Miljøministeriet
Miljøstyrelsen

Merkur: Web-baseret platform til vandbehandlingsdata

Rapport 2 i projektet ”Smart Re-design of Drinking Water Production”

MUDP Rapport

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Indhold

Forord

Denne rapport er en del af fyrtårnsprojektet "Smart Re-design of Drinking Water Production", som blev udført i perioden 2018 - 2022 og finansieret af projektdeltagernes egenfinansiering samt den offentlige støtteordning Miljøteknologisk Udviklings- og Demonstrationsprogram (MUDP) under Miljøministeriet. Projektets formål er at re-designe vandbehandling ved en dyb forståelse og en radikal nytænkning af vandbehandlingsprocessen. Da projektet omhandler helt almindelig dansk vandbehandling, er projektets resultater relevante for alle danske vandforsyninger.

Fyrtårnsprojektet er formidlet gennem 12 rapporter, samt en serie konferenceindlæg, tidskriftsartikler, og seminarer. Desuden er en række løsninger demonstreret ved fuldskalaanlæg på hhv. Østerbyværket syd for Aarhus og Lundeværket nord for Odense.

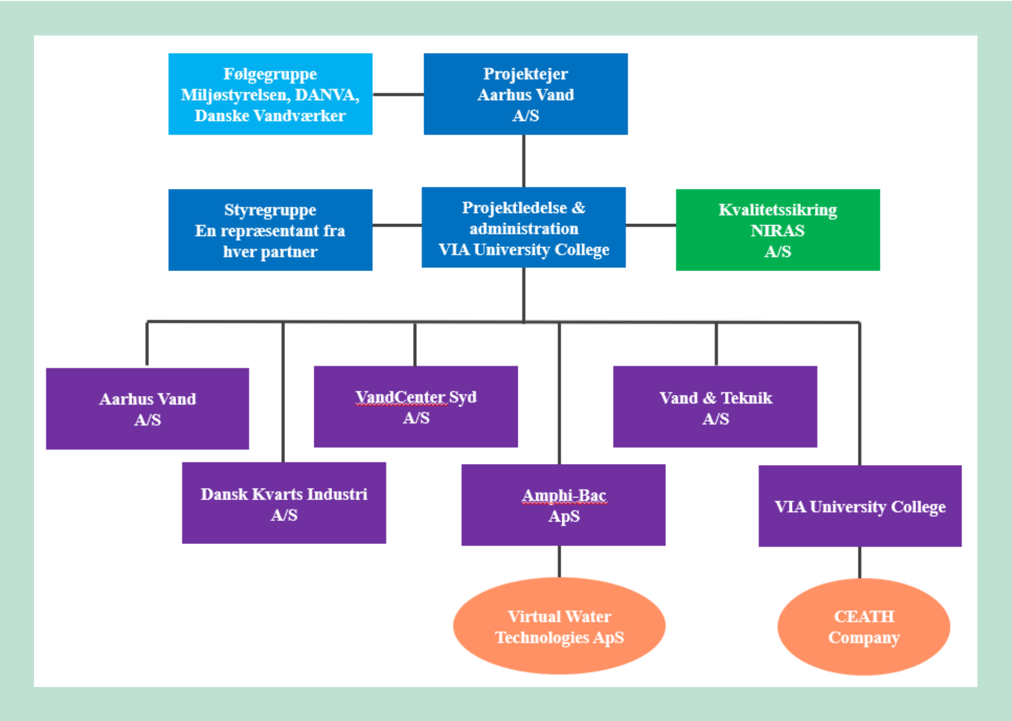
Baggrund

I Danmark er drikkevandsproduktion baseret på grundvand. Grundvandet behandles ved en ret enkelt proces, der kaldes for "normalbehandling" (Karlsen og Sørensen, 2014). Denne proces består af iltning af vandet efterfulgt af en biofiltrering med gravitations- eller trykfiltre. Biofiltrering indebærer en kompleks blanding af fysiske, kemiske og mikrobiologiske elementer. Da det indvundne grundvand ofte er kemisk reduceret, kan vandet indeholde opløste stoffer som jern, ammonium og mangan, der skal fjernes/omdannes. Avanceret vandbehandling kommer kun på tale, hvis der også er behov for at fjerne f.eks. gasser (svovlbrinte, methan, aggressiv kuldioxid), hårdhed, arsen eller pesticider. I Danmark anvendes hverken chlor eller andre former for kemisk desinfektion under behandling eller distribution af vandet.

Biofiltrering er hjertet af normalbehandling af drikkevand i Danmark. Design og drift af biofiltrering har dog ikke ændret sig væsentligt i mere end 100 år. Manglende proces- og mikrobiologisk viden kombineret med en konservativ tilgang har medført, at videreudvikling af biofiltrering har været begrænset, og at filtre har været betragtet som en black box. Nye og billigere mikrobiologiske analyser, sofistikerede prøvetagningsmetoder, at-line målinger og andre fremskridt har nu åbnet denne black box i vandbehandlingen og gjort det muligt at undersøge, forstå og manipulere processen i højere grad end før.

Projektorganisation

Projektet blev udført af syv partnere og to underleverandører, se FIGUR 1 nedenfor:



FIGUR 1. Diagram over projektorganisation.

