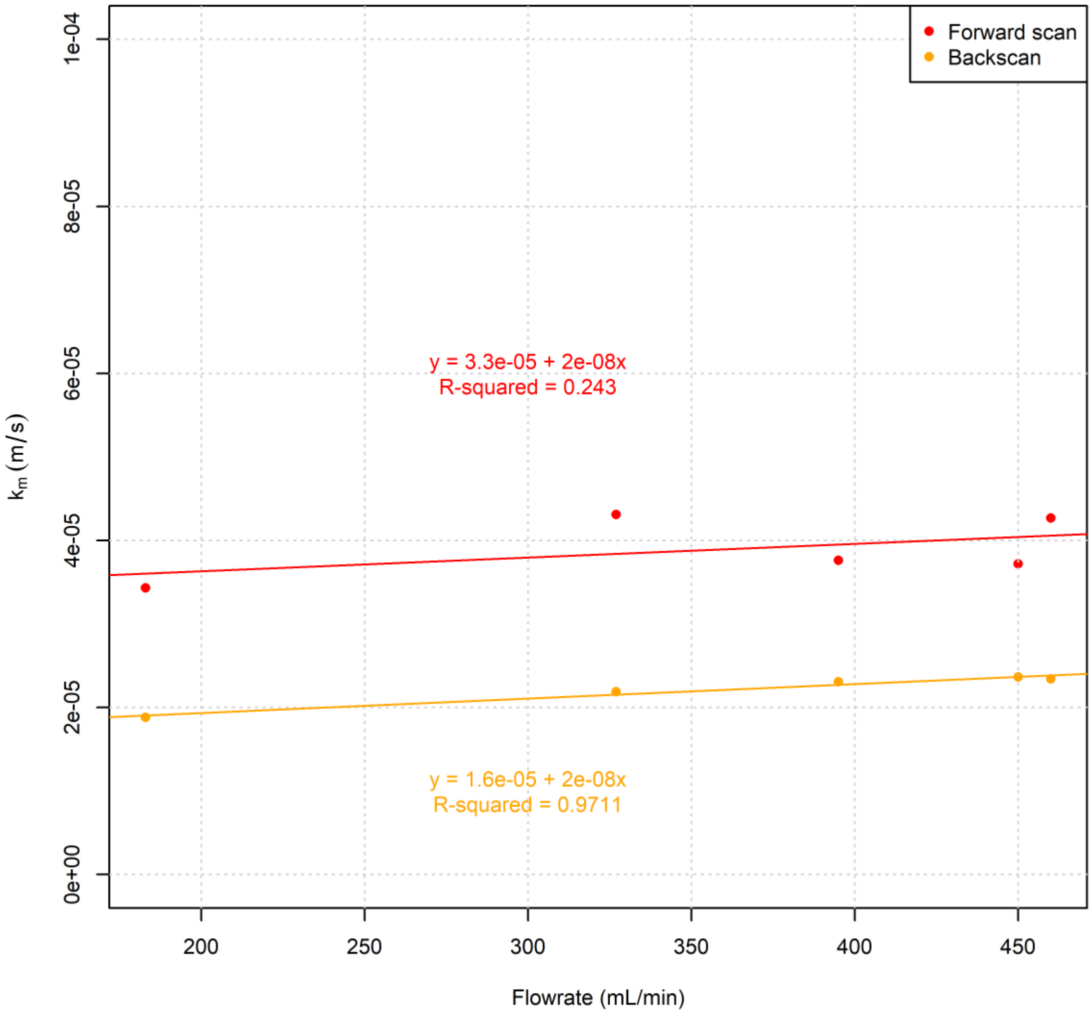


Figure 31 - k_m for the big cell as a function of flowrate

The forward scan for the big cell is colored red and the backscan for the big cell is colored orange. Here it can be seen that despite the good linear correlation for the forward scans, when looking at concentration of ferrocyanide and limiting current, there is no linear correlation between flowrate and mass transfer coefficient for the forward scan. The backscan showed a good linear correlation between flowrate and mass transfer coefficient. It was therefore decided to use the backscan to compare the cells and to perform calculations and modeling on. A comparison between the backscan for the big cell and the small cell with different spacers can be seen in figure 32.

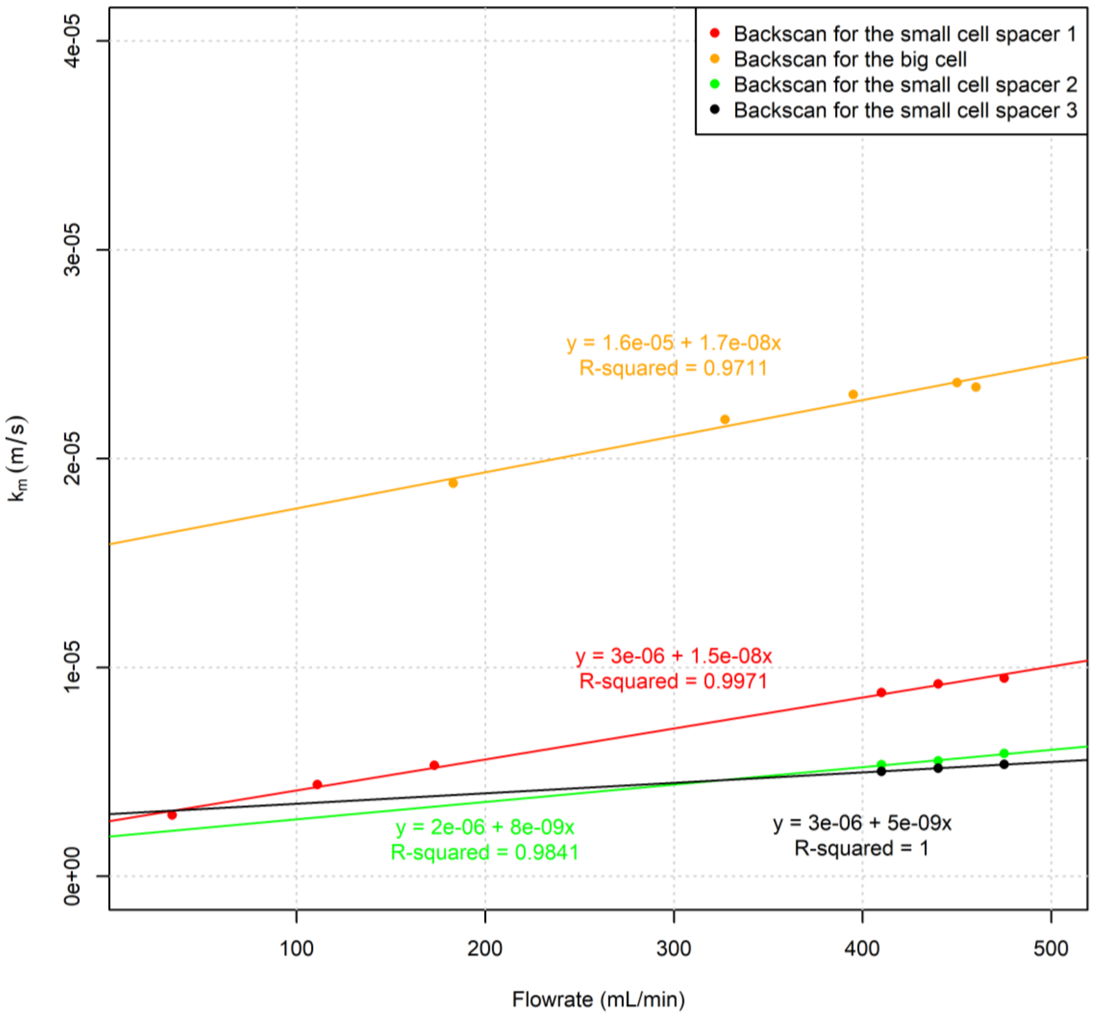


Figure 32 - Comparison between k_m as a function of flowrate between the big and small cell with different spacers

Figure 32 shows the backscan for the small cell with spacer 1 (red), spacer 2 (green), spacer 3 (black) and for the big cell (orange). As it can be seen from the figure, there is a good correlation between flowrate and k_m for all combinations. Since spacer 1 for the small cell was tested at the same conditions with the first run having a flowrate of 34, 111, 173 mL/min and the second run at a flowrate of 410, 440, and 475 mL/min these runs was combined into one as seen in the figure. This was not the case for spacer 2 and 3, meaning only the range from 410-475 mL/min has datapoints, thus flowrates far away from these points might be unreliable. From the figure, the function that resembles the big cell the most, was the small cell with spacer 1 with an almost identical slope.

The equation from the small cell with spacer 1 was therefore used to calculate the mass transfer coefficient at a flowrate of 100 mL/min and 200 mL/min, which will be used in the experiments as seen in equation 30 and 31.

$$k_{m,100} = 3 \cdot 10^{-6} + 1.5 \cdot 10^{-8} \cdot flow = 3 \cdot 10^{-6} + 1.5 \cdot 10^{-8} \cdot 100 = 4.5 \cdot 10^{-6} \frac{m}{s} \quad (30)$$

$$k_{m,200} = 3 \cdot 10^{-6} + 1.5 \cdot 10^{-8} \cdot flow = 3 \cdot 10^{-6} + 1.5 \cdot 10^{-8} \cdot 200 = 6.0 \cdot 10^{-6} \frac{m}{s} \quad (31)$$

Therefore, the mass transfer coefficient was determined to be $4.5 \cdot 10^{-6} \frac{m}{s}$ at a flowrate of 100 mL/min and $6.0 \cdot 10^{-6} \frac{m}{s}$ at a flowrate of 200 mL/min.

Determination of the limiting current for vinyl chloride and NVOC

Before determining the limiting current, well 114.2567 as shown in table 1 was analyzed again by ALS on 03/04/2023. Due to the late arrival of the ALS results, the average measured concentration in the AAU Esbjerg laboratory was used. These results showed a concentration of vinyl chloride of 1700 $\frac{\mu g}{L}$ and a concentration of NVOC of 4.4 $\frac{mg}{L}$. The rest of the results can be seen in appendix 2. The concentration of VC and NVOC was calculated in COD. For NVOC it was assumed that all NVOC would be present as CH. Equation 19 was then used to determine the limiting current of vinyl chloride to be 0.118 mA and 0.73 mA for NVOC. All calculations can be seen in appendix 3.

6.2 Degradation of vinyl chloride in the water phase

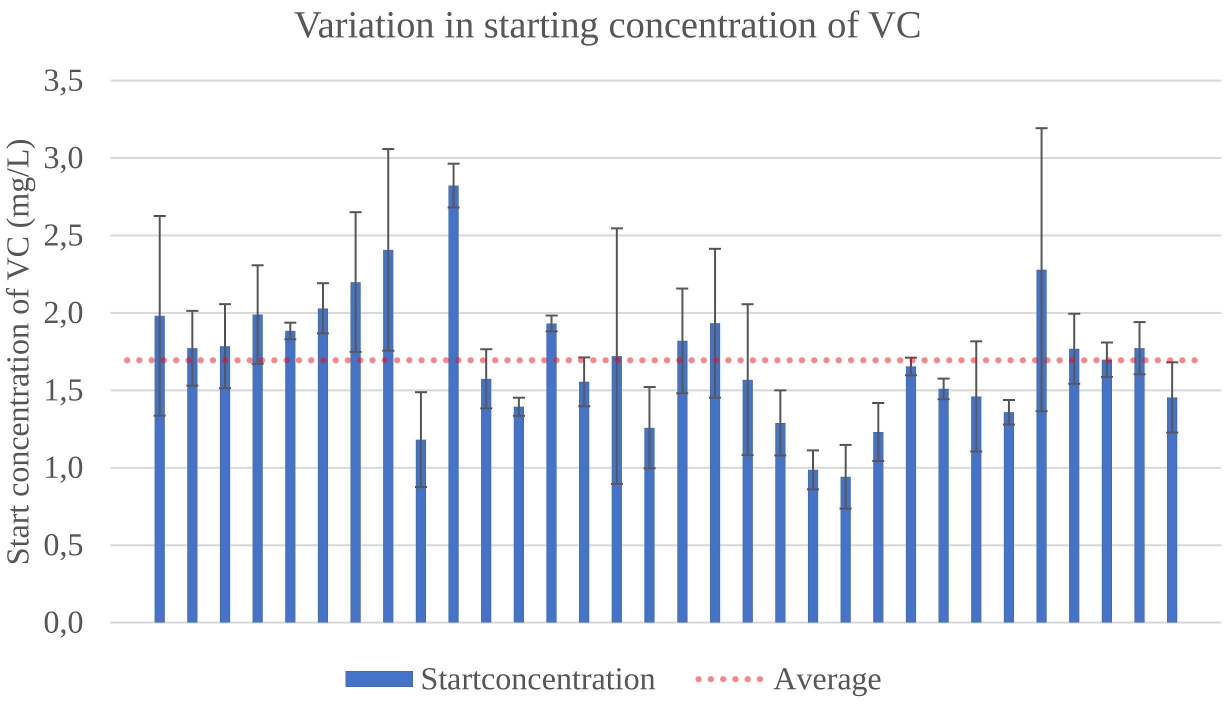


Figure 33 - Initial concentration of VC

Figure 33 shows the initial concentration of VC that was measured before the start of an experiment. The concentration varies randomly around an average of 1.7 (red line).

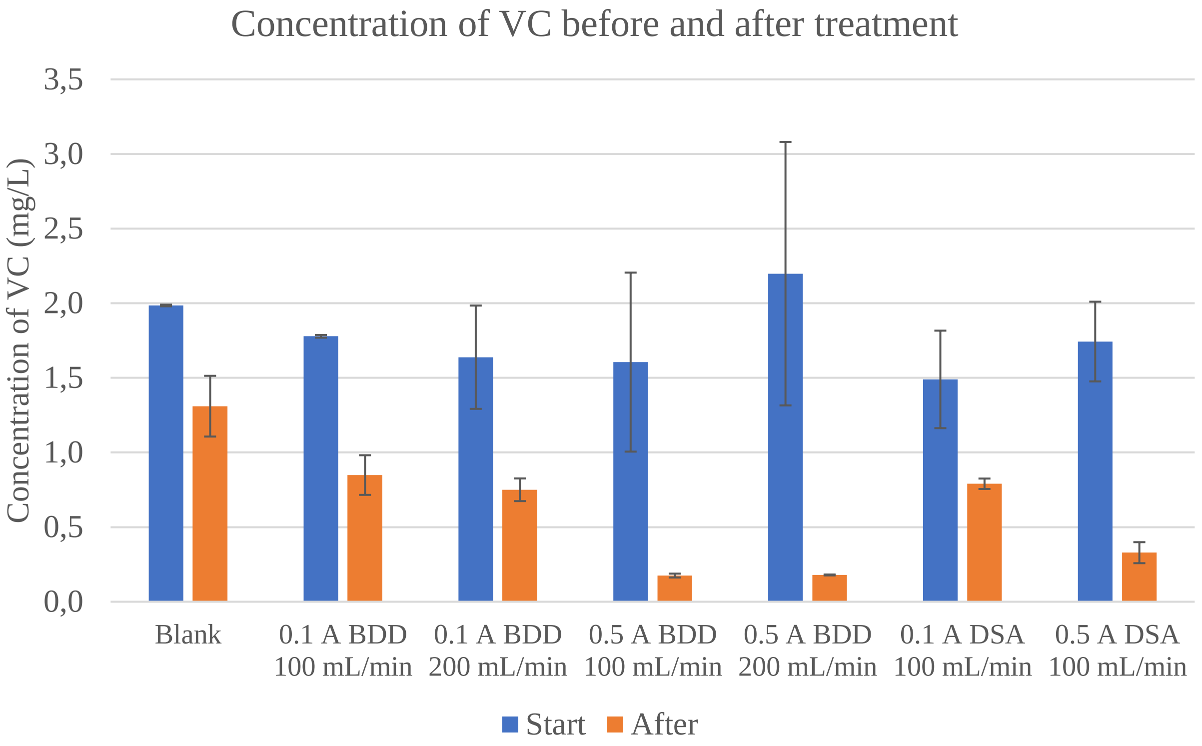


Figure 34 - Concentration of VC before and after treatment of 30 min

Figure 34 shows the start and end concentration of VC after 30 minutes treatment time where anode type (BDD/DSA), voltage (0.1/0.5 A) and flowrate (100/200 mL/min) were varied. The blank shown on the figure had no voltage applied, and it has less VC removal compared to the other runs where voltage was applied. 0.1 A also shows lower degradation compared to 0.5 A. The BDD electrode shows slightly higher degradation compared to the DSA electrode. A flowrate of 200 mL/min shows slightly higher degradation compared to the 100 mL/min flowrate, but because the difference between the two is not significant, 200 mL/min flowrate was not investigated with the DSA electrode.

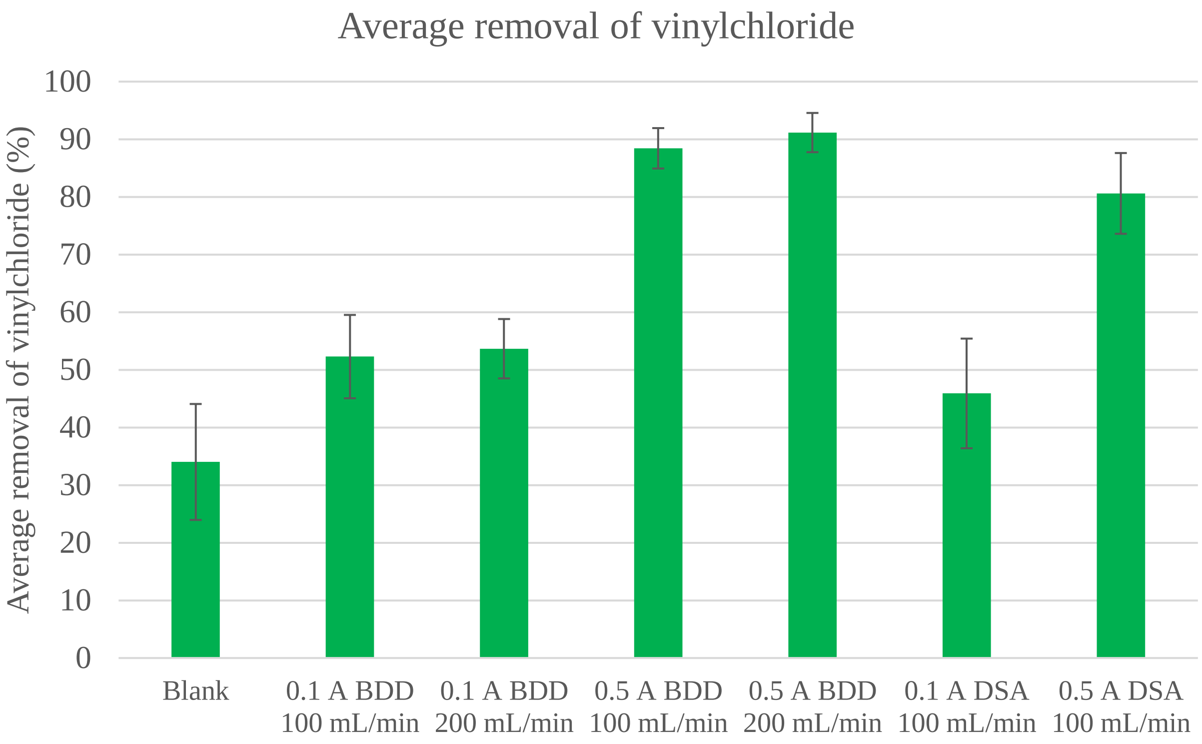


Figure 35 - Average removal of VC after 30 minutes

Figure 35 shows the average removal of VC in percentages after 30 minutes with variation of electrode type (BDD/DSA), voltage applied (0.1/0.5 A) and flowrate (100/200 mL/min). On average, the BDD electrode with 0.5 A resulted in the highest removal of VC. Using a flowrate of 100 mL/min resulted in 88% of VC removal and 200 ml/min in 91%. The second highest removal was provided by the DSA electrode with 0.5 A, which would indicate that higher voltage is more significant than the electrode type. Using 0.1 A and 100 mL/min, the average VC removal for the BDD electrode was 52%, while DSA removed 46%. The flowrate of 200 mL/min provided a slightly higher VC removal of 54%. As expected, the blank run has the lowest removal of 34%, which must be due to evaporation.

Conductivity was measured to around 0.8 mS/cm during all experiments, but no significant difference was observed, either between runs or after treatment, and they are therefore not shown in this report.