Projektets følgegruppe og styregruppe bestod af følgende personer:

Følgegruppe
Bolette D. Jensen, Miljøstyrelsen (formand)
Dorte Skræm, DANVA
Robert Jensen / Henrik Hermansen, Danske Vandværker
Flemming Fogh Pedersen, Aarhus Vand (projektejer)
Loren Ramsay, VIA University College (projektleder)

Styregruppe
Flemming Fogh Pedersen, Aarhus Vand
Finn Mollerup, VandCenter Syd
Jens Kristensen, Vand og Teknik
Claus Hove Sørensen, Dansk Kvarts Industri
Søren Bastholm Olesen, Amphi-Bac
John Kristensen, NIRAS
Loren Ramsay, VIA University College

Projektets arbejdspakker og rapporter

Projektet er inddelt i arbejdspakker og rapporter, se nedenfor. Arbejdspakkerne og rapporterne er identificeret som ”åbne” eller ”kommercielle” for at tydeliggøre, hvornår resultater frit formidles til hele branchen og hvornår resultater holdes internt blandt de relevante partnere af hensyn til kommercielle interesser.

Arbejdspakke 1: Etablering af designgrundlag (åben)
Rapport 1: Indsamling af vandbehandlingsdata
Rapport 2: Merkur: Web-baseret platform til vandbehandlingsdata

Arbejdspakke 2: Tekniske forsøg (åben)
Rapport 3: Flytning af filtermediekorn under returskyl
Rapport 4: Jernfjernelsesdybde i biofiltre
Rapport 5: Biostimulering med ammonium
Rapport 6: Jernfjernelse i returskyl
Rapport 7: Filtermediers gangtid

Arbejdspakke 3: SmartSand (kommerciel)
Rapport 8: Udvikling og produktion af SmartSand (fortrolig)

Arbejdspakke 4: SmartArkitektur (åben)
Rapport 9: Vandbehandlingsmodel

Arbejdspakke 5: Fyrtårnsdemonstration i fuldskala (åben)
Rapport 10: Demonstrationsanlæg ved Østerbyværket
Rapport 11: Demonstrationsanlæg ved Lundeværket

Arbejdspakke 6: Projektledelse
Rapport 12: Sammenfatning

Sammenfatning

Denne rapport omhandler Merkur: web-baseret platform til vandbehandlingsdata og er Rapport 2 af 12 om fyrtårnsprojektet ”Smart Re-design of Drinking Water Production”. Formålet med Rapport 2 er at dokumentere denne platform. Desuden er formålet at identificere Design, Drift og Performanceindikatorer (DDP-indikatorer), der kan sammenlignes mellem vandværker, hvorved forståelse for drikkevandsproduktion fremmes.

En landsdækkende opgørelse over den aktuelle drikkevandskvalitet viser, at der i januar 2019 forekommer knap 500 overskridelser af vandkvalitetskrav på de danske vandværker. Over halvdelen af disse skyldes utilstrækkelig vandbehandling frem for utilstrækkelig grundvandsbeskyttelse, dårligt grundvandskvalitet fra naturens hånd eller forureninger af distributionsnettet. Hermed bærer vandbehandlingsanlæg en stor del af ansvaret for uacceptabel drikkevandskvalitet.

For at finde årsager til overskridelser er der behov for monitering af vandbehandlingsprocessen. I Danmark samles mange vandkvalitetsdata i den landsdækkende database Jupiter. Dog er langt hovedparten af prøverne udtaget ved boringer og ved distributionsnettet (tidligere afgang vandværk), da lovgivning kræver det. Meget få prøver udtages i forbindelse med selve filtreringsprocessen til indlæsning i Jupiter. Motivationen for Rapport 2 er derfor en kombination af disse to faktorer: 1: At uacceptabel drikkevandskvalitet langt hen ad vejen skyldes utilstrækkelig vandbehandling og 2. At netop vandbehandling mangler moniteringsdata for vandkvalitet.

Performanceindikatorer er ofte anvendt i vandbranchen, især produktbaserede indikatorer med fokus på økonomi. En litteraturgennemgang viser dog, at der ikke tidligere er defineret tekniske indikatorer for vandbehandling, der kan bruges under danske forhold. I Rapport 2, udvides performanceindikator-begrebet til det mere retvisende Design, Drift og Performanceindikator (DDP-indikator). Rapporten identificerer seks faktorer, der kendetegner den gode DDP-indikator. Desuden identificeres fem potentielle barrierer mod implementering af DDP-indikatorer. Endelig gives eksempler på 14 specifikke DDP-indikatorer, der kan anvendes i forbindelse med drikkevandsbehandling i Danmark.

Merkur er en åben, web-baseret relationel database til vandbehandlingsdata udviklet i forbindelse med dette projekt. I dens nuværende version er databasen programmeret i FileMaker 14 platformen og omfatter otte hovedtabeller og en række støttetabeller. Brugerfladen omfatter en login-procedure, der muliggør, at det aktuelle vandværk fremhæves i diverse visualiseringer. Der er udarbejdet 21 standardgrafer. Data fra de 10 deltagende vandværker tilhørende Aarhus Vand og VandCenter Syd er indlæst i databasen og kvalitetssikret.

Jo flere vandværker, der deltager i Merkur, jo mere retvisende bliver de forskellige indikatorer. Derfor er der behov for at aftale permanent hosting af databasen samt indlemme flere vandværker. Merkur har potentiale både i Danmark samt internationalt i lande med lignende drikkevandsbehandling.

1. Introduktion

Formålet med Rapport 2 er at dokumentere skabelsen af en åben, web-baseret platform til strukturering, lagring, visualisering og deling af indsamlede vandbehandlingsdata med tilhørende metadata. Den resulterende nationale database er navngivet ”Merkur”, kommunikationsguden i den romerske mytologi. Merkur skal indeholde en skattekiste af informationer for vandforsyninger, rådgivere og forskere, der vil basere vandbehandlingsbeslutninger på evidens.

Der er mange krav til en god produktion af drikkevand, herunder høj vandkvalitet, stor behandlingsrobusthed, brugervenlige produktionsmetoder, minimalt vandspild, lavt energiforbrug samt lave omkostninger til anlæg og drift. Vandbehandlingsdata har en vigtig rolle at spille for at opfylde disse krav og kan bruges i vandbehandlingsprocessen både til problemløsning, optimering, design og innovation.