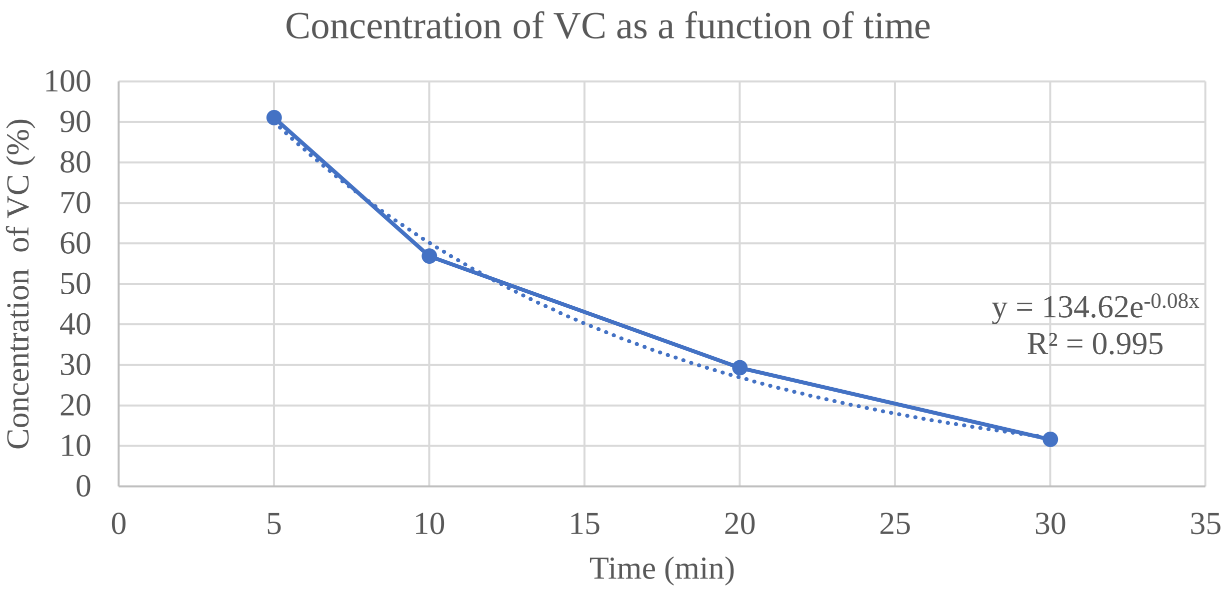


Figure 36 - Vinyl chloride concentration over time using 100 ml/min and 0.5 A

Figure 36 shows the percentage of VC concentration over time, with 0.5 A and 100 mL/min flowrate. The figure shows an exponential decrease in VC concentration over time. The obtained function shows a good fit with a R^2 equal to 0.995. After 5 minutes, 10% of the VC is removed, and the exponential degradation leads to 88% removal after 30 minutes.

6.2.2 Degradation of vinyl chloride efficiency

In order to evaluate the efficiency of the system, general current efficiency (GCE) can be calculated. Aside from the efficiency of the system energy consumption is calculated as well. The results can be seen in table 14. The values used correspond to the BDD electrode, 100 mL/min flowrate and 0.5 A.

Table 14 - Efficiency indicators

Time [min]	**GCE**	**E_{sp} [Wh/mg VC]**
5	0.03%	16.03
10	0.02%	21.37
20	0.01%	33.24
30	0.01%	44.87

6.3 Stripping vs. Degradation

Two methods were used to determine if vinyl chloride is degraded or evaporating: nitrogen flushing and GC-MS.

6.3.1 Determining evaporation of vinyl chloride with nitrogen

The initial qualitative experiment was to test if the cell was able to degrade VC, by adding heat and nitrogen to the system, with no applied current. The flowrate of 100 mL/min was still applied. During electrolysis of VC, gas and heat are produced. Since adding heat and air flow would simulate the effects observed when a current was applied, which could aid in the stripping of VC, it was determined that if more VC is removed using the cell compared to using the nitrogen, the cell does not degrade VC It was not possible to measure the flowrate of nitrogen accurately, however the flowrate was set, in such a way that more gas was visibly seen in the water, compared to when applying a current. The sample was heated to 30°C, as that was approximately the temperature at the end of the runs with 0.5 A applied.

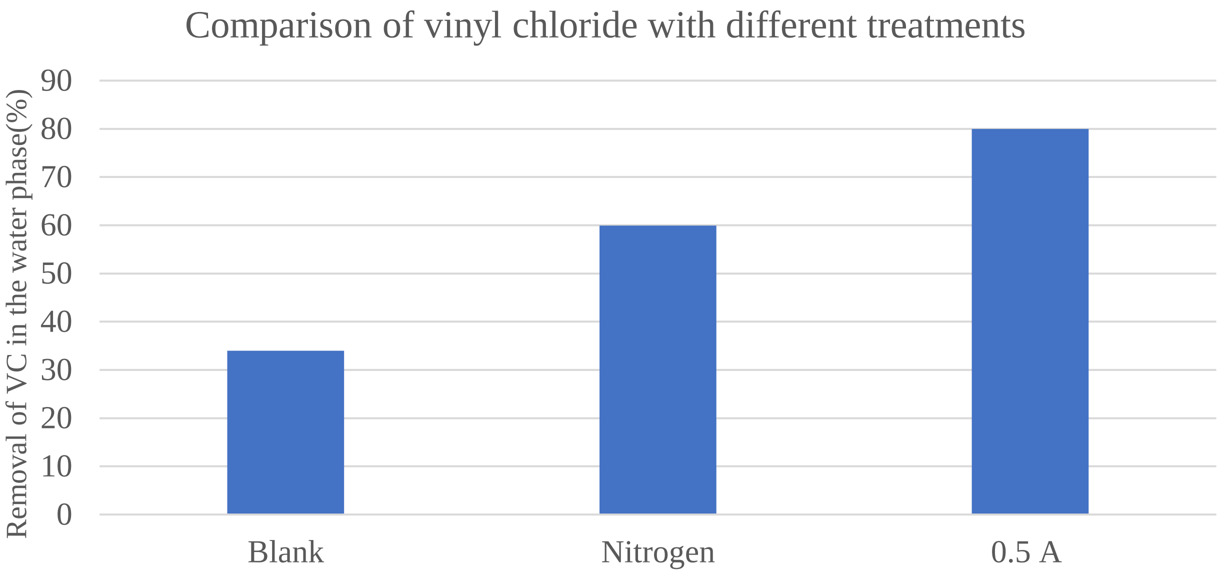


Figure 37 - Removal of vinyl chloride after 30 minutes using no treatment, nitrogen, or 0.5 A

The results shown in figure 37 showed that during a 30 min period, 60% of the VC evaporated, with the nitrogen and the external heating added. When no nitrogen, heating or current is applied, an average of 34% of VC evaporated. Adding a current of 0.5 A results in a removal of 80-90% depending on electrode materials. It is therefore possible to conclude that the cell is able to degrade vinyl chloride. Since it was not possible to quantify vinyl chloride in the gas with this method, other methods must be applied.

6.3.2 Determining evaporation of vinyl chloride with GC-MS

Tightness test

Before GC-MS could be used, the tightness of the system was tested to ensure all the evaporated VC was exiting through the outlet orifice. This was done by using a measuring cylinder, as described in the experimental set up in figure 15 in section 5.5.2. The experiment was performed with Grindsted water as well as sodium sulfate, which was used since it should not produce any CO_2, thus only producing hydrogen and oxygen. The experiment was done with the BDD electrode, at a flow of 100 and 200 mL/min and with 0.5 A applied. The results from the experiment can be seen in table 15. The rate of hydrogen formation was calculated using equation 32.

$$n_{H_2} = \frac{q \cdot I}{N_A \cdot e_{H_2}^-} = \frac{6.24 \cdot 10^{18} \frac{1}{A \cdot s} \cdot 0.5\ A}{6.02 \cdot 10^{23} \frac{1}{mol} \cdot 2} \approx 2.59 \cdot 10^{-6} \frac{mol}{s} \qquad (32)$$

Where I (A) is the current applied, N_a is Avogadro's constant (mol^{-1}), q is the number of electrons per coulomb ($A^{-1} \cdot s^{-1}$) and e_{H2}^- is the amount of electrons needed to produce molecular hydrogen.

The volume of produced hydrogen was calculated with an ideal gas equation at 25 °C and 1 atm.

Table 15 - Experimental results used for scaling and system tightness

100 mL/min of Grindsted water	144 mL
100 mL/min of 1M Na_2SO_4	127 mL
100 mL/min of 1M Na_2SO_4	130 mL
200 mL/min of Grindsted water	156 mL
Calculated hydrogen production mL	114 mL

Table 15 shows the sodium sulfate results are within 3 mL difference indicating reproducibility.

As it can be seen in the table, the calculated production of 114 mL of hydrogen matches well with the amount of gas produced in the experiments with Na_2SO_4 of 127 and 130 mL. The produced gas is slightly higher, as only the hydrogen is regarded in the calculation. But as an equal amount of oxygen is also produced, more gas will be formed than calculated. Since a large amount of the oxygen will be dissolved in the water, the 13-16 mL extra from oxygen seems reasonable. Thus, values of 127 and 130 mL indicates that most of the gas is captured. The extra gas produced using Grindsted water is due to degradation of organic materials producing CO_2.

It can therefore be assumed that the system is tight, and the amount of gas produced can therefore be used to get a quantitative value of VC in the gas bag.

Quantifying the amount of vinyl chloride evaporated

The amount of gas produced during the experiments for 30 minutes is now known and can therefore be used to estimate the concentration of vinyl chloride in the gas as described in section 5.4.3, based on the GC-MS responses shown in appendix 5. Gas volume produced after 5, 10, and 20 minutes were not measured, but gas production was assumed to be linear during the whole experiment.

Due to the volatility of vinyl chloride, it is investigated how much of the vinyl chloride will evaporate after 5, 10, 20, and 30 minutes without the cell being turn on, which can be seen in figure 38.

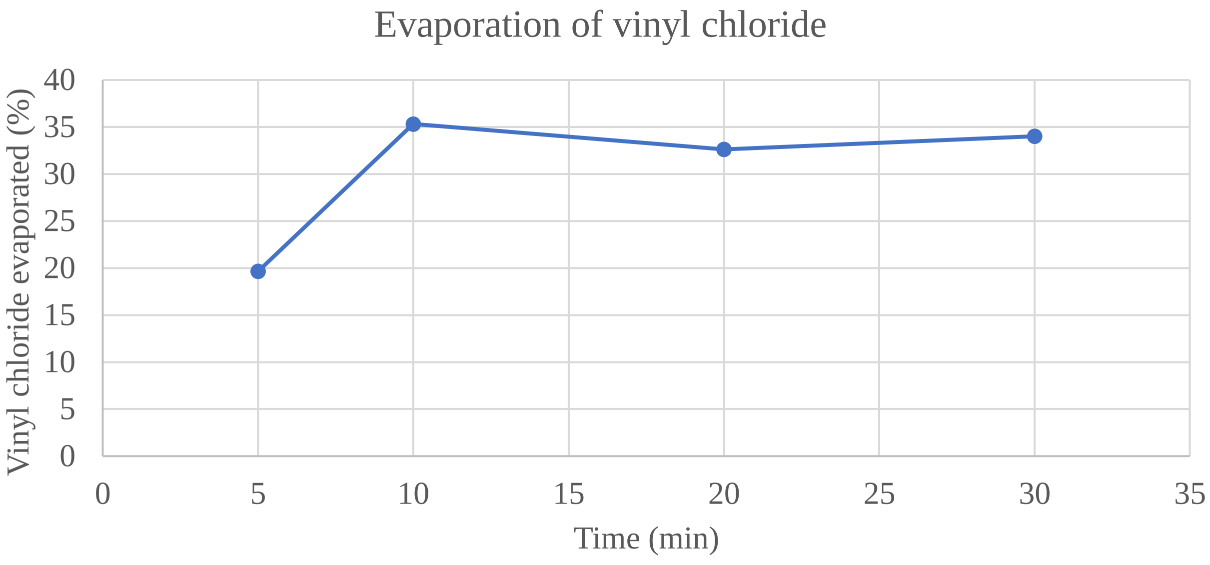


Figure 38 - Average evaporation at 0 A over time

Figure 38 shows the amount of vinyl chloride in percent that evaporates after 5, 10, 20, and 30 minutes without the cell being turn on. The figure shows that evaporation increase from 5 to 10 minutes, going from 20 to 35%. After 10 minutes the amount of vinyl chloride evaporated in percent stays relatively constant at 35% with a small decrease at 20 minutes down to 33%. This can be explained by uncertainty of the measurements.

These values can now be used to determine if more vinyl chloride in the gas is produced when the cell is turned on. This can be seen in figure 39.

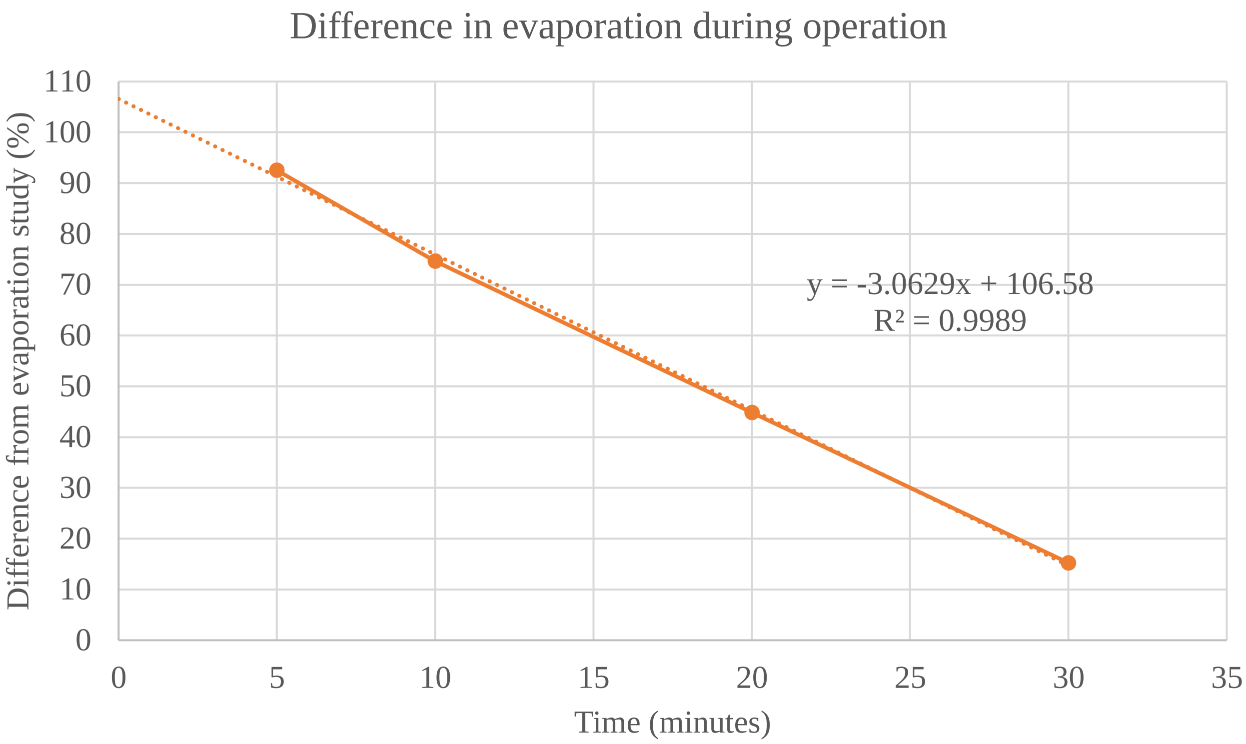


Figure 39 - Average difference in evaporation of VC during operation

Figure 39 shows how much less vinyl chloride is detected in the gas compared to if the cell was turned off, as seen in figure 38. A linear decrease with time can be seen from the figure, meaning that when time passes, the difference between the cell being on and turned off becomes smaller. This means that at 5 minutes, the number of VC molecules in the gas is 93% lower compared to when no current is applied. All values being positive means that the cell is degrading vinyl chloride and not increasing the evaporation.

Since an estimate of both vinyl chloride in the water and gas phase is known the amount of vinyl chloride degraded can be calculated, this can be seen in figure 40.

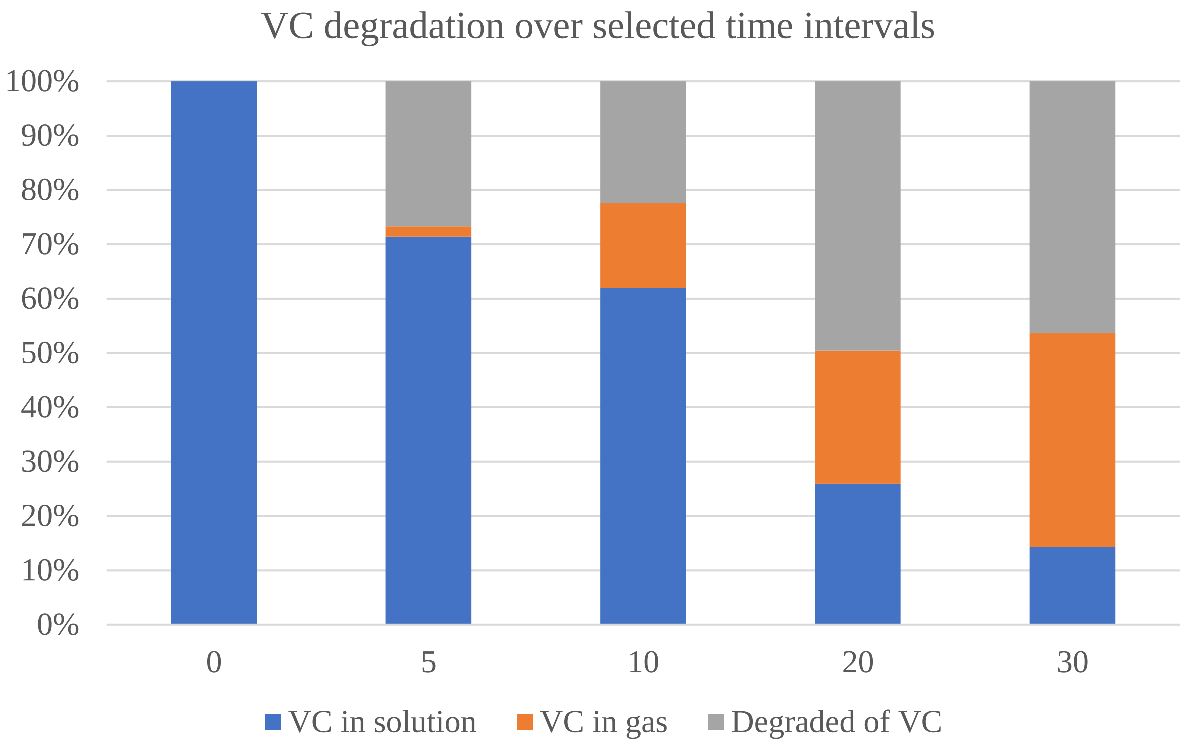


Figure 40 - Percentile stacked column plot showing VC in solution (blue), VC in the gas (orange) and degraded VC (gray) utilizing 0.5 A, 100 mL/min, and BDD

Figure 40 shows a percentile stacked column plot from time 0 to 30 min showing VC in solution, VC in gas and degraded VC. It is assumed that if the VC was not detected in the gas or the contaminated water, it must have been degraded. As time passes, the amount of vinyl chloride that has degraded or evaporated is increasing, and that the amount of vinyl chloride in the solution is decreasing. The amount of vinyl chloride that is evaporating is increasing steadily, however the amount of vinyl chloride that is degraded fluctuates, due to the uncertainties in the measurements, however 5 and 10 minutes have 28 and 22 % degradation respectively, while 20 and 30 minutes have 50 and 46 % degradation respectively.

6.4 Vinyl chloride degradation modelling

Based off the mass transfer coefficients determined for the cell used, a single parameter, an EOTR+evaporation, an EOTR+indirect, and an EOTR+evaporation+indirect model can be constructed based on the models presented in chapter 2.3.3. The evaporation and indirect models are also based on experimental data and are thus semi empirical models. The applied current is 0.5 A, and the limiting current when only accounting for the COD of vinyl chloride is 0.118 mA, meaning the characteristic parameter is 4234. This affects what the model predicts the concentration at time=0 to be, and thus all models are corrected to have the correct initial concentration, which was fixed to the average starting concentration of 1.7 mg/L. It also means that the critical time is a negative number, thus the model will always be in the mass transfer limited range.

An empirical rate constant for the evaporation was determined, based off the evaporation during the operation of the cell. The evaporation fits well with a linear model; however, a first order model was still fitted to the experimental data, as the model cannot be properly constructed otherwise. The rate constant was determined as -2.225E-4 s^{-1}. The chemical rate constant for the indirect oxidation model is determined based on the experimental values where the 100 mL/min and 0.5 A were utilized at 5, 10, 20, and 30 minutes. When the rate constant is changed, the initial concentration will also be changed, thus the time must also be adjusted when the rate constant is changed. The chemical rate constant is determined separately for the EOTR+indirect and the EOTR+indirect+evaporation models, as the rate constant in the model without evaporation intrinsically contains the evaporation, as it is fitted to the experimental data.

All the models are compared to the experimental values in figure 41. It is not possible to see the EOTR+indirect model, as it is overlapping with the EOTR+indirect+evaporation, as the data is fitted to the experimental values.

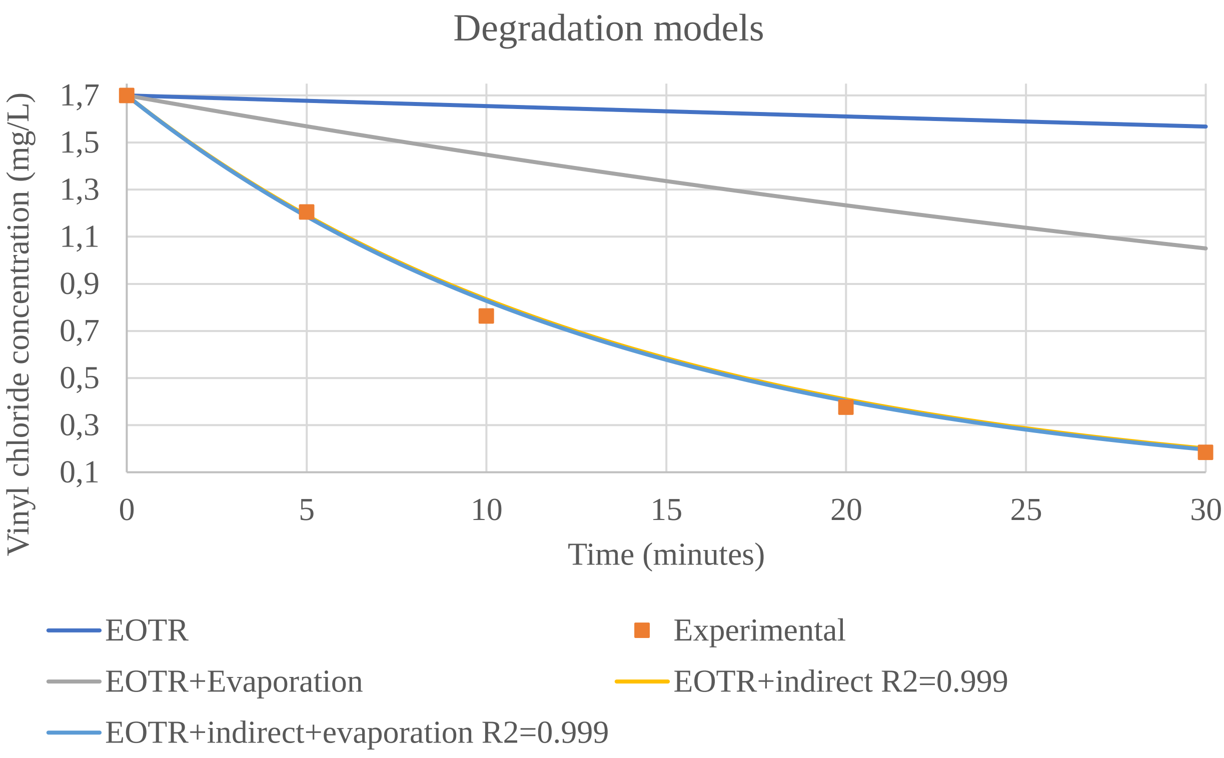


Figure 41 - Vinyl chloride degradation models

The EOTR and EOTR+evap models deviate heavily from the experimental values, as the models do not account for the indirect oxidation. The behavior of these models does not look exponential, but this is due to the concentration adjustment by changing the initial time for the model. The models at adjusted time=0 is far from what the models predicts as the initial concentration at the actual time=0.

It was possible to fit the EOTR+indirect and the EOTR+evaporation+indirect model to the experimental data, with a good fit as both models have an R^2 of 0.999. The models are thus able to be applied to predict the VC degradation utilizing the 0.5 A and 100 mL/min operating parameters. The k_{chem} for the EOTR+indirect model is 0.00114 s^{-1}, and the EOTR+evaporation+indirect model has a k_{chem} of 0.000932 s^{-1}.

6.5 Experiment based calculations and considerations

6.5.1 Model application with different parameters

The EOTR+evaporation+indirect model's performance is tested, by comparing it with several experimental trials, with different starting concentrations and operational parameters, at 30 minutes treatment time. The operational parameters, initial concentrations, end concentrations, and percentile difference are seen in table 16.

Table 16 - Application of the model at different current and flowrate

Current (A)	Flowrate (mL/min)	Starting concentration (mg/L)	Model concentration (mg/L)	Actual Concentration (mg/L)	Difference (%)
0.1	100	1.8	0.2	0.9	77
0.1	200	1.9	0.2	0.8	73
0.5	100	2.0	0.2	0.2	15
0.5	200	2.8	0.3	0.2	57

The model has poor performance when the flowrate and current are different from the 0.5 A and 100 ml/min it was modeled at, with the change in current having the largest effect on model performance. The model has acceptable accuracy when the operating parameters are 0.5 A and 100 mL/min, where the difference is only 15%.

6.5.2 Treatment time needed to reach the discharge limit

Since the discharge limit for VC is 0.05 μg/L [61], it is interesting to see how much time would be needed to degrade VC to the discharge limit using the setup presented in this report. If the average initial concentration of VC is taken (1.7 mg/L), approximately 0.00294% of the starting concentration is allowed to remain to reach the discharge limit. The time needed for the degradation to the discharge limit can be calculated to 135 minutes (2.25 hours) based on the empirical model, with equation 33.

$$discharge\ limit\ (\%) = 134.62e^{-0.08 \cdot time} \tag{33}$$

6.5.3 Scaling of flowrate, current and electrode area

Pilot scale operations will be done using a one pass through a bigger cell, which means an estimate of area, current and flowrate for a given treatment time for a VC concentration to be under the discharge limit (99.99% degraded). The specific charge needed to remove 99.99 % of VC is expressed using equation 34:

$$\text{Specific charge} = \frac{Current \cdot time}{L} = \frac{0.5\ A \cdot 135 \cdot 60\ s}{0.130\ L} \approx 31154 \frac{A \cdot s}{L} \tag{34}$$

And the current density (σ) for the 10 cm^2 electrodes can be calculated with equation 35.

$$\sigma = \frac{Current}{Area} = \frac{0.5\ A}{10\ cm^2} = 0.05 \frac{A}{cm^2} \tag{35}$$

31154 coulombs/L with a current density of $0.05 \frac{A}{cm^2}$ must therefore be added to the system to decrease the concentration of vinyl chloride under the discharge limit per liter of Grindsted water.

If a treatment time of 120 seconds (2 min) is desired and the amount of treated water is kept the same, equation 36 can be derived.

$$Current = \frac{Specific\ charge}{time} \cdot volume = \frac{31154 \frac{A \cdot s}{L}}{120\ s} \cdot 0.130\ L \approx 34\ A \tag{36}$$

34 A must therefore be supplied if 130 mL is treated in 2 minutes. If the current density is kept constant the surface area of the cell can be calculated with equation 37.

$$Area = \frac{Current}{\sigma} = \frac{34\ A}{0.05 \frac{A}{cm^2}} \approx 680\ cm^2 \tag{37}$$

A cell with an electrode area of 680 cm^2 would therefore be required.

Treating 0.130 L of water in 2 min gives a flowrate of 3.9 L/h. When treating water in full scale, the flowrate is usually in m^3/h. Therefore, it is calculated how much current must be added to the system if 1 m^3/h of water is treated (equation 38). With a flowrate of 1 m^3/h and a treatment time of 2 minutes results in a treated volume of 33.33 L.

$$Current = \frac{Specific\ charge}{time} \cdot volume \frac{31154 \frac{A \cdot s}{L}}{120\ s} \cdot 33.33\ L \approx 8653\ A \tag{38}$$

8653 A must therefore be applied to the system if a flowrate of 1 m^3/h is used. The current density (σ) should be kept the same, to keep the conditions as similar as possible given equation 39.

$$Area = \frac{Current}{\sigma} = \frac{8653\ A}{0.05 \frac{A}{cm^2}} \approx 17.3\ m^2 \tag{39}$$

7. Discussion

The initial concentration of VC found by the GC-MS showed a variation from 0.9 to 2.8 mg/L with an average initial concentration of 1.7 mg/L, likely due to sampling variation in the field, as well as variation while taking samples for analysis. To account for this difference, the starting concentration of vinyl chloride was measured before every run and the results are reported as percent to minimize this influence. The highest standard deviation observed between samples was 47 % with an average standard deviation of 16 %, with no systematic error detected. Each concentration is double determined, as it was determined that having more than two determinations was not providing less uncertainty, due to the evaporation of the vinyl chloride during the analysis. The experiments were performed with variation on the electrode type, current, and flowrate to determine the optimum, while keeping the time constant at 30 minutes. Applying 0.5 A removed more VC compared to 0.1 A as expected, as higher currents should increase the production rate of reactive oxidizing species, which results in increased degradation of VC. The BDD electrode had better removal compared to the DSA electrode, as expected due to BDD having higher oxidation potential compared to DSA. The BDD electrode has an oxygen potential of 2.2-2.6 V while DSA has an oxygen potential of 1.5-1.8, as well as higher oxidation power compared to DSA electrode. When working in-situ or for longer time periods, investigating long term performance of the electrode material should also be considered, as well as corrosion and fouling. Due to the short timeframe of this project this was not investigated. 200 mL/min showed no significant improvement in the degradation of VC, despite the system being in the mass transfer region. It is possible that the change in flowrate was not big enough to cause significant improvements to the VC degradation.

Time variation experiments were performed only on the optimum parameters: BDD electrode, 100 mL/min flowrate and 0.5 A. An exponential decrease of VC concentration over time was observed. This behavior was expected based on theoretical models, where a first order reaction rate is assumed for electrochemical oxidation. As it is not possible to take samples during operation, as it would increase the headspace and thus change the rate of evaporation during the operation, each different time value is therefore determined via separate experiments, which adds uncertainty to the results, due to different initial concentrations and uncontrollable variation during the experiments. It is however still possible to make a well-fitting exponential regression based off the absolute values found with the time variation, however the percentage-based regression is likely to be more accurate.

Models were constructed based on the time variation experiments, and as such the primary goal was to see how well they fit the experimental values from these experiments. The models constructed are based on the mass transfer coefficients which were obtained prior to the experiments regarding Grindsted water, with the experimental setups explained in section 5. The tubes used in the experimental setup for the experiments regarding mass transfer were not the same tubes used in the time variation experiments for which the model was fitted, introducing some uncertainties to the model. The mass transfer is likely to have been different, however the magnitude is likely to be insignificant compared to other uncertainties, such as the evaporation. The single parameter model was briefly investigated, regarding different flowrates and applied currents. However, due to the lack of experimental data across multiple time points, this was largely uninformative, as it could only be investigated at 30 minutes. The single parameter model resembled a linear model, which is grounded in the time adjustment, since the model is effectively running at the far end of the actual time scale. Similarly, it would be expected that the evaporation term would follow first order kinetics, however the experimental results fit better with a linear model, or zero order kinetics. The linear model has a good R^2 of 0.986, while the first order model with the rate constant shown in chapter 6.3 has an R^2 of 0.934. The reason as to why the linear model performs better is likely found in the determination of the evaporation. The temperature is continuously increasing during the operation of the cell, which will increase the evaporation, which could be a part of the reason why the evaporation is linear. Since both the chemical rate of oxidation and the rate of evaporation are experimental, the indirect and evaporation terms will also be accounting for some of the experimental parameters, due to their intrinsic link to the parameters. Thus, the rate constants for the evaporation- and indirect term, will likely be different depending on the flowrate and current parameters. Increasing the flowrate is likely to increase the performance of the indirect oxidation, as more VC is available for the oxidants to oxidize, as the oxidants are likely to react with each other or the water when not in contact with a contaminant or ion, effectively wasting the energy used. The change in evaporation is more uncertain, as the increased flowrate could potentially affect the size of gas bubbles, amongst many other considerations, that could lead to a change in the evaporation. The increase in current is likely to affect evaporation and indirect oxidation. Due to the increase in current, more gas is going to be produced, which will give more surface area for the vinyl chloride to evaporate from. Similarly, the temperature increase from the applied current will also lead to more evaporation. When the current is increased the formation of oxidants will also increase, however due to the limited number of electroactive ions in the solution, the effect of current could be reducing as the current increases, as a larger fraction of the electroactive ions are already being used. Thus, only hydroxyl radicals and other oxygen-based radicals would form.

The model performance under different operational parameters was investigated by comparing it to different experimental trials that were performed. The model performance is significantly reduced when the operational parameters are changed, and the model performs optimally under the operational conditions of 0.5 A and 100 mL/min. It was not possible to compare the model to more of the trials run, as most of the remaining trials are used to construct the model or used the DSA electrode. The poor performance is somewhat expected, due to the empirical nature of the model, as the evaporation and chemical rate constants are very likely to be dependent on the operational parameters. This reduces the applicability of the model and rate constants found in this project, however they can still be applied in a more narrow context when operating with similar parameters, primarily different starting concentrations and concentrations at specific times. However, it is also important to mention the importance of the total COD from NVOCs and other volatile compounds. The total COD is much higher than the VC COD, meaning a significant amount of the energy is used for degrading other organic compounds. This is not accounted for in the empirical terms, and as such changing the total COD will also affect the performance of the model. The empirical terms are also intrinsically linked to the electrode, as there is no electrode efficiency term in the model, thus the performance is also going to be poor when a different electrode material is used.

The GCE-efficiencies were calculated to be 0.03%-0.01% for the VC degradation. The applied current of 0.5 A is much larger than the limiting current of VC at 0.118 mA, which can explain why the efficiency is low. The NVOC concentration of 4.4 mg/L, results in a COD 6 times larger than the COD for VC. The assumption of the NVOC being only CH is inaccurate, but independent of that, the COD for it is still going to be much higher than for the VC. This also means that a large proportion of the applied current is going to be applied to NVOC instead of vinyl chloride. Other organic compounds found in the samples, that would not be accounted for in the NVOC, are also likely to be degraded. Similarly, the applied current is also heating the water from 4 °C to around 30 °C. Any electrolysis that does not produce an oxidant, is effectively also wasted current, and as the average voltage is 35 V, the oxidation potential of oxygen has been surpassed for the electrodes, meaning a large amount of gaseous hydrogen and oxygen are likely to be produced. GCE is decreasing with time as expected, due to VC being degraded while the current is kept constant resulting in increasing energy inefficiency. The GCE can be somewhat misleading, as it is only calculated for the VC, and the NVOC utilizes a large proportion of the current applied.

Energy consumption was calculated and resulted in values of 16-45 Wh/mg VC. The average electricity price in the fourth quarter of 2022 in Denmark was 4.64 kr/kWh [62]. The cost of treatment would then be 0.07-0.21 kr/mg. Thus, the price for treatment of contaminated Grindsted water would be 126 - 355 kr/m^3. This is however not accounting for the increasing energy consumption as the concentration decreases, and the price is likely to be significantly higher than this.

The nitrogen and applied heating experiment was performed to qualitatively investigate, if the cell is degrading VC, or the increased temperature and the gas flowrate causes increased evaporation. The experiment showed that less VC was removed while using nitrogen and heat compared to using the cell, thus it was concluded that the cell does degrade VC. The experiment was only performed once, however the large difference from 80-90% with the cell on to the 60% with nitrogen and heating, was seen as sufficient evidence to continue with experimentation. It was important to test if the cell degrades the VC and is not only increasing the evaporation to verify all water phase results. Since the nitrogen and heat could qualitatively prove the degradation of VC, a method for the quantification of the VC evaporation was needed. Several steps were required to quantify the VC in the evaporation. As the number of VC moles evaporated was necessary, it could be determined if the concentration of VC and volume of the total gas could be determined. Similarly, it was necessary to investigate how much of the gas was potentially being lost. The amount is unknown, but the magnitude of the gas loss is vastly smaller than the amount collected, due to the gas volumetric determination. An assumption was made that the amount of produced gas is linear. To obtain the concentration of VC in the gas phase, an assumption was made that the atmospheric CO_2 concentration could be used to estimate the VC concentration. Samples of the atmosphere were taken in the lab, close to the GC-MS, and the exact concentration is unknown, but an assumption of 412 ppm, based on the global concentration. It was also assumed that VC and CO_2 have the same response factor in the GC-MS which was required to estimate the amount of moles of VC, based on the total volume produced and captured by the gas bag or measuring cylinder. The results in terms of CO_2 and VC responses from the gas bag showed a concentration of approximately 50% more than the measuring cylinder from the GC-MS, as expected. The lowered responses were expected since VC and CO_2 will be somewhat dissolved in the water present in the measuring glass, as well as there being an increased amount of additional volume from both additional tubing and headspace in the measuring cylinder. However, the ratio between CO_2 and VC response in the gas from both the gas bag and the measuring glass were fairly constant between all measurements. Although the measuring glass would have allowed for continuous measurement of the gas volume it was deemed unsuited for compositional measurements, due to the increased uncertainty from additional headspace and tubing volume, that could not be accounted for, and the change in GC-MS.

Based on the evaporation study, when the cell is inactive, a large amount of the VC is evaporated. This is only measured based on the change in the liquid, as it was deemed that the pressure from the evaporation would not be sufficient to move the VC into the measuring cylinder or the gas bag. The evaporation without the cell is fairly constant, at about 35% VC after the first 5 minutes. It would be expected that the relative evaporation of VC would be increasing as time passes, as the temperature increase causes more evaporation. When the cell is running, the vinyl chloride evaporation is increasing as time passes, with a linear behavior. It is however reduced compared to the evaporation seen when the cell is inactive, with the ratio of the evaporation with and without the cell active increasing with time. Thus, the evaporation without the cell on is much more like the evaporation with the cell on at 30 minutes, compared to at 5 minutes. This behavior is likely caused by the exponential degradation from the cell lowering the concentration initially, and since there is a flowrate in the gaseous phase, the VC is moved from the headspace, which could increase the evaporation, compared to when there is little gaseous flowrate.

The discharge limit of VC is 0.05 μg/L, and the time estimated utilizing the presented set up is 135 minutes. However, the set up presented here cannot realistically be used in the field since the VC contaminated water should be recirculated for 135 minutes for 130 mL of water which would result in 31154 C/L. This is not feasible to do in the field as the volumes and time are impractical. Similarly, a large amount of the VC is evaporating over this time period. Further calculation was done to see how large a current as well as how large of a cell is needed for one pass degradation of VC under the discharge limit with a treatment time of 2 minutes. In the case of treating 130 mL a charge of 34 A and an electrode area of 680 cm^2 are needed to degrade VC to the discharge limit. As treating 130 mL is low a higher amount of 1 m^3 of Grindsted water treated was considered. In this case a current of 8653 A and an area of 17.3 m^2 is required for treatment under the discharge limit while keeping current density constant at 0.05 A/cm^2. The calculated current and electrode area are high but not unfeasible. Electrocell offers an Electro Prod Cell which has a maximum area of 16 m^2 and a current density of 0.4 A/cm^2, meaning that based on the calculations performed increasing the current density the electrode area can be decreased and the Electro Prod Cell can be utilized. This would result in treatment of 1 m^3 of Grindsted water using one pass with a retention time of 2 minutes. The calculated current is high but expected, as the degradation of VC needs to happen in 2 minutes with one pass, while there is a large concentration of NVOC in the water as well, thus necessitating the high current and cell area. These considerations are likely to be somewhat inaccurate, due to changing the flowrate, the flow geometry being different with a larger electrode, and the degradation efficiency eventually hitting a plateau.

8. Conclusion

Based on the results produced in this project it is possible to conclude, that there is a significant difference in vinyl chloride removal after 30 min when the current is increased from 0.1 to 0.5 A. 0.1 A resulted in a removal of 46-52% depending on electrode material used. 0.5 A resulted in a removal of 88-91% depending on electrode material. The BDD electrode material performed slightly better than DSA removing 12% more at 0.1 A and 9% more at 0.5 A. Flowrate had no significant effect on degradation on vinyl chloride. 0.5 A should therefore be used with a flowrate of 100 mL/min, resulting in a general current efficiency for vinyl chloride degradation of 0.03%-0.01%. The concentration of vinyl chloride was 0.2 mg/L after a treatment time of 30 minutes with 0.5 A, which is still larger than the discharge limit of 0.05 μg/L. Based on the empirical model produced from varying the time, it is possible to determine that a treatment time of 135 minutes is required to get below the discharge limit of 0.05 μg/L when treating 130 mL of Grindsted water with 0.5 A. A semi empirical model was produced, based on a theoretical one-parameter model, an evaporation term, and an indirect oxidation term, that is able to predict the behavior of vinyl chloride degradation. This allows for estimation of the performance of different cells with different operational conditions and vinyl chloride concentrations. The one parameter model did not fit the experimental results, even when adding evaporation to the model. When the indirect oxidation term is included, a model with an R^2 of 0.999 is produced. However, due to the model being semi empirical, the model performance is significantly decreased when operational parameters are changed.

Experiments performed on the gas phase showed that between 20 and 35% of the vinyl chloride evaporates without any treatment, depending on time. From 5 to 10 min a significant difference was observed going from 20 to 35%. After 10 minutes no significant difference in the amount of vinyl chloride evaporated was observed. GC-MS results showed that the amount of vinyl chloride in the gas produced when the cell is on, was between 11-92% less than when the cell was not turned on, meaning the cell can degrade vinyl chloride and is not only increasing the evaporation. Combining the vinyl chloride amounts in the water and gas phase, it is possible to conclude that 27% is degraded after 5 min, 22 % after 10 minutes, 50 % after 20 minutes and 46 % after 30 minutes.