I denne rapport omtales følgende emner:

1. Opgørelse af drikkevandskvalitet i Danmark.
2. Fastlæggelse af Design, Drift og Performanceindikatorer (DDP-indikatorer).
3. Design af Merkur databasen.

2. Aktiviteter

I dette kapitel angives en oversigt over de aktiviteter, der blev gennemført i dette studie.

2.1 Opgørelse over overskridelser af drikkevandskvalitetskrav

Formålet med denne aktivitet er at fastlægge den aktuelle status for Danmarks drikkevandskvalitet. Overskridelser af kvalitetskrav blev opgjort på basis af et udtræk af alle målinger i Jupiter databasen den. 10. jan. 2019. Arbejdet bestod af en datavask (i forbindelse med overførsel af data til en datawarehouse) samt en række automatiske og manuelle forespørgsler. Overskridelser af vandkvalitetskrav er en af de motiverende faktorer for udvikling af den nye nationale database.

2.2 Fastlæggelse af DDP-indikatorer

Formålet med denne aktivitet er at give et bud på, hvilke DDP-indikatorer, der kan bruges af driftoperatører til gennemførelse af evidensbaserede beslutninger om drift, af ingeniører til design af vandbehandlingsprocesser samt af personale til vurdering af vandbehandlingens performance. Indledningsvis blev faktorer, der er vigtige for gode vandbehandlings performance identificeret. Derefter blev forskellige forhindringer for implementering af DDP-indikatorer gennemgået. Endelig blev et bud på specifikke, anvendelige DDP-indikatorer givet.

2.3 Design af databasen

Formålet med denne aktivitet er at designe en relationel database til vandbehandlingsdata. De forskellige opgaver i denne aktivitet vises nedenfor:

Software: Et første skridt var at vælge databasesoftware.

Tabeller, felter og relationer: Herefter blev hovedtabellerne bestemt, navngivet og programmeret, herunder de indbyrdes relationer mellem tabellerne. Desuden blev en række støttetabeller bestemt. Endelig blev datafelterne i hver tabel fastlagt og programmeret.

Brugerflade: Opgaver i forbindelse med brugerfladen inkluderer programmering af log-in (evt. til at opnå adgang til forskellige niveauer af rettigheder) og menupunkter.

Visualisering af data: Et antal grafer, der vises i databasen, blev fastlagt. Hver graf blev designet og programmeret.

Datainput og kontrol: Indsamlet data fra de 10 vandværker blev indtastet i Merkur. Derefter blev data kontrolleret for at sikre mod fejl.

3. Drikkevandskvalitet i Danmark

Det siges, at Danmark har noget af verdens bedste drikkevand (Miljøstyrelsen, 2018). For at opnå større indblik i dette udsagn, blev et øjebliksbillede over overskridelser af drikkevandets kvalitetskrav opgjort på landsplan. Til dette formål blev alle målinger af drikkevandsprøver i den offentlige og landsdækkende boringsdatabase ”Jupiter” (tabellen PLTCHEMANALYSIS) anvendt.

3.1 Fremgangsmåde ved opgørelsen

Fremgangsmåden ved opgørelsen omfattede en indledende datavask i forbindelse med, at data blev overført til et datawarehouse. Herefter blev overskridelser identificeret ved at stille en række automatiske udvælgelsesforespørgsler i en nøje-planlagt rækkefølge ind i datawarehouse. Hermed var det muligt at opgøre vandværkernes aktuelle overskridelser af drikkevandets kvalitetskrav. Opgørelsen er udført pr. stof og pr. vandværk og gælder kun for den seneste udførte måling (for hvert stof på hvert vandværk). Hermed er historiske overskridelser ikke medtaget i denne opgørelse.

I det følgende angives fremgangsmåden ved opgørelsen. Placeringen af de omtalte data i Jupiter angives i parentes som følger: (TABEL/Felt).

3.1.1 Datavask ved overførsel til datawarehouse

I forbindelse med overførsel af data til en datawarehouse struktur blev følgende udvælgelser udført:

1. Manglende enheder (PLTCHEMANALYSIS/Unit): Poster uden enheder blev ikke overført til datawarehouse.
2. Analysedubletter (DRWCHEMANALYSIS): Ved dubletter (poster med hver deres AnalyseID, med samme SampleID, Amounts og Units), der skyldes forskellige værdier i felterne AnalysisMethod, DetectionLimit, og AnalysisLocation, blev den post, der har den højere AnalyseID udvalgt, mens posten med den lavere AnalyseID ikke blev overført til datawarehouse.

Desuden blev følgende tilpasninger udført:

1. Enhedsomregning (PLTCHEMANALYSIS/Unit og PLTCHEMANALYSIS/Amount): Amounts, der har enheder af samme type (fx mg/L og µg/L) blev omregnet således at alle Amounts med samme type fik samme enhed
2. Virksomhedstype (DRWPLANTCOMPANYTYPE/CompanyType): Da hvert plant kan have mere end én CompanyType registreret over tiden, blev kun den seneste CompanyType overført til datawarehouse.

3.1.2 Automatiske udvælgelser

Den indledende udvælgelse af aktuelle overskridelser blev gennemført automatisk ved hjælp af nedenstående kriterier.

I databehandlingen sikres det, at der ikke opstår dubletter af data på baggrund af forskellige værdier i irrelevante felter i de anvendte tabeller fra Jupiterdatabasen. Det betyder at hvor alle relevante felter er ens, men der angives forskellige værdier i felter som eks. AnalysisResultIdentifier, UpdateDate, InsertDate og Laboratory fastholdes antallet af rækker ved udvælgelse af antallet af unikke rækker i outputtabellen.