9. Further work

There are a lot of interesting aspects that could be improved or investigated further. Performing the experiments on the big cell as well would be useful for the field tests that will be using the big cell. Different electrode materials and electrode spacings would be beneficial to test as well since they might contribute to better degradation of vinyl chloride. The electrode spacing for the small cell was selected based on which spacing was most comparable to the big cell. Even though the BDD electrode is well suited for degrading organics, it would be interesting to test a less costly electrode, for example Fe electrode which has also been proven to provide satisfactory results while dealing with chlorinated ethenes, although in in-situ where other electrode considerations are involved. The use of catalysts, nanoparticles and polarity reversal could be investigated. Catalysts and various nanoparticles could potentially increase current efficiency, however they would also need to be collected in the system, as it could be problematic to discharge these to the environment. The polarity reversal was not considered here due to an insignificant amount of fouling, but in a field test it might become a problem since larger volumes are treated.

The Grindsted water was at 4 °C at the start of the experiment and around 30 °C at the end. These conditions are unlikely to be the case in the field, since it will be a one pass setup, meaning the water temperature will be constant. Being able to control the temperature would be beneficial as the results would be more comparable to the field test. Controlling the temperature would also provide more reliable results since the start and end concentration would be determined at the same temperature. The temperature increase will affect the evaporation, and potentially also affect the efficiency of the cell.

The evaporation of vinyl chloride is a problem especially when working in a pump-and-treat setting. Analyzing the gas is important and having a better method would be extremely beneficial as it would provide more reliable results. The way this project quantified the results is using CO_2 in the atmosphere and assuming that both vinyl chloride and CO_2 have the same response factor in the GC-MS. Having a way to measure the vinyl chloride concentration in the gas without the previous assumptions being made would lead to more reliable results.

Testing with further time points would be interesting to investigate, primarily to see when the discharge limit would be reached, and how much of the vinyl chloride has evaporated compared to degraded. Calculations showed that running the experiment for 135 minutes would decrease the vinyl chloride concentration to below the discharge limit.

A fully theoretical model, or a semi-empirical model that can account for more of the operational parameters would likely be a significant improvement to the current model. However, this is likely to be a very arduous and extensive endeavor.

10. References

[1] M. L. Brusseau, I. L. Pepper, and C. P. Gerba, “The Extent of Global Pollution,” in *Environmental and Pollution Science*, Elsevier, 2019, pp. 3–8. doi: 10.1016/B978-0-12-814719-1.00001-X.

[2] K. R. Hakeem, M. S. Akhtar, and S. N. A. Abdullah, Eds., *Plant, Soil and Microbes*. Cham: Springer International Publishing, 2016. doi: 10.1007/978-3-319-27455-3.

[3] N. Donley, “The USA lags behind other agricultural nations in banning harmful pesticides,” *Environ. Health*, vol. 18, no. 1, p. 44, Dec. 2019, doi: 10.1186/s12940-019-0488-0.

[4] A. Cordner, V. Y. De La Rosa, L. A. Schaider, R. A. Rudel, L. Richter, and P. Brown, “Guideline levels for PFOA and PFOS in drinking water: the role of scientific uncertainty, risk assessment decisions, and social factors,” *J. Expo. Sci. Environ. Epidemiol.*, vol. 29, no. 2, pp. 157–171, Mar. 2019, doi: 10.1038/s41370-018-0099-9.

[5] J. W. N. Smith *et al.*, “Environmental fate and effects of polyand perfluoroalkyl substances (PFAS).” CONCAWE Reports, 2016. [Online]. Available: https://www.concawe.eu/wp-content/uploads/2016/06/Rpt_16-8.pdf

[6] R. D. Morrison, B. L. Murphy, and R. E. Doherty, “Chlorinated Solvents,” in *Environmental Forensics*, Elsevier, 1964, pp. 259–277. doi: 10.1016/B978-012507751-4/50034-3.

[7] “Groundwater analyses for vinylchloride,” *GEUS*, 2023. https://data.geus.dk/geusmap/?mapname=grundvand (accessed Feb. 18, 2023).

[8] X. Maymó-Gatell, Y. Chien, J. M. Gossett, and S. H. Zinder, “Isolation of a Bacterium That Reductively Dechlorinates Tetrachloroethene to Ethene,” *Science*, vol. 276, no. 5318, pp. 1568–1571, Jun. 1997, doi: 10.1126/science.276.5318.1568.

[9] B. van der Zaan *et al.*, “Correlation of *Dehalococcoides* 16S rRNA and Chloroethene-Reductive Dehalogenase Genes with Geochemical Conditions in Chloroethene-Contaminated Groundwater,” *Appl. Environ. Microbiol.*, vol. 76, no. 3, pp. 843–850, Feb. 2010, doi: 10.1128/AEM.01482-09.

[10] C. Scheutz *et al.*, “Concurrent Ethene Generation and Growth of *Dehalococcoides* Containing Vinyl Chloride Reductive Dehalogenase Genes During an Enhanced Reductive Dechlorination Field Demonstration,” *Environ. Sci. Technol.*, vol. 42, no. 24, pp. 9302–9309, Dec. 2008, doi: 10.1021/es800764t.

[11] D. E. Fennell, J. M. Gossett, and S. H. Zinder, “Comparison of Butyric Acid, Ethanol, Lactic Acid, and Propionic Acid as Hydrogen Donors for the Reductive Dechlorination of Tetrachloroethene,” *Environ. Sci. Technol.*, vol. 31, no. 3, pp. 918–926, Mar. 1997, doi: 10.1021/es960756r.

[12] P. K. H. Lee, D. Cheng, K. A. West, L. Alvarez-Cohen, and J. He, “Isolation of two new *Dehalococcoides mccartyi* strains with dissimilar dechlorination functions and their characterization by comparative genomics via microarray analysis: Physiology and genome of new *Dehalococcoides*,” *Environ. Microbiol.*, vol. 15, no. 8, pp. 2293–2305, Aug. 2013, doi: 10.1111/1462-2920.12099.

[13] X. Maymó-Gatell, T. Anguish, and S. H. Zinder, “Reductive Dechlorination of Chlorinated Ethenes and 1,2-Dichloroethane by ‘ *Dehalococcoides ethenogenes* ’ 195,” *Appl. Environ. Microbiol.*, vol. 65, no. 7, pp. 3108–3113, Jul. 1999, doi: 10.1128/AEM.65.7.3108-3113.1999.

[14] A. C. Heimann, A. K. Friis, C. Scheutz, and R. Jakobsen, “Dynamics of reductive TCE dechlorination in two distinct H2 supply scenarios and at various temperatures,” *Biodegradation*, vol. 18, no. 2, pp. 167–179, Feb. 2007, doi: 10.1007/s10532-006-9052-z.

[15] "Danmarks generationsforureninger," *Danske regioner*, May 18, 2022. https://storymaps.arcgis.com/stories/2279b5b1b2d746428fda77a84c8a82ae (accessed Feb. 15, 2023).

[16] M. Christensen, "Ny forskning afslører voldsom forurening fra gammelt giftdepot i Grindsted," *DR*, Jan. 26, 2018. https://www.dr.dk/nyheder/indland/ny-forskning-afsloerer-voldsom-forurening-fra-gammelt-giftdepot-i-grindsted (accessed Feb. 15, 2023).

[17] "Vurdering af påvirkning af Grindsted Å og Grindsted Engsø fra jordforureningerne fra Grindstedværket." Miljøministeriet, Feb. 02, 2011. Accessed: Feb. 15, 2023. [Online]. Available: https://mst.dk/media/mst/67666/Notat%20om%20p%C3%A5virkning%20af%20Grindsted%20%C3%85.pdf

[18] "En samlet plan for generationsforureninger." Danske regioner, Feb. 2023. Accessed: Feb. 15, 2023. [Online]. Available: https://www.regioner.dk/media/13094/plan-for-generationsforureninger-marts-2020.pdf

[19] M. Frederiksen, M. M. Broholm, and P. L. Bjerg, "Vurdering af jord- og grundvandsforurening på Grindstedværkets grund og påvirkning af nedstrøms grundvand." Danmarks Tekniske Universitet (DTU), 2019. Accessed: Feb. 15, 2023. [Online]. Available: https://backend.orbit.dtu.dk/ws/portalfiles/portal/178417249/dtu_notat_om_fabriksgrunden_i_grindsted.pdf

[20] *Risikovurdering af overfladevand, som er påvirket af punktkildeforurenet grundvand*. Miljøstyrelsen, 2014.

[21] "Grundvandskemi for boring 114.1447," *GEUS*, Apr. 28, 2022. https://data.geus.dk/JupiterWWW/proeve.jsp?proeveid=2020024579 (accessed Feb. 18, 2023).

[22] "Grundvandskemi for boring 114.1495," *GEUS*, Apr. 28, 2022. https://data.geus.dk/JupiterWWW/proeve.jsp?proeveid=2021025083 (accessed Feb. 18, 2023).

[23] COWI, "Laboratorieforsøg til test af AOP metoder overfor forureningsfanen fra det tidligere Grindstedværkets fabriksgrund." Region Syddanmark, Oct. 27, 2023. [Online]. Available: https://regionsyddanmark.dk/media/0emdx0t0/grindsted-rapport-test-af-aop-metoder-overfor-forureningsfanen-fra-fabriksgrunden.pdf

[24] S. Henry, C. Hardcastle, and S. Warner, "Chlorinated Solvent and DNAPL Remediation: An Overview of Physical, Chemical, and Biological Processes," in *ACS Symposium Series*, 2002, pp. 1–20. doi: 10.1021/bk-2002-0837.ch001.

[25] Environmental Security Technology Certification Program, "Bioaugmentation for Remediation of Chlorinated Solvents: Technology Development Status and Research Needs.," Environmental Security Technology Certification Program (ESTCP), 2005. [Online]. Available: https://clu-in.org/download/remed/bioaug2005.pdf

[26] "Miljøprojekt, 983 Teknologiudviklingsprogrammet for jord- og grundvandsforurening – Stimuleret in situ reduktiv deklorering. Vidensopsamling og screening af lokaliteter - Hovedrapport – 2 Nedbrydning af klorerede ethener samt 1,1,1-triklorethan." https://www2.mst.dk/udgiv/publikationer/2005/87-7614-527-1/html/kap02.htm (accessed Feb. 18, 2023).

[27] PubChem, "Trichloroethylene." https://pubchem.ncbi.nlm.nih.gov/compound/6575 (accessed Feb. 18, 2023).

[28] PubChem, "Tetrachloroethylene." https://pubchem.ncbi.nlm.nih.gov/compound/31373 (accessed Feb. 18, 2023).

[29] PubChem, "Vinyl Chloride." https://pubchem.ncbi.nlm.nih.gov/compound/6338 (accessed Feb. 18, 2023).

[30] PubChem, "cis-1,2-Dichloroethylene." https://pubchem.ncbi.nlm.nih.gov/compound/643833 (accessed Feb. 18, 2023).

[31] “Tetrachloroethylene - Part 1 - Environment.” Institute for health and consumer protection - European Chemicals Bureau, 2005.

[32] “Trichloroethylene.” Institute for health and consumer protection - European Chemicals Bureau, 2004. [Online]. Available: https://echa.europa.eu/documents/10162/83f0c99f-f687-4cdf-a64b-514f1e26fdc0

[33] “Dichloroethylener.” Miljøstyrelsen, Apr. 13, 2005. [Online]. Available: https://mst.dk/media/196500/dichlorethylen-540-59-0.pdf

[34] “Vinyl Chloride.” OECD SIDS - UNEP publications, Nov. 09, 2001. [Online]. Available: https://hpvchemicals.oecd.org/ui/handler.axd?id=c39b3fef-21c9-4d3d-a685-4698e7280ebc

[35] S. Gao *et al.*, “Mixed Redox Catalytic Destruction of Chlorinated Solvents in Soils and Groundwater: From the Laboratory to the Field,” *Ann. N. Y. Acad. Sci.*, vol. 1140, pp. 435–445, Oct. 2008, doi: 10.1196/annals.1454.044.

[36] “Groundwater Pump and Treat | FRTR Remediation Technologies Screening Matrix.” https://www.frtr.gov/matrix/Groundwater-Pump-and-Treat/ (accessed May 01, 2023).

[37] H. Meuser, “Groundwater, Soil Vapour and Surface Water Treatment,” in *Soil Remediation and Rehabilitation: Treatment of Contaminated and Disturbed Land*, H. Meuser, Ed., in Environmental Pollution. Dordrecht: Springer Netherlands, 2013, pp. 279–346. doi: 10.1007/978-94-007-5751-6_7.

[38] A. Kokkoli, N. Agerholm, H. R. Andersen, and K. M. S. Kaarsholm, “Synergy between ozonation and GAC filtration for chlorinated ethenes-contaminated groundwater treatment,” *J. Water Process Eng.*, vol. 44, p. 102356, Dec. 2021, doi: 10.1016/j.jwpe.2021.102356.

[39] J. Muff, “Electrochemical Oxidation - A Versatile Technique for Aqueous Organic Contaminant Degradation,” in *Chemistry of Advanced Environmental Purification Processes of Water Fundamentals and Applications*, Elsevier, 2014, p. http://dx.doi.org/10.1016/B978-0-444-53178-0.00003-1. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780444531780000031

[40] F. Miao *et al.*, “Degradation of polyvinyl chloride microplastics via an electro-Fenton-like system with a TiO2/graphite cathode,” vol. 399, Nov. 2020, doi: https://doi.org/10.1016/j.jhazmat.2020.123023.

[41] G. Santana-Martínez, G. Roa-Morales, E. Martin del Campo, R. Romero, B. A. Frontana-Uribe, and R. Natividad, “Electro-Fenton and Electro-Fenton-like with in situ electrogeneration of H2O2 and catalyst applied to 4-chlorophenol mineralization,” vol. 195, pp. 246–256, Mar. 2016, doi: https://doi.org/10.1016/j.electacta.2016.02.093.

[42] L. Martin-Pozo, M. del C. Gómez-Regalado, M. Teresa García-Córcoles, and A. Zafra-Gómez, “Removal of quinolone antibiotics from wastewaters and sewage sludge. Electrochemical processes,” in *Emerging Contaminants in the Environment Challenges and Sustainable Practices*, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780323851602000159

[43] R. Fu, P.-S. Zhang, Y.-X. Jiang, L. Sun, and X.-H. Sun, “Wastewater treatment by anodic oxidation in electrochemical advanced oxidation process: Advance in mechanism, direct and indirect oxidation detection methods,” in *Chemosphere*, 2023.

[44] Y.-J. Liu, C.-Y. Hu, and L. Shang-Lien, “Direct and indirect electrochemical oxidation of amine-containing pharmaceuticals using graphite electrodes,” vol. 366, pp. 592–605, Mar. 2019, doi: https://doi.org/10.1016/j.jhazmat.2018.12.037.

[45] C. Comninellis, “ELECTROCATALYSIS IN THE ELECTROCHEMICAL CONVERSION/COMBUSTION OF ORGANIC POLLUTANTS FOR WASTE WATER TREATMENT,” vol. 39 (11–12), 1862 1857, doi: 10.1016/0013-4686(94)85175-1.

[46] M. Panizza and G. Cerisola, “Influence of anode material on the electrochemical oxidation of 2-naphthol: Part 1. Cyclic voltammetry and potential step experiments,” vol. 48, no. 23, pp. 3491–3497, Oct. 2003, doi: https://doi.org/10.1016/S0013-4686(03)00468-7.

[47] J. Muff, “Advanced Redox and Separation Processes Electrochemical advanced oxidation processes,” Aalborg university Esbjerg, Feb. 23, 2023.

[48] C. A. Martínez-Huitle and M. Panizza, “Electrochemical oxidation of organic pollutants for wastewater treatment,” *Curr. Opin. Electrochem.*, vol. 11, pp. 62–71, Oct. 2018, doi: https://doi.org/10.1016/j.coelec.2018.07.010.

[49] A. Kapałka, G. Fóti, and C. Comninellis, “Kinetic modelling of the electrochemical mineralization of organic pollutants for wastewater treatment,” *J. Appl. Electrochem.*, vol. 38, pp. 7–16, 2008.

[50] N. Nadeeshani, J. Bhakthi, and P. Gayani, “ELECTROCHEMICAL WATER POLLUTANT REMOVAL; CAN WE MAKE IT SUSTAINABLE,” Dec. 2012, [Online]. Available: https://www.researchgate.net/publication/264122026_ELECTROCHEMICAL_WATER_POLLUTANT_REMOVAL_CAN_WE_MAKE_IT_SUSTAINABLE

[51] J. Muff, H. Jepsen, and E. Søgaard, “Bench-Scale Study of Electrochemical Oxidation for On-Site Treatment of Polluted Groundwater,” *J. Environ. Eng.*, vol. 138, no. 9, pp. 915–922, Sep. 2012, doi: 10.1061/(ASCE)EE.1943-7870.0000561.

[52] C. A. Martínez-Huitle, M. A. Rodrigo, I. Sirés, and O. Scialdone, “Single and Coupled Electrochemical Processes and Reactors for the Abatement of Organic Water Pollutants: A Critical Review,” Dec. 2015, doi: https://doi-org.zorac.aub.aau.dk/10.1021/acs.chemrev.5b00361.

[53] A. Baddouh *et al.*, “Electrochemical decolorization of Rhodamine B dye: Influence of anode material, chloride concentration and current density,” vol. 6, no. 2, pp. 2041–2047, Apr. 2018, doi: https://doi.org/10.1016/j.jece.2018.03.00.

[54] B. H. Hyldegaard, “ELECTROCHEMICAL ZONE FOR DEGRADATION OF CHLORINATED ETHENES IN AQUIFERS,” Technical University of Denmark, Department of Civil Engineering, Kongens Lyngby, Jul. 2019.

[55] B. Højlund Hyldegaard and L. M. Ottosen, “Selecting Electrode Materials and Sequence for Electrochemical Removal of Chlorinated Ethenes in Groundwater,” *Springer Nat. Switz. AG 2020*, p. 16, Sep. 2019, doi: https://doi.org/10.1007/s11270-020-04641-8.

[56] H. Chow, M. Ingelsson, E. P. L. Roberts, and A. Le-Tuan Pham, “How does periodic polarity reversal affect the faradaic efficiency and electrode fouling during iron electrocoagulation?,” vol. 203, Sep. 2021, doi: https://doi.org/10.1016/j.watres.2021.117497.

[57] L. Rajic, N. Fallahpour, and A. N. Alshawabkeh, “Impact of electrode sequence on electrochemical removal of trichloroethylene from aqueous solution,” vol. 174–175, pp. 427–434, Sep. 2015, doi: https://doi.org/10.1016/j.apcatb.2015.03.018.

[58] “Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Vinyl Chloride,” *Goverment of Canada*, Apr. 22, 2022. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-vinyl-chloride/page-5-guidelines-canadian-drinking-water-quality-vinyl-chloride.html (accessed May 08, 2023).

[59] “Vinyl chloride, Health-based maximum contaminant level,” *New Jersey Department of Environmental Protection*. https://www.state.nj.us/dep/watersupply/pdf/append-b-section-s.pdf (accessed May 08, 2023).

[60] S. U. H. I. on E. C. A. A. F.-P. S. B. A. B. Laboratory NASA’s Jet Propulsion, “The Atmosphere: Getting a Handle on Carbon Dioxide,” *Climate Change: Vital Signs of the Planet*.

https://climate.nasa.gov/news/2915/the-atmosphere-getting-a-handle-on-carbon-dioxide (accessed May 12, 2023).

[61] Miljøministeriet, “Bekendtgørelse om miljøkvalitetskrav for vandområder og krav til udledning af forurenende stoffer til vandløb, søer eller havet, BEK nr 1022 af 25/08/2010,” *Retsinformation*, Aug. 25, 2010. https://www.retsinformation.dk/eli/lta/2010/1022 (accessed May 12, 2023).

[62] “Elprisstatistik 4. kvartal 2022,” *Forsyningstilsynet*, Feb. 03, 2023. https://forsyningstilsynet.dk/media/11445/elprisstatistik-4-kvartal-2022.pdf (accessed May 25, 2023).

11. Appendix

Appendix 1 - Determining mass transfer coefficients

Forward scan for the small cell with different spacers and flowrates

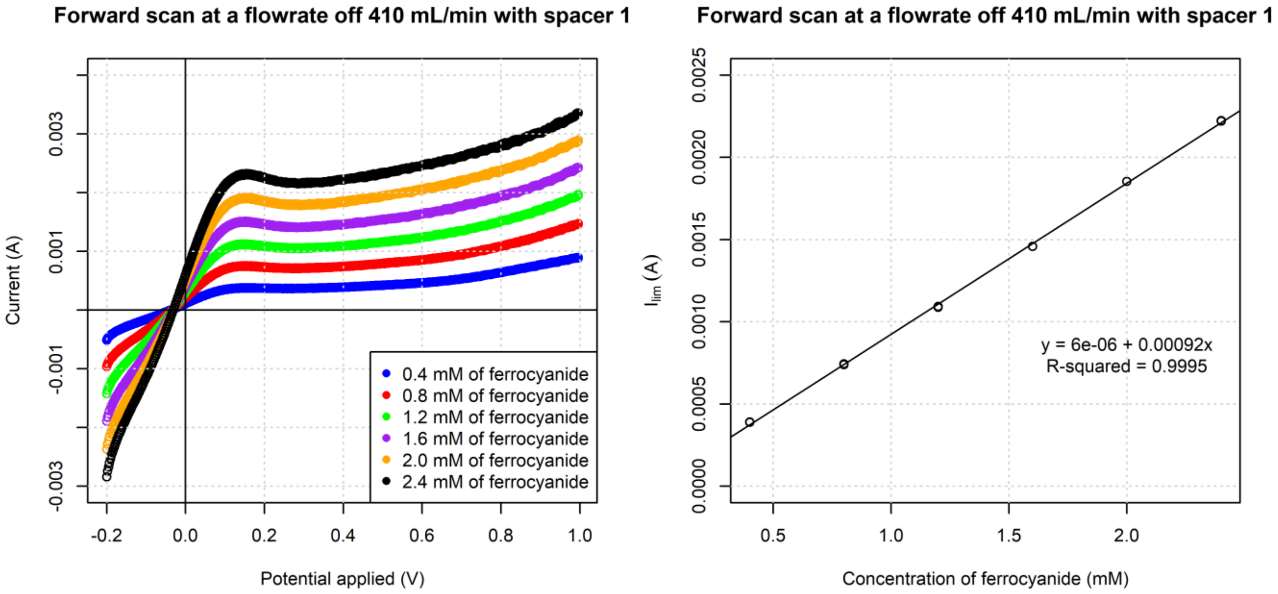


Figure 42 - Forward scan at 0.4 V for spacer 1 at a flowrate of 410 mL/min

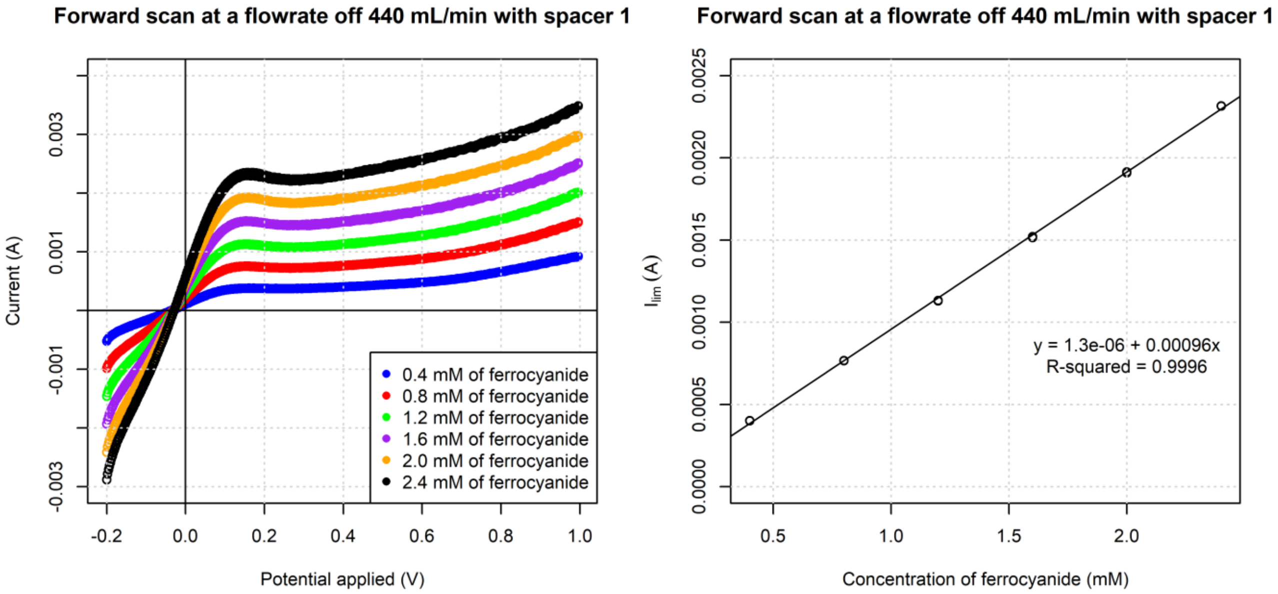


Figure 43 - Forward scan at 0.4 V for spacer 1 at a flowrate of 440 mL/min

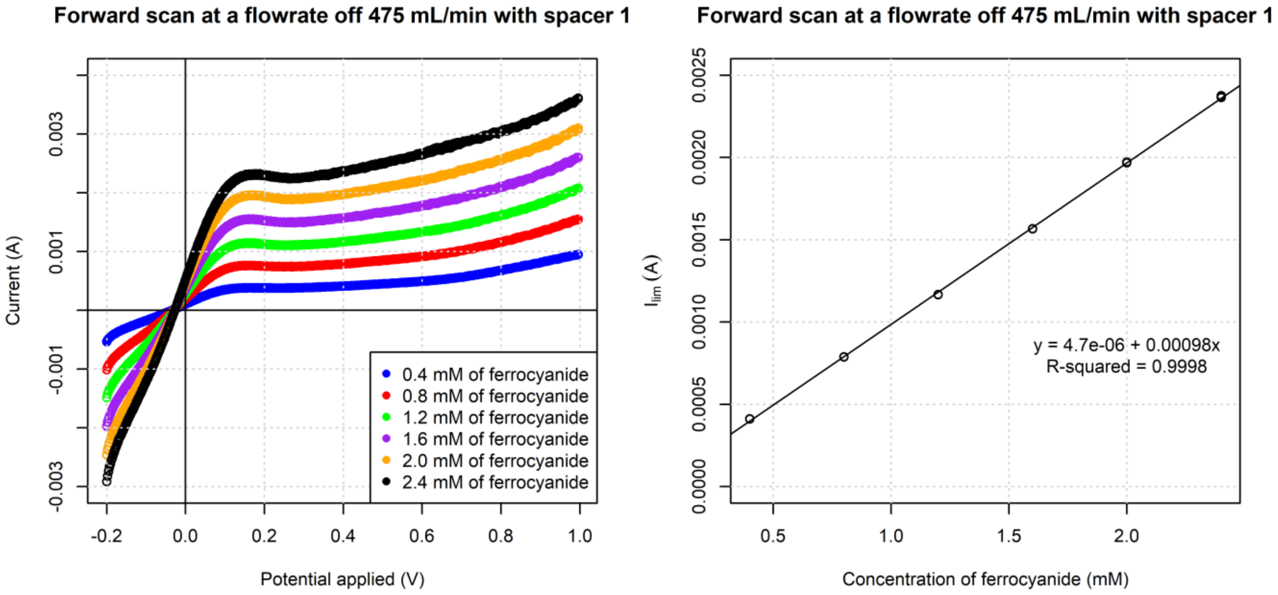


Figure 44 - Forward scan at 0.4 V for spacer 1 at a flowrate of 475 mL/min

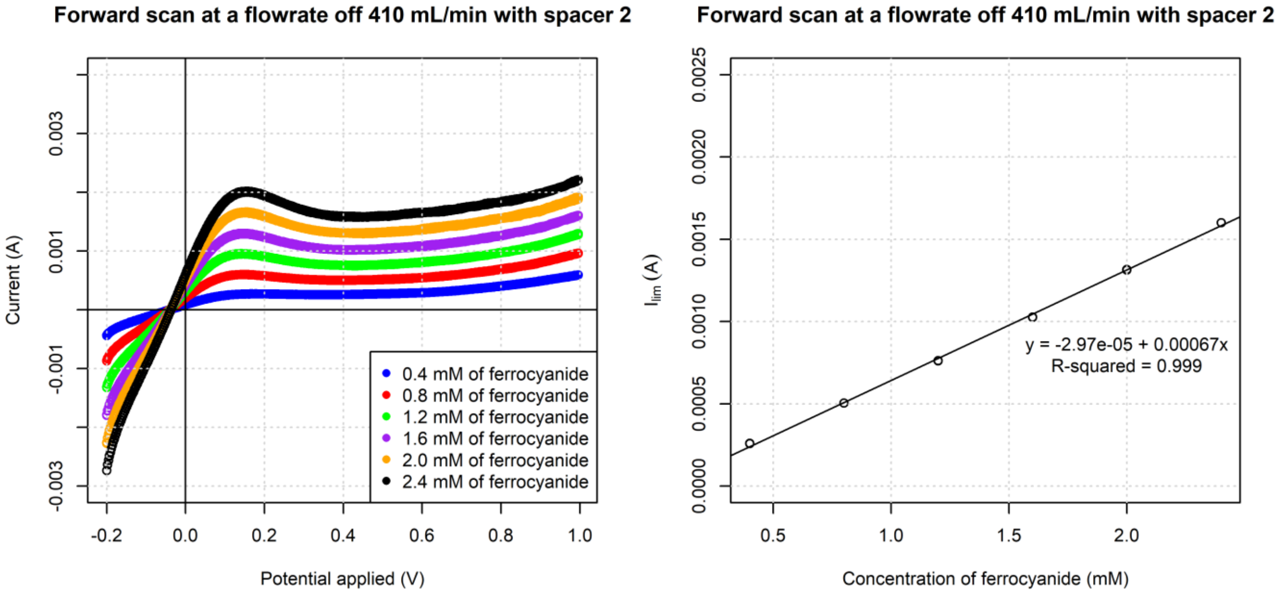


Figure 45 - Forward scan at 0.4 V for spacer 2 at a flowrate of 410 mL/min

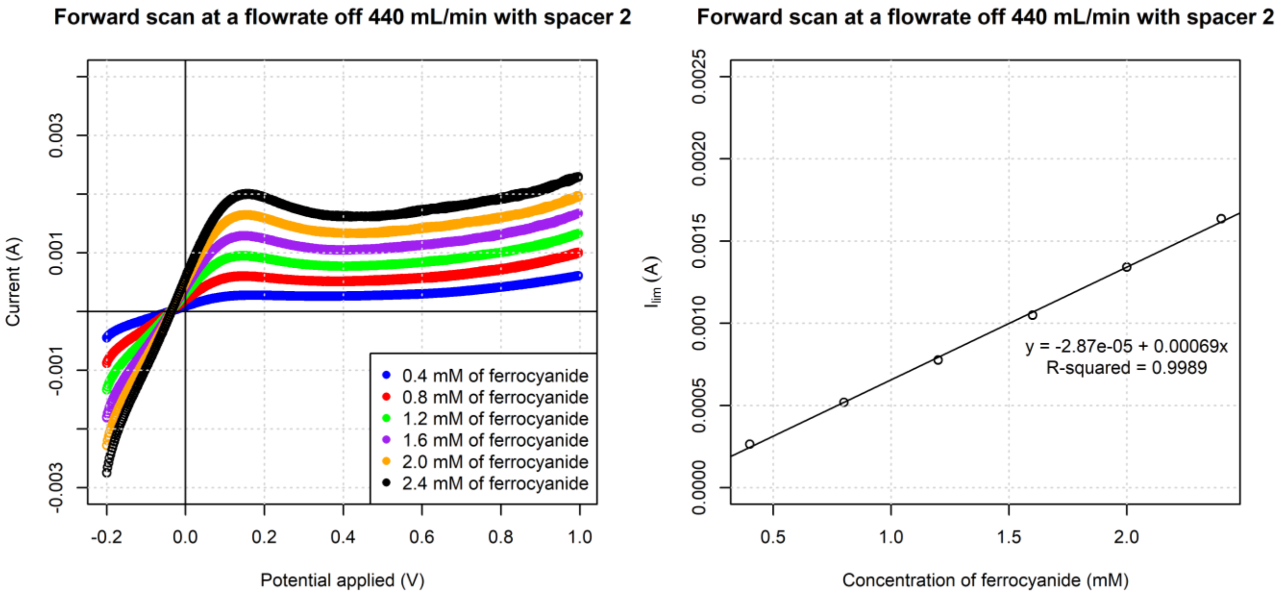


Figure 46 - Forward scan at 0.4 V for spacer 2 at a flowrate of 440 mL/min

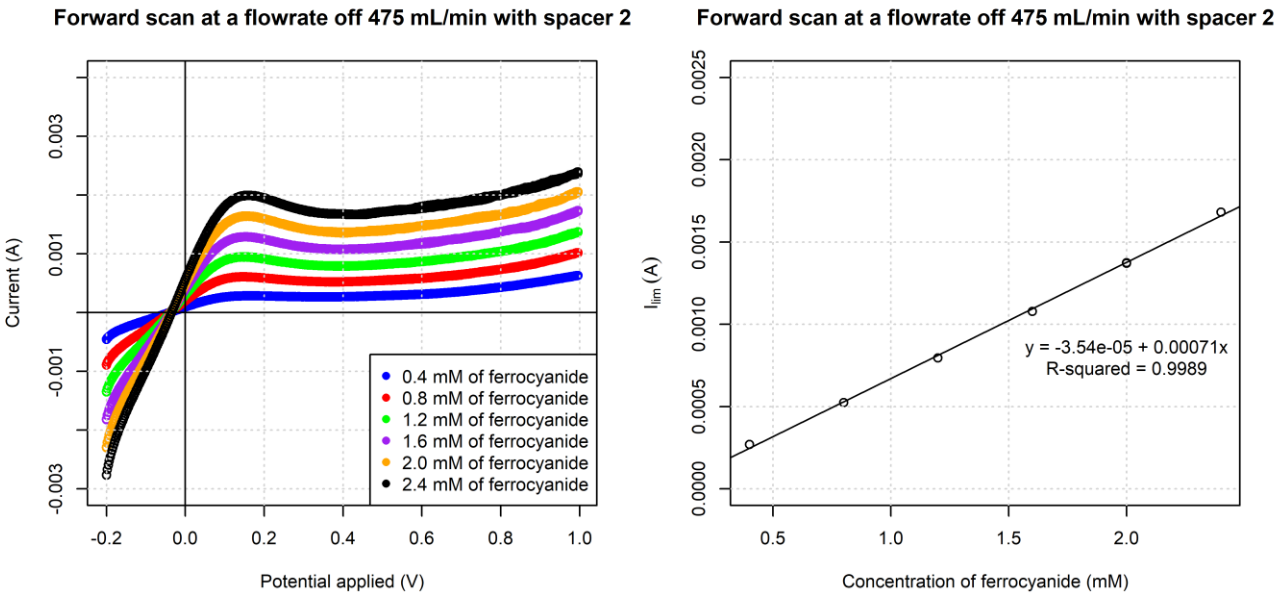


Figure 47 - Forward scan at 0.4 V for spacer 2 at a flowrate of 475 mL/min

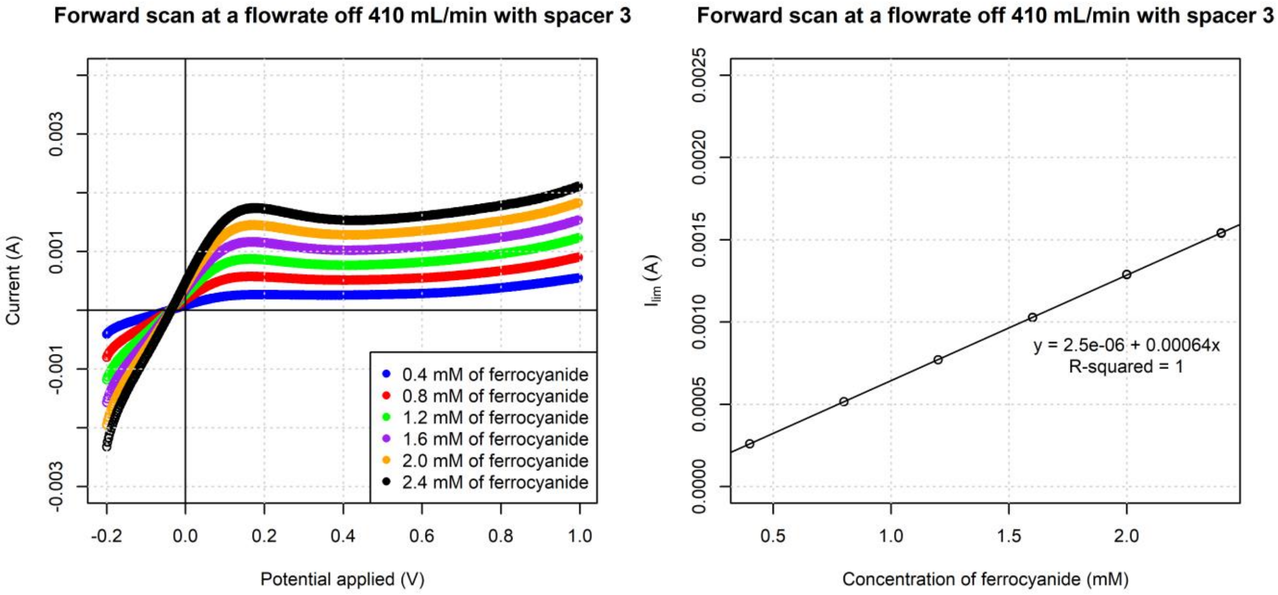


Figure 48 - Forward scan at 0.4 V for spacer 3 at a flowrate of 410 mL/min

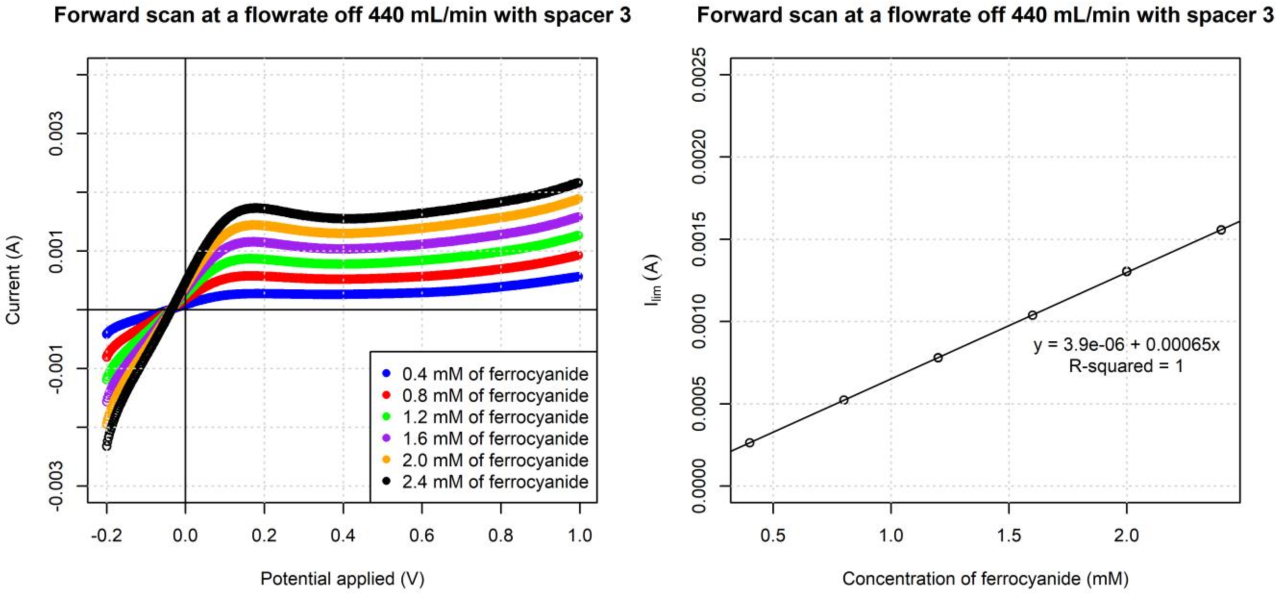


Figure 49 - Forward scan at 0.4 V for spacer 3 at a flowrate of 440 mL/min

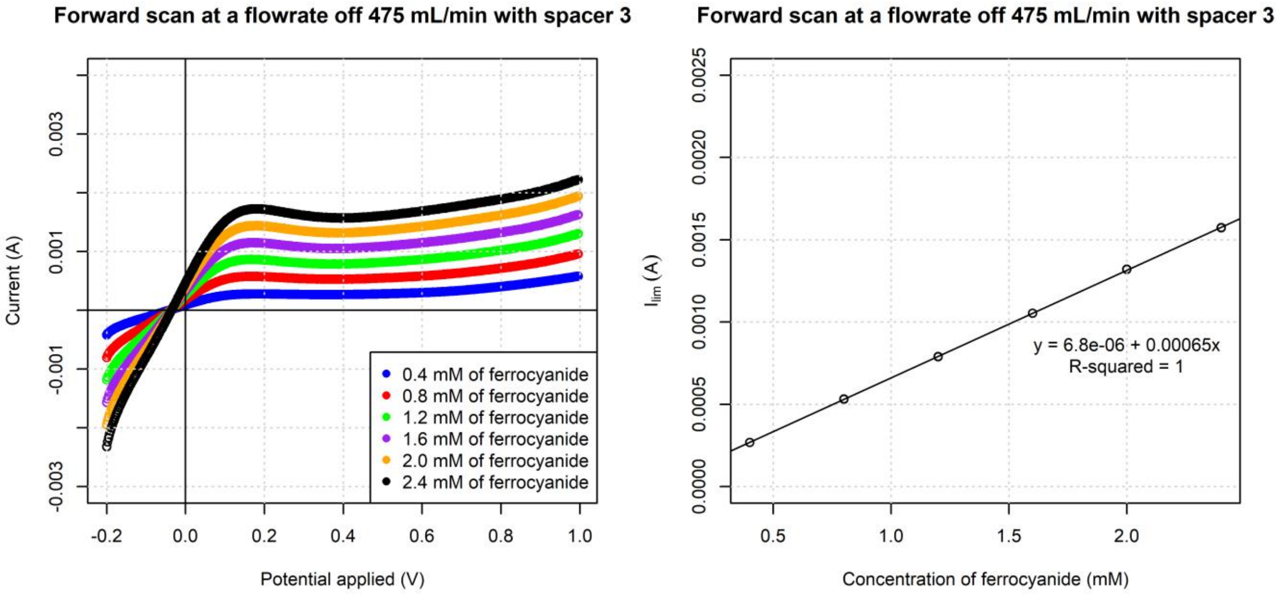