1. Virksomhedstype (DRWPLANTCOMPANYTYPE/CompanyType): Til at identificere relevante anlæg blev der kun medtaget tre virksomhedstyper, nemlig: "vandforsyning", "private fælles vandforsyningsanlæg" og "offentlige fælles vandforsyningsanlæg". Hermed blev "husholding 1-2 hustande", "markvanding", og mange andre virksomhedstyper sorteret fra.
2. Geografi (DRWPLANT/Yutm32euref89): Til at identificere relevante anlæg blev der yderligere udeladt alle anlæg med nordkoordinater > 6.450.000 m. Hermed medtages anlæg i Grønland ikke, og der fokuseres alene på anlæg i Danmark.
3. Stoffer/parametre (PLTCHEMANALYSIS/CompoundNo): I skrivende stund er den seneste "tilsynsbekendtgørelse" fra august 2018 (Miljø- og Fødevareministeriet, 2018). Kun navngivne stoffer (eller parametre såsom pH) i denne bekendtgørelse, hvor der er angivet et kvalitetskrav, blev medtaget i opgørelsen. Listen findes i Bilag 1.
4. Afskæringsdato (PLTCHEMSAMPLE/Sampledate): I opgørelsen er der kun interesse for overskridelser på aktive vandværker. Derfor blev der fastsat afskæringsdatoen 1/1/2011, se TABEL 1.
5. Udladelse af alle ældre analyser giver en ekstra sikring af, at inaktive vandværker ikke indgår i opgørelsen. Hyppighed, hvormed enkelte parametre måles varierer afhængig af stof og vandværkets produktion. Den mindste hyppighed er én gang hver tredje år for såkaldt "Gruppe B" stoffer og vandværker, der producerer mindre end 10 m^3/døgn. For ikke at udelukke aktive vandværker blev de tre år fordoblet (i tilfælde af, at en enkelt prøvetagning blev glemt) og der blev tillagt yderligere to år for evt. langsom indberetning og frigivelse i Jupiter. Hermed blev afskæringsdatoen ca. 8 år før udtræksdatoen.
6. Detektionsgrænse (PLTCHEMANALYSIS/Attribute): Det kan hænde, at en parameter har en detektionsgrænse, der er højere end kvalitetskravet. For målinger under detektionsgrænsen, kan man ikke vide, om målingerne repræsenterer en overskridelse. Derfor blev disse poster udelukket fra opgørelsen. I praksis blev målinger, hvor der står "<" i feltet "Attribute" samtidig med amount > kvalitetskravet derfor udelukket.
7. Råvandsprøver (SAMPLE/PltChemSampleRemark): Opgørelsen gælder kun rentvandsprøver. Ved fejl er enkelte råvandsprøver i Jupiter registreret som rentvandsprøver. Derfor blev alle prøver, hvor ordene "råvand" eller "boring" optræder i feltet PltChemSampleRemark udelukket fra opgørelsen. Hermed risikeres der fejlagtigt at udelukke prøver fra forsyninger, hvor råvand fra boringer pumpes direkte til forbrugere uden behandling.
8. Seneste måling (SAMPLE/Sampledate): For hvert vandværk blev alle målinger for et bestemt stof - undtaget den seneste - udelukket fra opgørelsen.
9. Overskridelser (PLTCHEMANALYSIS/Amount): Kun prøver, hvor feltet "amount" er højere end kvalitetskravet for den pågældende stof/parameter blev identificeret som en overskridelse.
10. Nedlagte vandværker: Anlæg som har ordet "Nedlagt" i deres navn frasorteres
11. Aktive vandværker (COMPANY): Anlæg, der formodes at være inaktive blev udelukkede. For at identificeres som formodet inaktiv skal følgende kriterier opfyldes samtidigt: WWRCATCHMENT/Indvindingsmængde for 2017 = null, INTAKECATCHMENT/Indvindingsmængde for 2017 = null, DWRPLANT/Status = Inaktiv, CATCHPERM/Tilladelse slutdato ældre end 2019, BORECATCHCOND/Tilladelse slutdato ældre end 2019.
12. Under detektionsgrænse: Kun prøver, hvor Attribute ≠ "<" blev medtaget.

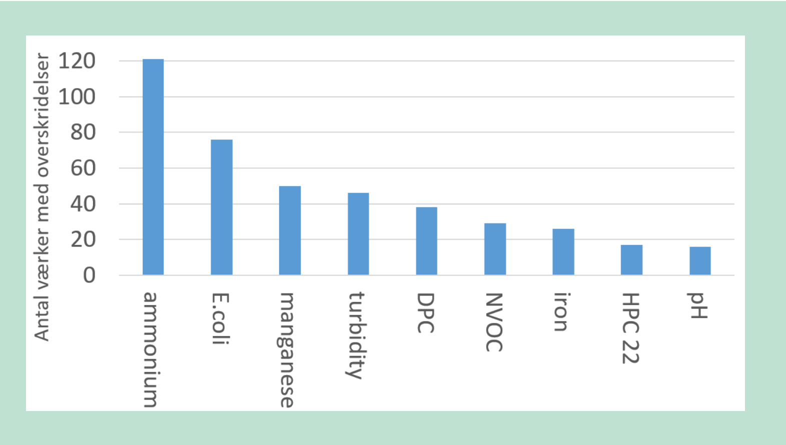
3.2 Resultat af udvælgelsen

TABEL 2 viser det tilbageværende antal poster i Jupiter-tabellen ”PLTCHEMANALYSIS” efter hvert af ovenstående kriterier blev anvendt. På udtræksdatoen var der over 9 millioner målinger i alt i tabellen. Opgørelsen identificerede i alt 490 aktuelle overskridelser, se TABEL 1.

TABEL 1. Udvælgelseskriterier (der er anvendt i den angivne rækkefølge) og antal tilbageværende poster til fastlæggelse af antal overskridelser. Har vi tal for spørgsmålene?