Figure 50 - Forward scan at 0.4 V for spacer 3 at a flowrate of 475 mL/min

Backscan for the small cell with different spacers and flowrates

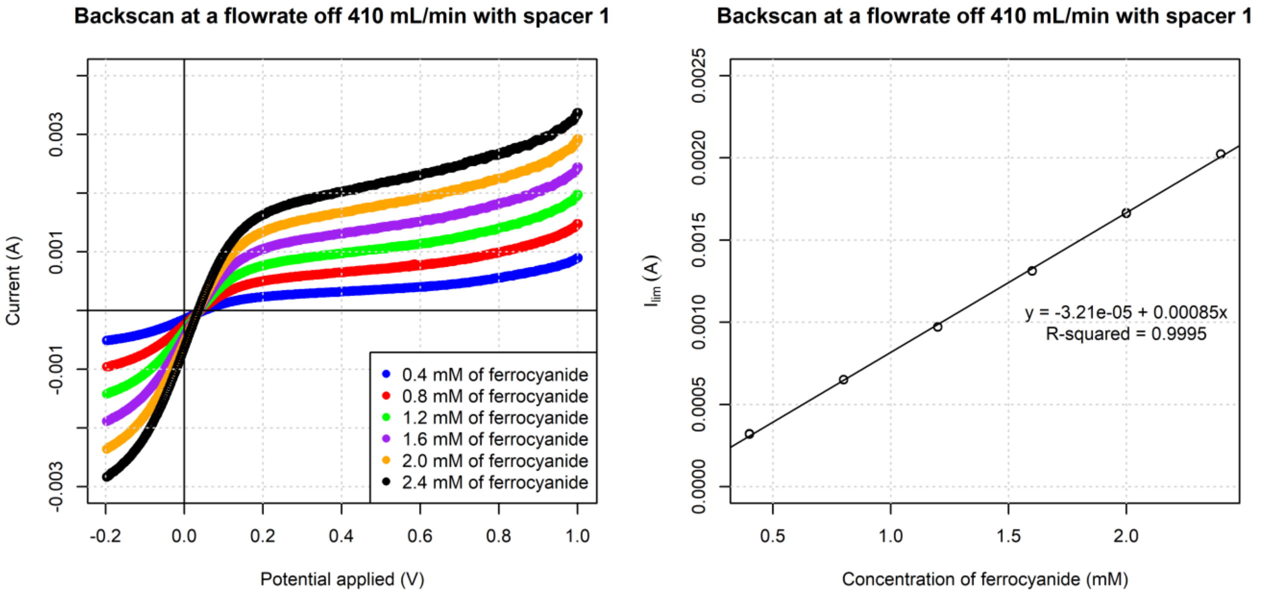


Figure 51 - Backscan at 0.4 V for spacer 1 at a flowrate of 410 mL/min

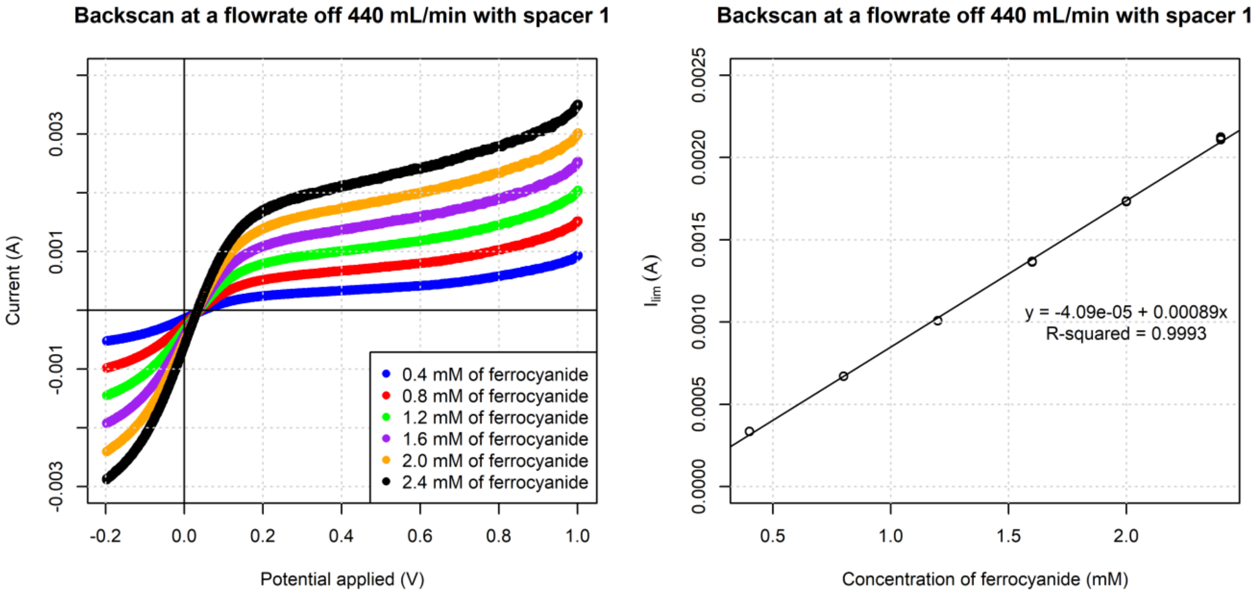


Figure 52 - Backscan at 0.4 V for spacer 1 at a flowrate of 440 mL/min

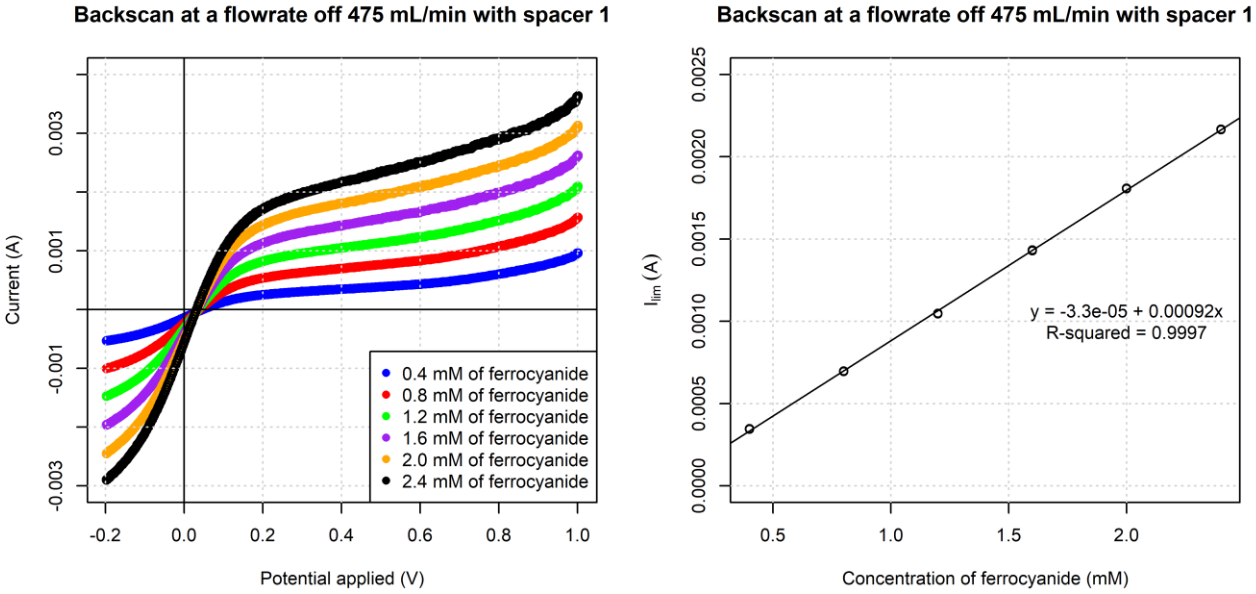


Figure 53 - Backscan at 0.4 V for spacer 1 at a flowrate of 475 mL/min

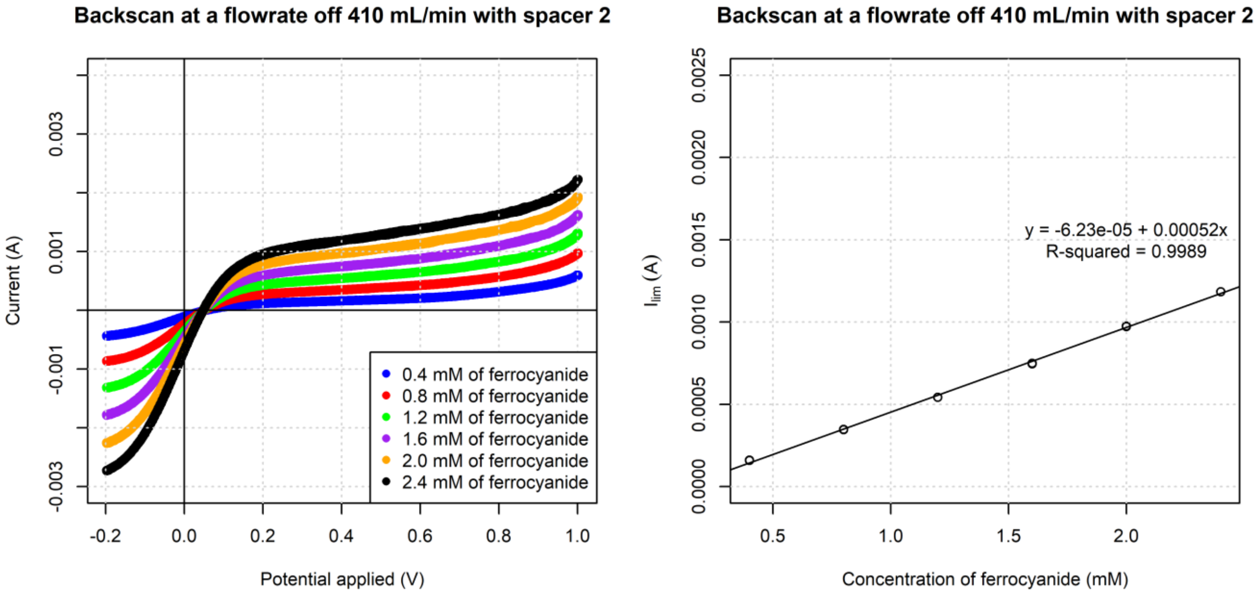


Figure 54 - Backscan at 0.4 V for spacer 2 at a flowrate of 410 mL/min

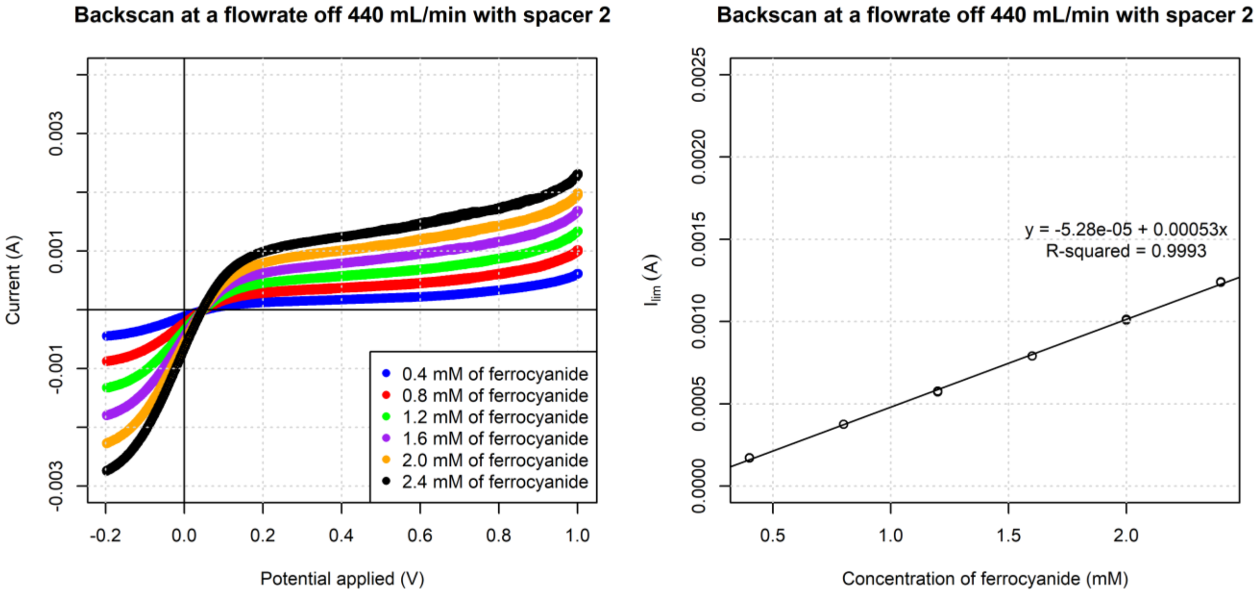


Figure 55 - Backscan at 0.4 V for spacer 2 at a flowrate of 440 mL/min

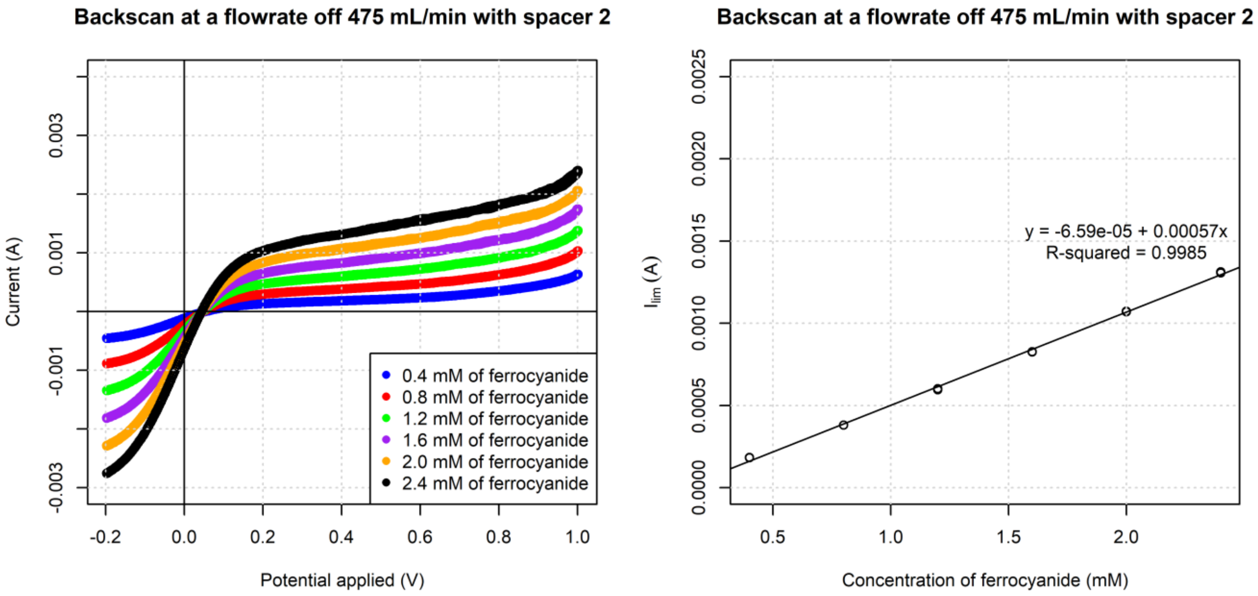


Figure 56 - Backscan at 0.4 V for spacer 2 at a flowrate of 475 mL/min

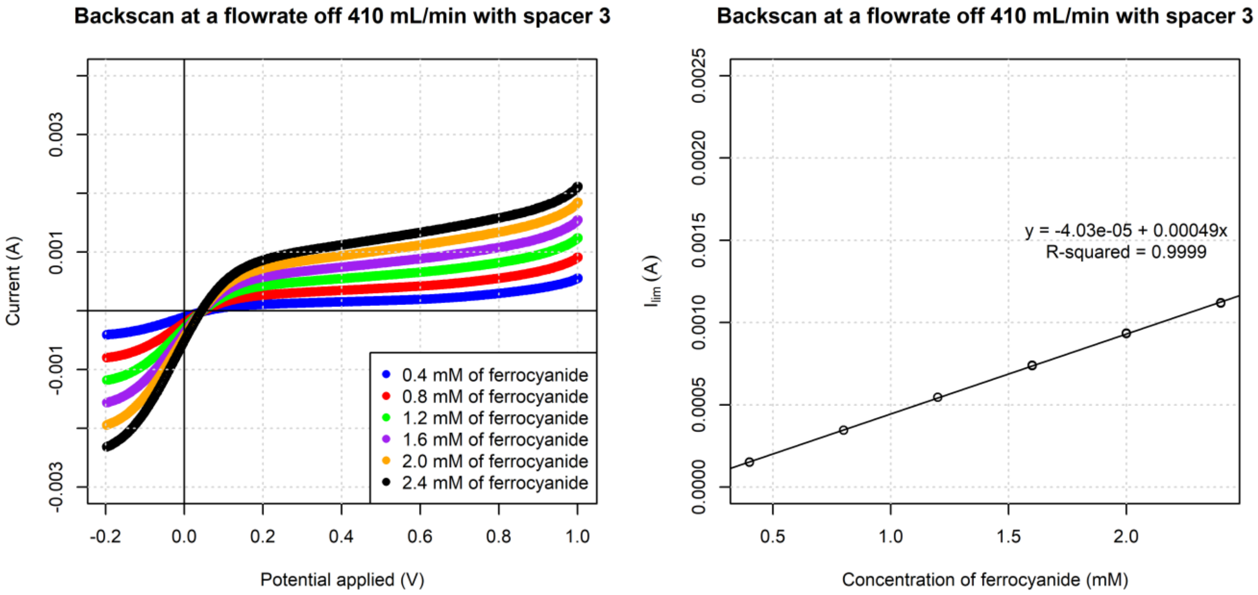


Figure 57 - Backscan at 0.4 V for spacer 3 at a flowrate of 410 mL/min

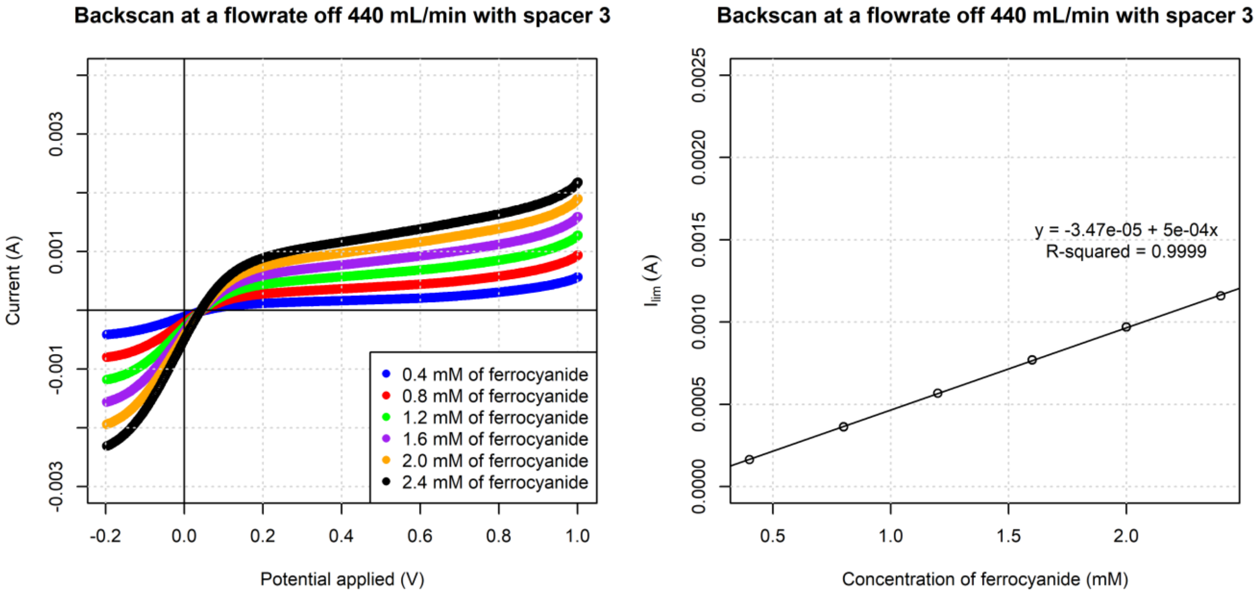


Figure 58 - Backscan at 0.4 V for spacer 3 at a flowrate of 440 mL/min

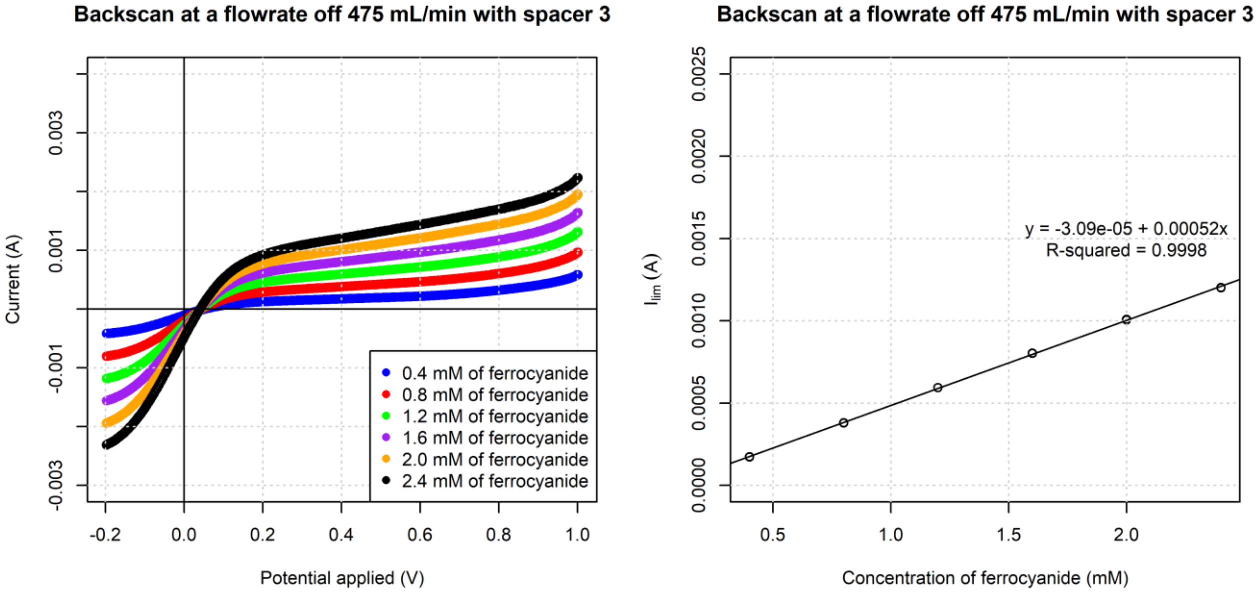
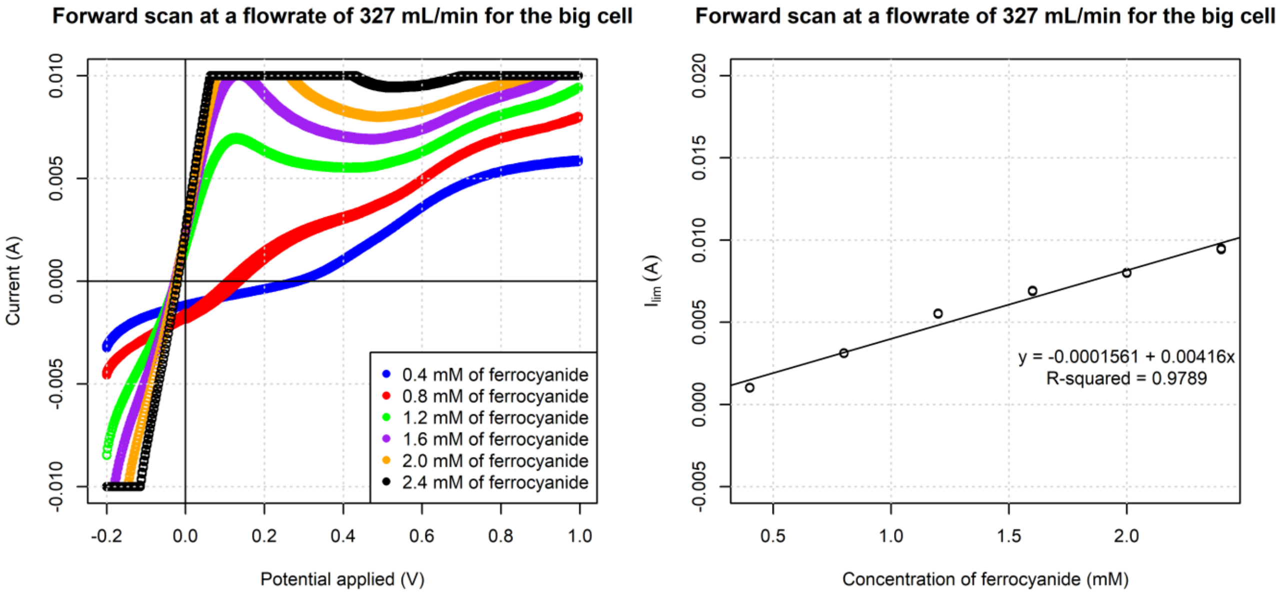