Nr.	Kriterier Udtræksdato: 10/01/2019		Resultater, udelukket	Resultater, resterende
Datavask				
1	Alle poster i tabellen PLTCHEMANALYSIS		-	9.181.465
2	Unikke kombinationer af SMPLÆEID, COUNDNO, ATTRIGUTE, AMOUNT og UNIT i PLTCHEMANALYSIS tabellen		13.176	9.168.289
3	Manglende enheder i tabellen PLTCHEMANALYSIS		134.650	9.033.639
Automatiske udvælgelser				
1	Virksomhedstype	Kun vandværker medtaget	1.637.139	7.428.245
2	Geografi	Anlæg fra Grønland udelukket	59.569	7.368.676
3	Stoffer/parametre	Kun stoffer, som fremgår af tilsynsbekendtgørelsen medtaget	3.546.614	3.822.062
4	Afskæringsdato	Ingen gamle data medtaget	2.325.444	1.496.618
5	Detektionsgrænse	Resultatet udelukket hvis amount < detektionsgrænse & amount > kvalitetskrav samtidig	113.950	1.382.668
6	Råvandsprøver	Prøver som ikke er drikkevand udelukket på basis af prøvetagningskommentarer	2.090	1.380.578
7	Seneste måling	Kun den nyeste måling for hvert stof og hvert vandværk medtaget	1.201.194	179.384
8	Overskridelser	Kun målinger hvor amount > kvalitetskrav er medtaget	177.976	1.408
9	Nedlagte vandværker	Kun plants som ikke har ”Nedlagt” i navnet	17	1.391
10	Aktive vandværker	Meget sandsynligt inaktive plants fjernes	425	963
11	Under detektionsgrænse	Kun overskridelser, hvor Attribut ≠ ”<” er medtaget	473	490

FIGUR 2 nedenfor viser resultatet af opgørelsen af aktuelle overskridelser i dansk drikkevand. Stofferne er rangeret efter dem, der hyppigst overskrider.



FIGUR 2. Parameter, der hyppigst overskrider drikkevandskvalitetskrav.

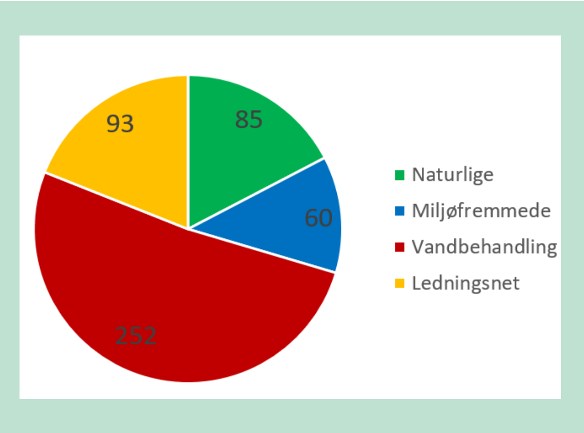
3.3 Vurdering

De parametre, der hyppigst overskrider drikkevandskvalitetskrav, kan inddeles i fire typer: vandbehandling, naturlige, miljøfremmede og ledningsnet. Stoffer i kategorien "Vandbehandling" stammer fra grundvandet, men bør kunne fjernes ved normal vandbehandling. Stoffer i kategorien "Naturlige" stammer ligeledes fra grundvandet, men fjernes ikke nødvendigvis ved normal vandbehandling. Stoffer i kategorien "Miljøfremmede" er menneskeskabt, enten som resultat af forurening af utilstrækkeligt beskyttede grundvand eller fra anlægstekniske udfordringer. Stoffer i kategorien "Ledningsnet" finder vej ind i vandledninger eksempelvis ved ledningsbrud eller i forbindelse med oversvømmelser. Stoffer i FIGUR 2 er opdelt i TABEL 2 nedenfor.

TABEL 2. Kategorier og løsning for stoffer, der hyppigst overskrider vandkvalitetskrav.

Kategori	Stofeksempler	Eksempler på løsninger
Vandbehandling	ammonium, mangan, turbiditet, jern	Velfungerende normal vandbehandling
Naturlige	NVOC, pH, arsen	Ny kildeplads, avanceret vandbehandling
Miljøfremmede	DPC, DMS	Grundvandsbeskyttelse, oprensning af forurening, ny kildeplads, avanceret vandbehandling
Ledningsnet	E.coli, kim 22	Hygiejniske ledningsreparationer og skylninger

Denne inddeling i kategorier er vigtigt, da den angiver, hvor løsningen til overskridelser skal søges. Som det ses af FIGUR 3, bærer vandforsyningernes normale vandbehandling den største del af ansvaret for overskridelser af drikkevandskvalitetskrav i Danmark. FIGUR 3 nedenfor viser inddeling af overskridelse efter årsag-



FIGUR 3. Oversigt over antal overskridelser og årsager hertil.

4. Design, drift og performanceindikatorer

Performanceindikatorer (PI) bruges til at evaluere organisationers succes inden for områder lige fra uddannelse til sundhed. Inden for drikkevand er PI typisk begrænset til det finansielle domæne, f.eks. produktionsomkostninger per produceret m^3 eller det meget brugte energiforbrug pr. m^3 (kWh/m^3). Yderligere domæner såsom de tekniske aspekter omkring vandbehandlingsprocessen har fået mindre opmærksomhed. Undersøgelserne, der er beskrevet her, fokuserer på dette domæne med henblik på at fremme den tekniske forståelse for vandbehandling og det ultimative mål at kunne re-designe vandværker.

PI'er er typisk produktbaserede snarere end procesbaserede. Imidlertid er det procesbaserede PI'er, der er ideelle til at give operatørerne det nødvendige værktøj til gennemførelse af evidensbaserede beslutninger. Selvom flere undersøgelser har set på tekniske PI'er for vandbehandlingsprocessen, blev der ikke fundet undersøgelser med fokus på drikkevandsbehandling, hvor der anvendes grundvandskilder og biofiltrering. Blandt relevante referencer er IWA (2002), EBC (2020), DANVA (2020), de Goede et al (2016).

Ud over indikatorer, der fortæller om et vandværks performance, kan der udvikles indikatorer, der fortæller om vandværkets design og drift. Tilsammen kaldes disse her for design, drift og performanceindikatorer eller DDP-indikatorer for at fremhæve, at anvendelse af disse indikatorer spænder over design og drift af vandbehandlingsanlæg såvel som deres performance. I dette kapitel bliver faktorer, der er vigtige for gode DDP-indikatorer identificeret og barrierer mod brug af DDP-indikatorer gennemgået. Endelig er specifikke indikatorer beskrevet.

4.1 Krav til den gode DDP-indikator

Det første skridt, når der skal vælges indikatorer, er at identificere hvilke generelle faktorer, der er vigtigst for valget (se FIGUR 4). Nedenfor beskrives disse faktorer.

En god DDP Indikator bør, for at den giver værdi for vandforsyninger:

1. give indsigt i et **essentielt aspekt** af vandbehandlingsprocessen, såsom behandlingseffektivitet, drikkevandskvalitet, energiforbrug, mv.
2. udvise **stor variation** mellem forskellige vandværker, da der er begrænset læring at hente, hvis variationen er lille. Når en ny DDP-Indikator er fastlagt og målt, ses ofte at variationen mellem vandværker indsnævres over tid, da personale lærer af hinandens praksis og implementerer forbedringer.
3. bør **kunne påvirkes** ved implementering af gode beslutninger. En PI, der beskriver et aspekt, hvor der ingen mulighed for påvirkning er, har ikke så stor en værdi.
4. være **kvantificerbar** ved hjælp af objektive målemetoder med specifikke enheder.
5. pege vejen frem mod en **specifik løsning**, der kan forbedre DDP-Indikator-værdien. En DDP-Indikator, der er så generel, at den ikke indebærer et vink om, hvad skal ændres, har mindre værdi.
6. **balancere omkostninger og fordele**. De omkostninger og kræfter, der kræves for at indsamle PI-data (dvs. prøveudtagning og analyse) bør ikke være større end de potentielle fordele ved den indsigt, der opnås.

Disse faktorer er visualiseret i FIGUR 4 nedenfor:

FIGUR 4. Faktorer, der definerer den gode performanceindikator.

4.2 Barriere mod brug af DDP-indikatorer

Der kan forekomme flere forhindringer, der virker som barriere mod implementering af PI'er. Disse barrierer omtales nedenfor:

1. Der er i øjeblikket **ingen lovgivning**, der kræver indsamling af data om vandbehandling. Derfor kan indsamling af disse data opfattes om unødvendig. Da den lovgivningsmæssige driver savnes, er brug af PI'er et frivilligt tiltag.
2. De mest relevante tekniske PI'er for vandbehandlingsprocessen er hidtil **ikke fastlagte**.
3. I Danmark er der **ingen systematisk opbevaringssted**, hvor vandbehandlings-PI'er er hjemmehørende. Den landsdækkende Jupiter-database for data om borings- og vandkvalitetsdata er i verdensklasse, men vandbehandlingsdata er ikke en del af databasen. For at være af værdi for behandlingsprocessen skal der f.eks. indsamles samhørende data fra indløb og udløb af hver enhedsoperation, og de nødvendig metadata skal medtages.
4. Indsamling af vandbehandlingsdata **indebærer omkostninger og kræver mandskabsressourcer**, hvilket kan være en barriere.
5. Der er behov for en **kritisk masse** af deltagende vandværker for at sikre en gyldig benchmark, for at muliggøre et forum til deling af data og for at øge bevidstheden om de potentielle fordele ved måling af DDP-indikatorer til vandbehandling.

4.3 Udvalgte DDP-indikatorer

Nedenfor beskrives et udvalg af specifikke DDP-indikatorer, der har værdi for drikkevandsbranchen i Danmark. I takt med, at der opnås flere erfaringer med brug af DDP-indikatorer, forventes denne liste at blive udvidet og tilpasset. TABEL 3 er en liste over disse indikatorer sammen med værdier fra de 10 undersøgte vandværker. Hver indikator er tildelt mål på tre niveauer: grøn (acceptabel værdi), gul (opmærksomhed anbefales) og rød (kan kræve handling).

4.3.1 Filterudnyttelse

Filterudnyttelse udtrykker i procent, hvor meget et filteranlæg udnyttes (baseret på vandværkets aktuelle årsproduktion) sammenlignet med en tænkt situation, hvor vandværkets filtre belastes mest muligt (dvs. maksimum flow på filtret, 24/7). Da der er behov for pauser i produktion til returskylleprocessen, kan 100% udnyttelse ikke opnås i praksis. Værdier kan variere fra langt under 50% for værker, der er overdimensioneret (eller som har for lille en rentvandstank til at udligne forskelle mellem indvinding og udpumpning) til 98% for et grundlastværk, hvor indvinding og udpumpning er stort set ens 24/7. Indikatoren er hermed en kombination af både maks. filterhastighed ved spidsbelastning samt stilstand, f.eks. om natten.

$$\frac{\frac{1.095.000m^3}{år}}{\frac{250m^3}{t} \times \frac{24t}{d} \times \frac{365d}{år}} \times 100\% = 50\%$$