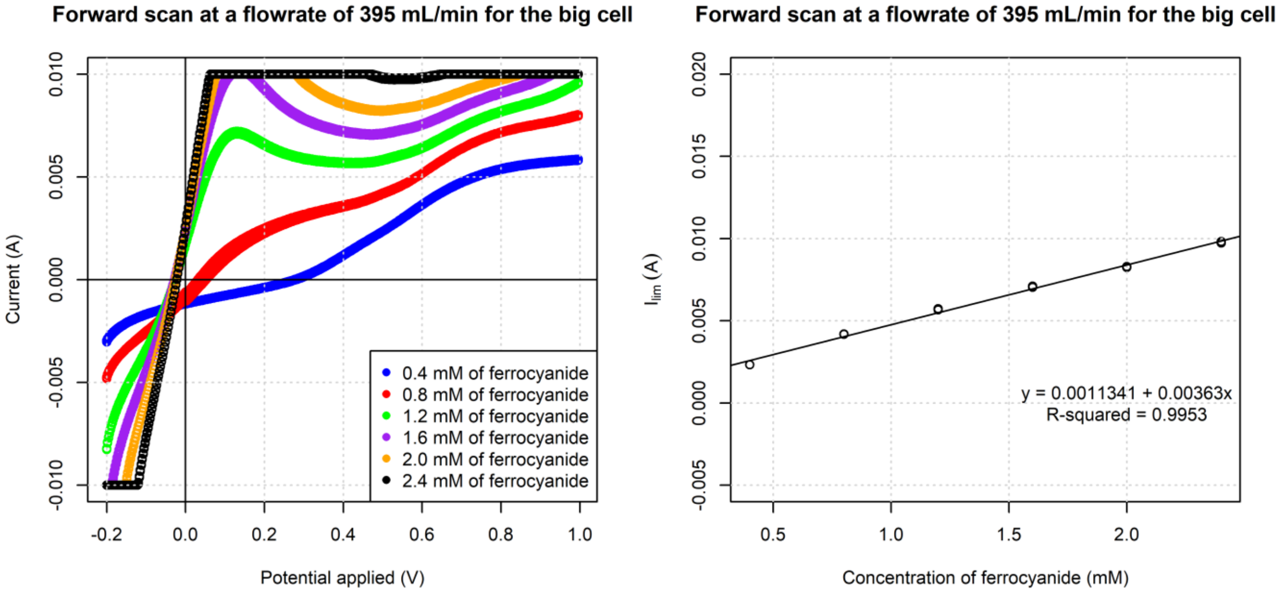
Figure 59 - Backscan at 0.4 V for spacer 3 at a flowrate of 475 mL/min

Forward scan for the big cell


Forward scan at a flowrate of 327 mL/min for the big cell

Forward scan at a flowrate of 327 mL/min for the big cell

Figure 60 - Plateau of forward scan for the big cell at a flowrate of 327 mL/min


Forward scan at a flowrate of 395 mL/min for the big cell

Forward scan at a flowrate of 395 mL/min for the big cell

Figure 61 - Plateau of forward scan for the big cell at a flowrate of 395 mL/min

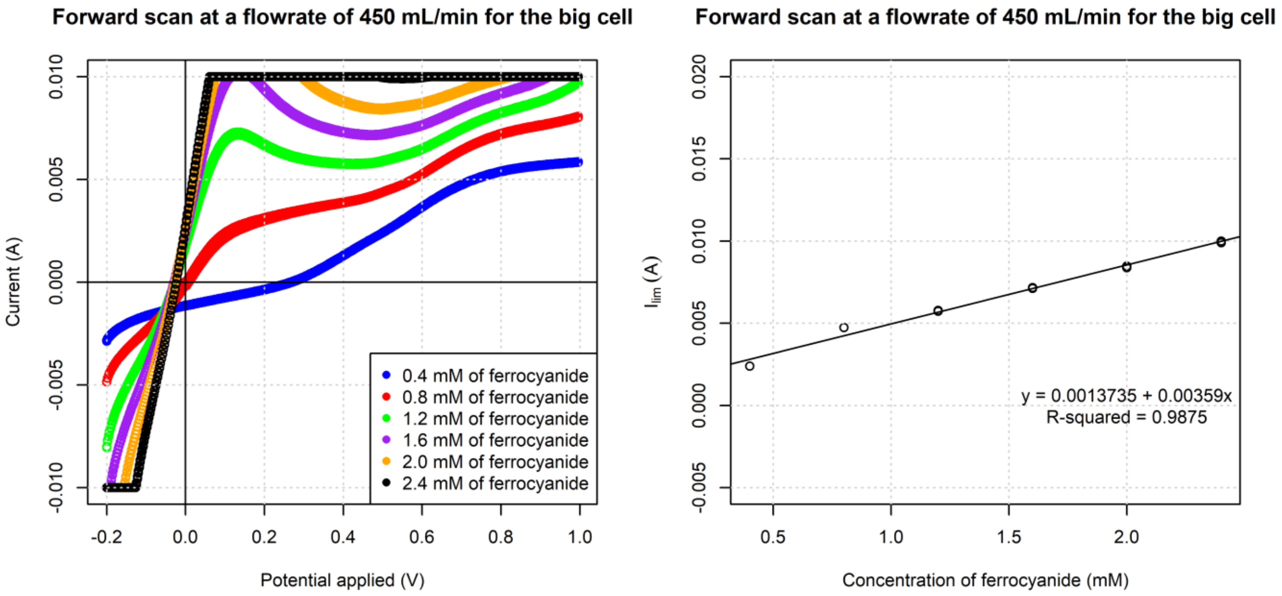


Figure 62 - Plateau of forward scan for the big cell at a flowrate of 450 mL/min

Backscan of the big cell

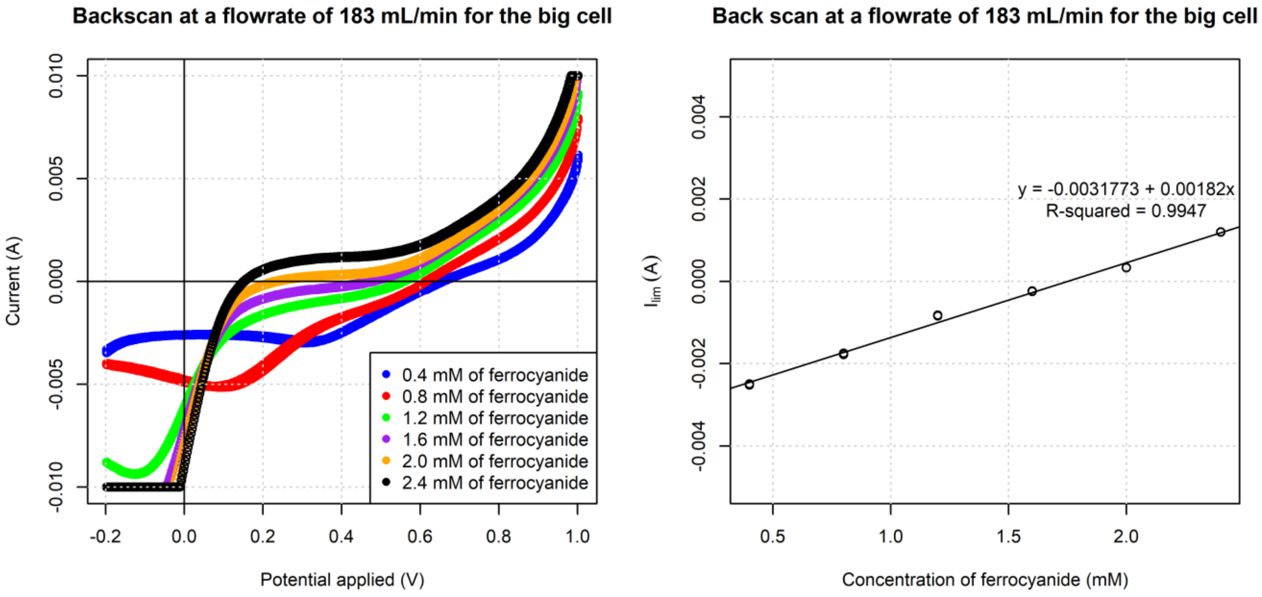


Figure 63 - Backscan for the big cell at a flowrate of 183 mL/min

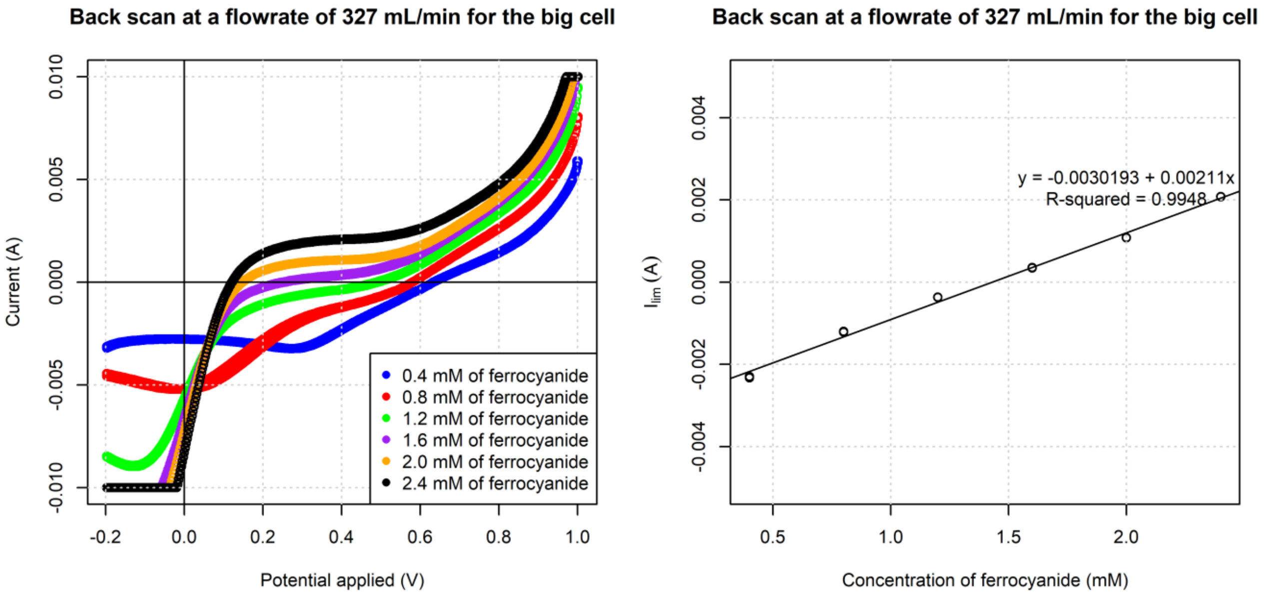


Figure 64 - Backscan for the big cell at a flowrate of 327 mL/min

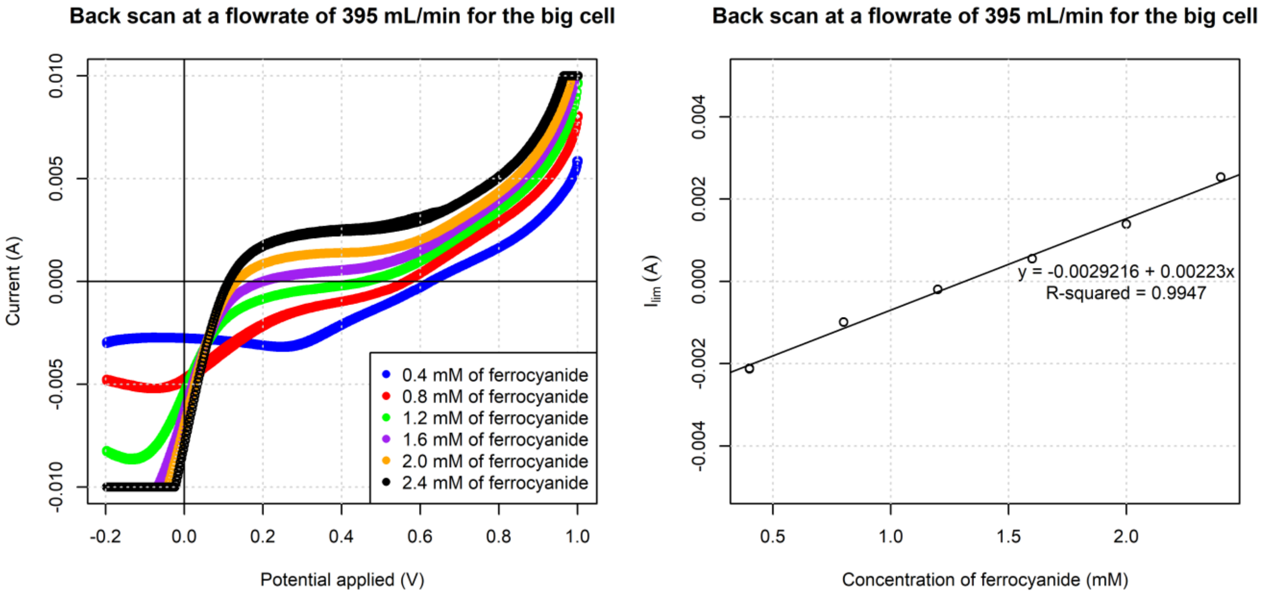


Figure 65 - Backscan for the big cell at a flowrate of 395 mL/min

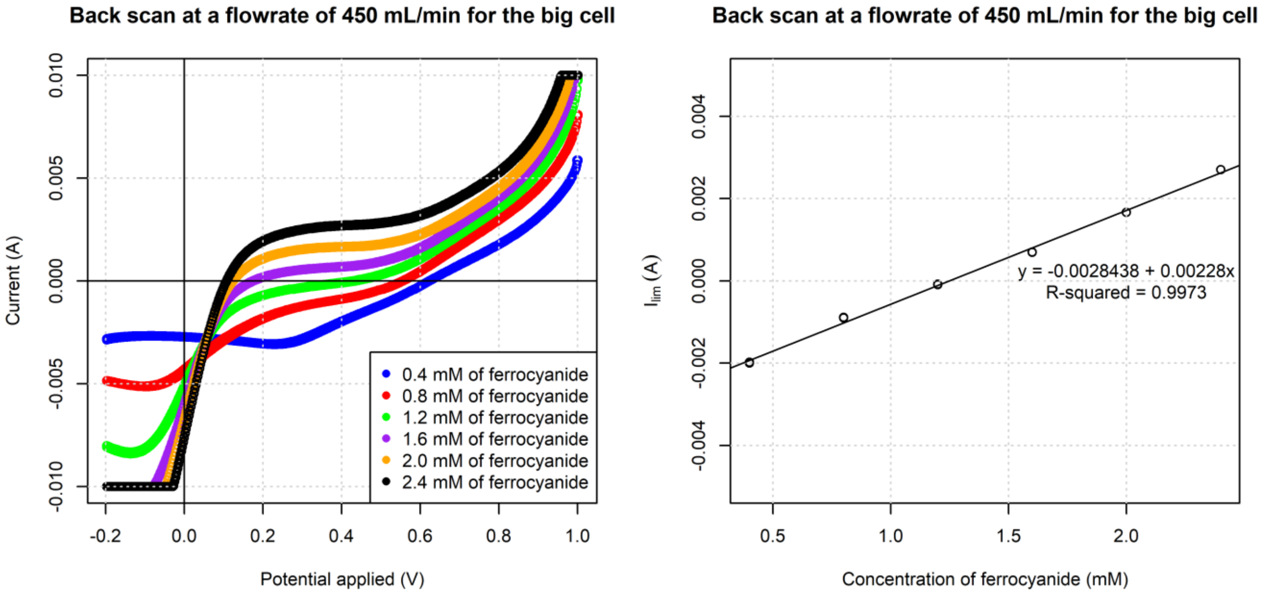
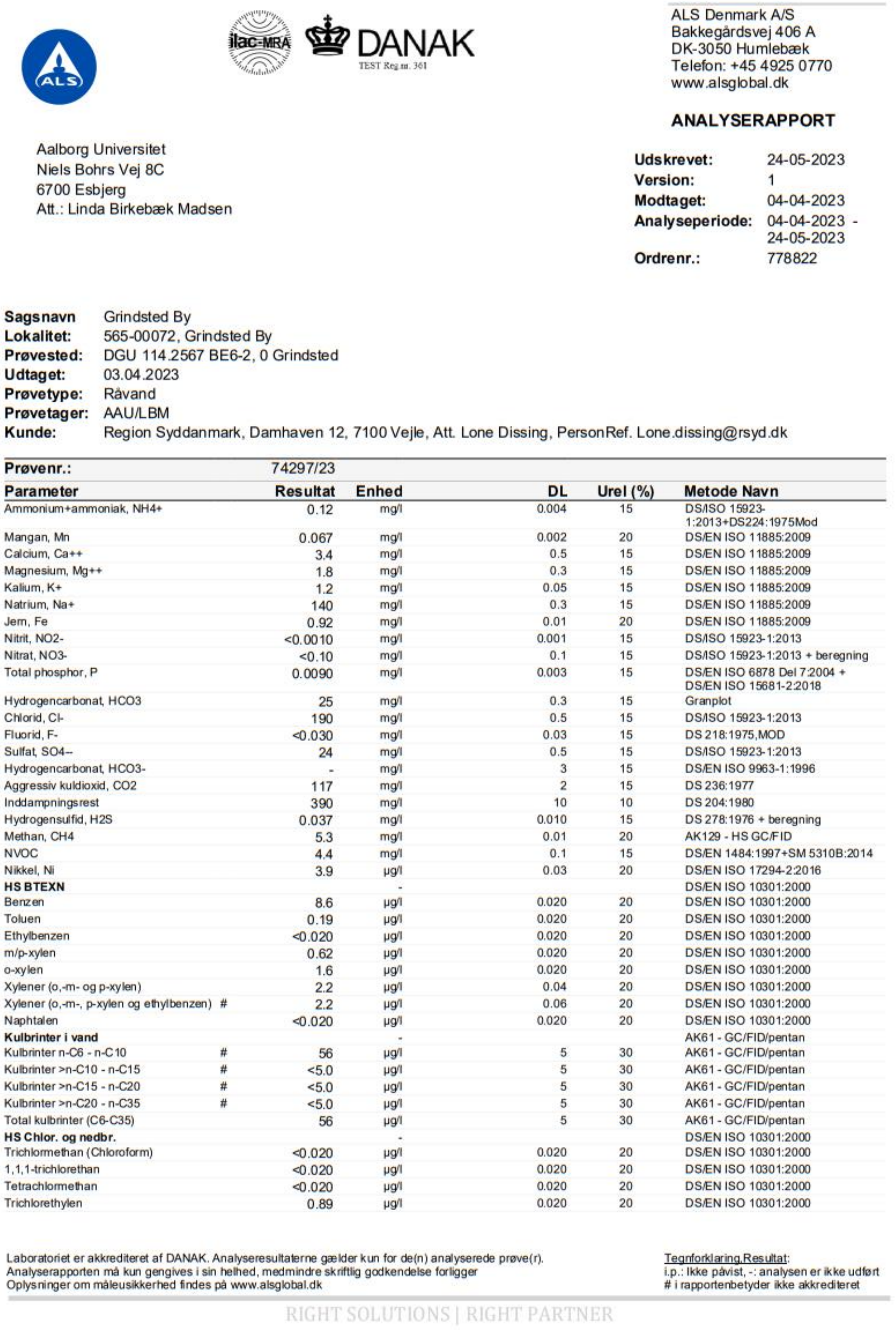