4.3.2 Filter footprint

Filter footprint giver en indikation af, om vandværket i teorien er under- eller overdimensioneret i forhold til den aktuelle produktion. Den beregnes som det filterareal i m^2, der bruges for at producere 1 mio. m^3/år. Bemærk, at denne indikator ser bort fra råvandets kvalitet (man vil forvente et større filter footprint, jo vanskeligere råvandet er at behandle). Da trykfiltre ofte har et lagtykkelse/filterareal-forhold, der er 2-4 gange større end gravitationsfiltre, vil man alt andet lige forvente ca. 2-4 gange mindre areal footprint for trykfiltre. Typiske værdier for gravitationsfiltre er 50-100 m^2 (per 10^6 m^3/år). Denne indikator er derfor tæt beslægtet til den foregående Filterudnyttelse, blot med filterarealet medtaget i beregningen.

$$\frac{171\ m^2}{\frac{2.850.000m^3}{år}} \times \frac{10^6 m^3}{år} = 60m^2\ (gravitationsfilter)$$

4.3.3 Maksimum filterhastighed (eng: Max. Hydraulic Loading Rate – HLR)

Filterhastighed udtrykkes i m/t og beregnes ved at dele flowet for et filter med det samme filters areal. Filterhastigheden har faldet på mange anlæg i de senere årtier i takt med, at vandforbruget er dalet. Hermed er den aktuelle filterhastighed ofte lavere end anlægget var dimensioneret til. Generelt bruges en højere filterhastighed i trykfiltre end i gravitationsfiltre. For lav en filterhastighed kan fremme uønsket kagefiltrering mens for høj filterhastighed kan medføre meget stor opstuvning i gravitationsfiltre. Til denne indikator bruges den maksimale filterhastighed, der beregnes ud fra det største flow, der anvendes i mindste en time på en normal dag.

$$\frac{\frac{40\ m^3}{t}}{20m^2} = \frac{2m}{t}$$

4.3.4 Minimum Empty Bed Contact Time (EBCT)

EBCT opgives i minutter og er proportionel til filtrets flowhastighed og tykkelsen af det aktive filterlag. Den udtrykker en fiktiv opholdstid for vandet i filtret ved at antage, at der intet filtermedium er (herfra kommer det engelske udtryk ”empty bed”). Fordelen med EBCT frem for den aktuelle kontakttid (som er noget kortere) er, at man ikke behøver at have en nøjagtig måling af porøsiteten til at beregne størrelsen. Indikatoren ”minimum EBCT” fortæller om den aktuelle drift er inden for et område, hvor man vil forvente, at ammonium kan nå at blive omsat. Indikatoren beregnes ved at dividere et udvalgt filters aktive volumen (dvs. eksklusivt bærelaget) med det maksimale flow for samme filter. Minimum EBCT skal naturligvis være større for råvandskvaliteter med meget ammonium. Minimum EBCT for både gravitationsfiltre og trykfiltre er typisk i størrelsesorden 10-30 minutter.

$$\frac{49{,}77m^2 \times 1{,}40m}{\frac{250\,m^3}{t}} \times \frac{60min}{t} = 17\,min$$

4.3.5 Gangtidens produktion (eng: Unit Filter Run Volume – UFRV)

Gangtidsproduktion udtrykkes i m^3/m^2 og er den mængde vand, der gennemløber et filter mellem to returskyl delt med det samme filters areal. Gangtidsproduktion kan naturligvis variere med råvandets indhold af jern, med ligger ofte i størrelsesorden 200-300 m^3/m^2. Trykfiltre, der generelt har en større filterhastighed og dermed dybdefiltrering kan udvise væsentlig højere gangtidsproduktion.

$$\frac{5000m^3}{16m^2} = \frac{312m^3}{m^2}$$

4.3.6 Gangtidens jernbelastning

Denne DDP-indikator kvantificerer den mængde jern, som et kvadratmeter belastes med inden filtret returskylles. Den beregnes ved at gange råvandets gennemsnitlige jernkoncentration med det antal m^3, det aktuelle filter behandler på en gangtid og dele dette produkt med det aktuelle filters areal i m^2. En tommelfingerregel siger, at man skal kunne fjerne mere end 1 kg Fe/m^2 filterareal før der skal returskylles, men denne værdi opnås sjælden i virkeligheden.

$$\frac{0{,}80gFe}{m^3} \times \frac{5000m^3}{gangtid} \times \frac{1}{16m^2} = \frac{250gFe}{m^2}$$

4.3.7 Maksimal ammoniumbelastning (volumetric loading rate)

Ammoniumbelastning er et udtryk for filtrets aktuelle belastning og tager højde både for råvandskvalitet og den maksimale flowhastighed på et filter. Den opgives i g ammonium per time per m^3 filtermedium. På engelsk kaldes indikatoren ”volumetric loading rate”. Den aktuelle værdi ændres hver gang man skifter mellem råvandsboringer med forskellige sammensætning eller ændrer flowet til filtret. Den maksimale stofbelastning beregnes ved at gange stofkoncentrationen i råvandet med det maksimale samlede flow gennem vandværket og dele med vandværkets totale aktive filtervolumen. En maksimal belastning beregnes for andre parametre såsom jern og mangan. Værdien for ammonium ligger typisk i størrelsesorden 0,5-2,0 $g/t/m^3$ medie.