Figure 66 - Backscan for the big cell at a flowrate of 450 mL/min

Appendix 2 - Results from ALS



DANAK
TEST Reg.nr. 361

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Aalborg Universitet
Niels Bohrs Vej 8C
6700 Esbjerg
Att.: Linda Birkebæk Madsen

Udskrevet:	24-05-2023
Version:	1
Modtaget:	04-04-2023
Analyseperiode:	04-04-2023 - 24-05-2023
Ordrenr.:	778822

Sagsnavn	Grindsted By
Lokalitet:	565-00072, Grindsted By
Prøvested:	DGU 114.2567 BE6-2, 0 Grindsted
Udtaget:	03.04.2023
Prøvetype:	Råvand
Prøvetager:	AAU/LBM
Kunde:	Region Syddanmark, Damhaven 12, 7100 Vejle, Att. Lone Dissing, PersonRef. Lone.dissing@rsyd.dk

Prøvenr.: 74297/23

Parameter		**Resultat**	**Enhed**	**DL**	**Urel (%)**	**Metode Navn**
Ammonium+ammoniak, NH4+		0.12	mg/l	0.004	15	DS/ISO 15923-1:2013+DS224:1975Mod
Mangan, Mn		0.067	mg/l	0.002	20	DS/EN ISO 11885:2009
Calcium, Ca++		3.4	mg/l	0.5	15	DS/EN ISO 11885:2009
Magnesium, Mg++		1.8	mg/l	0.3	15	DS/EN ISO 11885:2009
Kalium, K+		1.2	mg/l	0.05	15	DS/EN ISO 11885:2009
Natrium, Na+		140	mg/l	0.3	15	DS/EN ISO 11885:2009
Jern, Fe		0.92	mg/l	0.01	20	DS/EN ISO 11885:2009
Nitrit, NO2-		<0.0010	mg/l	0.001	15	DS/ISO 15923-1:2013
Nitrat, NO3-		<0.10	mg/l	0.1	15	DS/ISO 15923-1:2013 + beregning
Total phosphor, P		0.0090	mg/l	0.003	15	DS/EN ISO 6878 Del 7:2004 + DS/EN ISO 15681-2:2018
Hydrogencarbonat, HCO3		25	mg/l	0.3	15	Granplot
Chlorid, Cl-		190	mg/l	0.5	15	DS/ISO 15923-1:2013
Fluorid, F-		<0.030	mg/l	0.03	15	DS 218:1975,MOD
Sulfat, SO4--		24	mg/l	0.5	15	DS/ISO 15923-1:2013
Hydrogencarbonat, HCO3-		-	mg/l	3	15	DS/EN ISO 9963-1:1996
Aggressiv kuldioxid, CO2		117	mg/l	2	15	DS 236:1977
Inddampningsrest		390	mg/l	10	10	DS 204:1980
Hydrogensulfid, H2S		0.037	mg/l	0.010	15	DS 278:1976 + beregning
Methan, CH4		5.3	mg/l	0.01	20	AK129 - HS GC/FID
NVOC		4.4	mg/l	0.1	15	DS/EN 1484:1997+SM 5310B:2014
Nikkel, Ni		3.9	µg/l	0.03	20	DS/EN ISO 17294-2:2016
HS BTEXN			-			DS/EN ISO 10301:2000
Benzen		8.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Toluen		0.19	µg/l	0.020	20	DS/EN ISO 10301:2000
Ethylbenzen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
m/p-xylen		0.62	µg/l	0.020	20	DS/EN ISO 10301:2000
o-xylen		1.6	µg/l	0.020	20	DS/EN ISO 10301:2000
Xylener (o,-m- og p-xylen)		2.2	µg/l	0.04	20	DS/EN ISO 10301:2000
Xylener (o,-m-, p-xylen og ethylbenzen)	#	2.2	µg/l	0.06	20	DS/EN ISO 10301:2000
Naphtalen		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Kulbrinter i vand			-			AK61 - GC/FID/pentan
Kulbrinter n-C6 - n-C10	#	56	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C10 - n-C15	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C15 - n-C20	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Kulbrinter >n-C20 - n-C35	#	<5.0	µg/l	5	30	AK61 - GC/FID/pentan
Total kulbrinter (C6-C35)		56	µg/l	5	30	AK61 - GC/FID/pentan
HS Chlor. og nedbr.			-			DS/EN ISO 10301:2000
Trichlormethan (Chloroform)		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1,1-trichlorethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Tetrachlormethan		<0.020	µg/l	0.020	20	DS/EN ISO 10301:2000
Trichlorethylen		0.89	µg/l	0.020	20	DS/EN ISO 10301:2000

Laboratoriet er akkrediteret af DANAK. Analyseresultaterne gælder kun for de(n) analyserede prøve(r).
Analyserapporten må kun gengives i sin helhed, medmindre skriftlig godkendelse forligger
Oplysninger om måleusikkerhed findes på www.alsglobal.dk

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

RIGHT SOLUTIONS | RIGHT PARTNER

TEST Reg.nr. 361

ALS Denmark A/S
Bakkegårdsvej 406 A
DK-3050 Humlebæk
Telefon: +45 4925 0770
www.alsglobal.dk

ANALYSERAPPORT

Prøvenr.: 74297/23

Parameter		Resultat	Enhed	DL	Urel (%)	Metode Navn
Tetrachlorethylen		2.2	µg/l	0.020	20	DS/EN ISO 10301:2000
Chlorethan		0.23	µg/l	0.10	20	DS/EN ISO 10301:2000
Vinylchlorid		930	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethylen		0.26	µg/l	0.020	20	DS/EN ISO 10301:2000
trans-1,2-dichlorethylen		23	µg/l	0.020	20	DS/EN ISO 10301:2000
cis-1,2-dichlorethylen		120	µg/l	0.020	20	DS/EN ISO 10301:2000
1,2-dichlorethan		0.53	µg/l	0.020	20	DS/EN ISO 10301:2000
1,1-dichlorethan		0.079	µg/l	0.020	20	DS/EN ISO 10301:2000
Dichlormethan		<0.10	µg/l	0.1	20	DS/EN ISO 10301:2000
Grindstedpakke A - Vand			-			AK186 - LC-GC/MS/MS
Acetylsulfaguanidin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Acetylsulfanilsyre	#	76	µg/l	0.1	30	AK186 - LC/MS/MS
Aetallymal	#	1.7	µg/l	0.1	30	AK186 - GC/MS
Allyl-n-butylbarbityrat	#	11	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-isobutyl-barbitursyre (Butalbital)	#	11	µg/l	0.1	30	AK186 - GC/MS
5-allyl-5-(methylbutyl)-barbitursyre	#	11	µg/l	0.1	30	AK186 - GC/MS
Barbital	#	14	µg/l	0.1	30	AK186 - GC/MS
Butobarbital (N-butylethylbarbitursyre)	#	5.1	µg/l	0.1	30	AK186 - GC/MS
Butylbarbiturat	#	15	µg/l	0.1	30	AK186 - GC/MS
5,5-diallylbarbitursyre (Allobarbital)	#	10	µg/l	0.1	30	AK186 - GC/MS
N-N-diethylnicotinamid	#	2.5	µg/l	0.1	30	AK186 - GC/MS
Dipropenylamin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
5-ethyl-5-sec-butylbarbitursyre (Butabarbital)	#	7.9	µg/l	0.1	30	AK186 - GC/MS
Ethylurethan	#	<0.10	µg/l	0.1	30	AK186 - GC/MS
Phthalylsulfathiazol	#	8.7	µg/l	0.1	30	AK186 - LC/MS/MS
Hexobarbital	#	<1.0	µg/l	0.1	30	AK186 - GC/MS
Isobutylbarbitursyre	#	440	µg/l	0.1	30	AK186 - GC/MS
Isopropylbarbitursyre	#	12	µg/l	0.1	30	AK186 - GC/MS
Meprobamat	#	110	µg/l	0.1	30	AK186 - GC/MS
Methoxyproprionitril	#	<0.10	µg/l	0.1	30	AK210 - HS GC/MS
N-methyldiethylbarbitursyre (Metharbital)	#	<1.0	µg/l	0.1	30	AK186 - GC/MS
Monoethylbarbitursyre	#	7.8	µg/l	0.1	30	AK186 - GC/MS
Pentobarbital	#	61	µg/l	0.1	30	AK186 - GC/MS
Amobarbital	#	69	µg/l	0.1	30	AK186 - GC/MS
Sulfanilamid	#	8.3	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfaguanidine	#	82	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamethazin (Sulfadimidin)	#	73	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfamethizol	#	6.5	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfadiazin	#	1.9	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilsyre	#	130	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfacetamid	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfadoxin	#	<0.5	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfamerazin	#	3.2	µg/l	0.05	30	AK186 - LC/MS/MS
Sulfanilylurinstof	#	6.9	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfapyridin	#	<1.0	µg/l	0.1	30	AK186 - LC/MS/MS
Sulfathiazol	#	0.66	µg/l	0.05	30	AK186 - LC/MS/MS

Kommentar

Prøven har et indhold af kulbrinter, der ikke umiddelbart kan sammenlignes med et kendt olie- eller tjæreprodukt. Kogepunktsintervallet for de påviste kulbrinter ligger på ca. 75 - 200 °C.

Tegnforklaring,Resultat:
i.p.: Ikke påvist, -: analysen er ikke udført
i rapportenbetyder ikke akkrediteret

Appendix 3 - Determination of the limiting current

Vinyl chloride

In order to determine the COD, it must first be determined how many electrons are produced. This is done by balancing the equation for a complete degradation of vinyl chloride.

$$C_2H_3Cl + \ 4H_2O \rightarrow 2CO_2 + 11\,H^+ + 10\,e^- + Cl^-$$

And for oxygen (COD)

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

The initial COD_{VC} can now be determined by inserting the values in the equation below.

$$COD_{VC} = \frac{[VC]}{M_{VC}} \cdot \frac{e^-_{VC}}{e^-_{O_2}} \cdot M_{O_2} = \frac{1700 \cdot 10^{-6}\,\frac{g}{L}}{(12.01 \cdot 2 + 1.008 \cdot 3 + 35.45)\,\frac{g}{mol}} \cdot \frac{10}{4} \cdot 32\,\frac{g}{mol} \approx 0.002176\,\frac{g}{L}$$

The initial COD of VC can now be used to determine COD in $\frac{mol}{m^3}$

$$COD_0 = \frac{COD_{VC}}{M_{O_2}} = \frac{0.002176\,\frac{g}{L} \cdot 1000\,\frac{L}{m^3}}{32\,\frac{g}{mol}} \approx 0.0680\,\frac{mol}{m^3}$$

The limiting current can now be determined.

$$i_{lim} = 4Fk_mCOD_0A = 4 \cdot 96485\,\frac{C}{mol} \cdot 4.5 \cdot 10^{-6}\,\frac{m}{s} \cdot 0.0680\,\frac{mol}{m^3} \cdot 0.001\,m^2 \approx 0.118\,mA$$

The limiting current of vinyl chloride is therefore 0.118 mA.

NVOC

The same calculations are performed for NVOC. It is assumed all NVOC are on CH form.

$$CH + 2\,H_2O \rightarrow CO_2 + 5\,H^+ + 5\,e^-$$

$$COD_{NVOC} = \frac{[NVOC]}{M_{NVOC}} \cdot \frac{e^-_{NVOC}}{e^-_{O_2}} \cdot M_{O_2} = \frac{4.4\,\frac{mg}{L} \cdot 10^{-3}\,\frac{g}{mg}}{(12.01 \cdot 1 + 1.008 \cdot 1)\,\frac{g}{mol}} \cdot \frac{5}{4} \cdot 32\,\frac{g}{mol} \approx 0.0135\,\frac{g}{L}$$

$$COD_0 = \frac{COD_{NVOC}}{M_{O_2}} = \frac{0.0135\,\frac{g}{L} \cdot 1000\,\frac{L}{m^3}}{32\,\frac{g}{mol}} = 0.4219\,\frac{mol}{m^3}$$

$$i_{lim} = 4Fk_mCOD_0A = 4 \cdot 96485\,\frac{C}{mol} \cdot 4.5 \cdot 10^{-6}\,\frac{m}{s} \cdot 0.4219\,\frac{mol}{m^3} \cdot 0.001\,m^2 \approx 0.73\,mA$$

The limiting current of vinyl chloride is therefore 0.73 mA.

Appendix 4 - GC-MS for analyzing for vinyl chloride in solution

Stock solution (SA): Vinyl chloride 2000 ppm/ml MeOH (1 ml ampoule)

It is recommended to keep the ampoule and all solutions on ice.

Initial temperature is 50 °C for 2 minutes and ramp up to 45 °C/min to 140 °C

Standard 400 mg/L

The ampoule (1.00 ml) is diluted with 4 ml of cold demineralized water in a headspace glass and sealed with a tight lid…

Stored in a refrigerator.

Working solution 4 mg/L

1 ml Standard 400 mg/L is diluted to 100.00 ml with cold demineralized water. Stored in a refrigerator.

Quantitative method for the water phase SIR

IS - Mlm STAM Bromoform 29000 mg/L pentane

100 µl Bromoform is diluted to 10.00 ml with pentane

IS – Solution Bromoform 58 mg/L

200 µl Mlm STAM is diluted to 10.00 ml with pentane

Fragments (62-64+81+173) are collected using the SIR method.

Standard	**Take out standard 400 mg/L**	**Add IS - solution**	**Concentration Vinyl chloride mg/L**	**Conc IS mg/L**
Std 1	50 µl	2.00 ml	10	58
Std 2	100 µl	2.00 ml	20	58
Std 3	200 µl	2.00 ml	40	58
Std 4	400 µl	2.00 ml	80	58

Extract the pentane phase into a vial. There will be a water droplet at the bottom

It is recommended to analyze each standard 3 times, as there is significant variation in the solutions. (see calibration on the next page).

Sample preparation

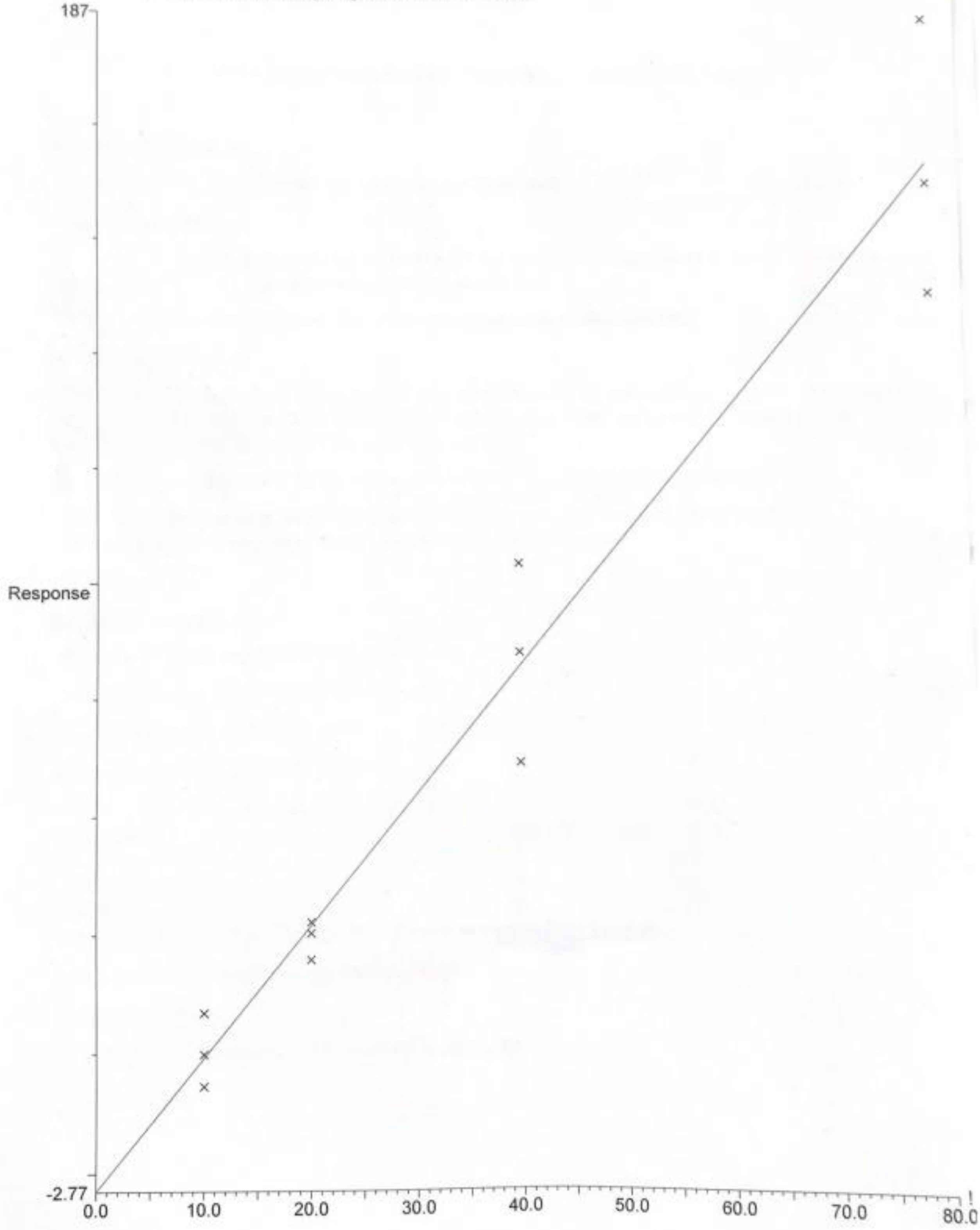
The water sample is extracted with 1/10 volume of IS solution (12.00 mL sample with 1.20 mL IS).

The repeatability is good for standards/samples with concentrations within the calibration range, but very uncertain for concentrations <10 mg/L.

The detection limit is estimated to be around 0.5 mg/L of water. However, it will be possible to detect the presence of vinyl chloride.

, 22-Mar-2023 + 09:22:41

Compound 1 name: Vinylchlorid
Correlation coefficient: r = 0.977698, r^2 = 0.955894
Calibration curve: 2.06635 * x + -2.76982
Response type: Internal Std (Ref 2), Area * (IS Conc. / IS Area)
Curve type: Linear, Origin: Exclude, Weighting: Null, Axis trans: None



Appendix 5 - Additional results from calculations and experiments

Table 17 - VC in the gas phase calculations

Time [min]	VC GC-MS response
5	45204.5
5	86875.3
10	161424.1
10	254834.8
20	162476.6
20	254834.8
30	159473.5
30	303728.7
Atmospheric CO_2	493698.9