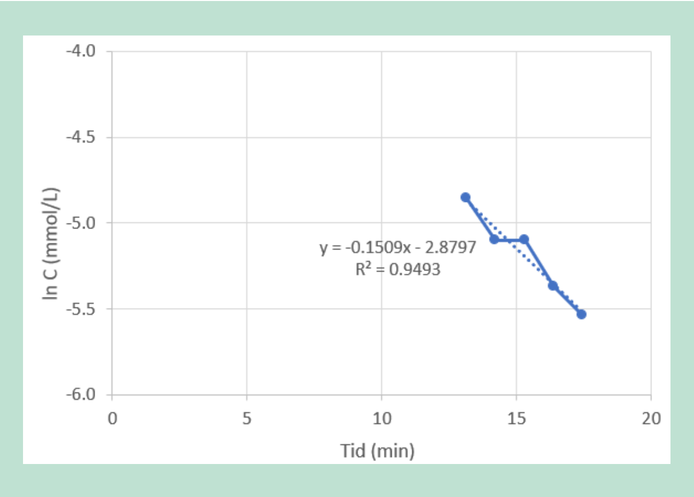
$$\frac{0{,}24\,gNH_4^+}{m^3} \times \frac{250m^3}{t} \times \frac{1}{3 \times 16m^2 \times 1{,}4m} = \frac{0{,}9gNH_4^+}{t \cdot m^3medie}$$

4.3.8 Hastighedskonstant for ammoniumfjernelse

Hastighedskonstanten for ammoniumfjernelse er en meget central DDP-Indikator. Der udarbejdes indledningsvist en graf af ln C mod t for ammoniumkoncentration ned igennem filterdybden. ”C” angives i mmol/L mens ”t” angives i minutter (beregnes ud fra den aktuelle flowhastighed, porøsiteten samt dybden under toppen af filtermediet af prøvetagningshanen).

Herefter udvælges den samling af intervaller (minimum 3 dybdeintervaller af 10 cm’s tykkelse) med den hurtigste fjernelse (i.e. den stejleste del af profilkurven), se eksemplet nedenfor. Det valgte dybdeinterval skal yderligere opfylde krav til, at intervallets indløbskoncentration er større end 0,05 mg/L (dvs. $\ln C > -5{,}9$) og at 10% eller mere af intervallets indløbskoncentration fjernes i intervallet.
Der antages stoffjernelsen er proportionel til indløbskoncentration i første potens (1. ordens fjernelse). En hastighedskonstant udregnes ved hjælp af lineær regression som den rette linjes hældning. Herved er hastighedskonstanten uafhængig af indløbskoncentration. Værdier

angives som absolutte værdier i enhederne min^{-1} og varierer for ammonium ofte fra 0,1 – 1,0 min^{-1}. Hastighedskonstant for stoffjernelse kan også beregnes for stoffer som jern og mangan.



FIGUR 5. Beregning af hastighedskonstant for ammoniumfjernelse.

4.3.9 Filtermediets coating

Når råvandet består af jern- og manganholdigt grundvand, dannes en coating på filtermediekornene gennem årene. Coatingen kan måles i % som vægtforskellen mellem tørrede korn før og efter afsyring, delt med den afsyrede vægt, se nedenstående ligning. Der er målt værdier op til ca. 40%, afhængig af vandkemien, returskylleproceduren samt antal år filtermediet har været i drift.

$$\frac{2{,}62 - 1{,}93\ g\ medie}{1{,}93\ g\ medie} \times 100\% \ = 35\%$$

4.3.10 Filtermediets uensformighedstal

Uensformighedstal (eng. = Coefficient of uniformity – Cu) beskriver bredden af filtermediets kornstørrelsesfordeling. Det beregnes ved at dele 60%-fraktilen i mm (d_{60}) med 10%-fraktilen i mm (d_{10}). Resultatet er dimensionsløst. For at opnå gode hydrauliske egenskaber i et drikkevandsfilter ønskes korn, der er så ens i størrelse som muligt og tallet må gerne være < 1,5. Men tallet kan stige mod 2,0 med filtermediets alder - i takt med at nogle korn slides mens andre får en coating. Hvis filtret består af to medier og er lagdelt, kan tallet variere med dybde. Men hvis disse to medier er blevet blandet i filtret, vil tallet være højere for hele filtret. Her anvendes tallet for filtermedieprøver udtaget fra et dybdeinterval på 0-20 cm.

$$U_{0-20cm} = \frac{2{,}3\ mm}{1{,}1\ mm} = 2{,}1$$

4.3.11 Returskyllets effektivitet

Returskyllets effektivitet sammenholder den mængde jern, der ophobes på et filter i løbet af en gangtid (i g Fe/gangtid) med skyllevandsforbruget (i m^3) for returskylning af samme filter. Beregningen udføres ved at gange råvandets jernkoncentration med antal m^3, der gennemløber filtret på en gangtid og dele resultatet med skyllevandsforbruget for samme filter. Typiske værdier er 50-200 gFe/m^3 skyllevand.

$$\frac{2{,}1gFe}{m^3} \times \frac{5000m^3}{gangtid} \times \frac{gangtid}{116m^3_{skyllevand}} = \frac{90gFe}{m^3_{skyllevand}}$$

4.3.12 Filtermediets ekspansion

Filtermediets ekspansion under et returskyl med vand (uden samtidigt luftskyl) er en funktion af filtermediets densitet og kornstørrelse samt skyllevandshastigheden. Denne DDP-Indikator udtrykker, hvor meget bedet med filtermedie ekspanderer (i % af det aktive lag) under returskyl med vand alene, se eksemplet nedenfor. Mange vandværker i Danmark opnår begrænset filtermedieekspansion, dvs. < 15%.

$$\frac{10cm}{120cm} \times 100\% = 8\%$$

4.3.13 Rentvandstankens reserve

Rentvandstankens reserve udtrykker (i timer), hvor meget reserve der findes i en fuld rentvandstank, forudsat et middeltimeforbrug (årsforbrug delt med 365 og 24). For meget reserve medfører øget risiko for stagneret vand i tanken med risiko for eftervækst af kim, mens for lille reserve øger risikoen for at løbe tør f.eks. i tilfælde af ekstraordinært stort forbrug ved brand. Et eksempel på beregning ses nedenfor. Værdier ligger ofte i intervallet 5-10 timer, men der findes underdimensionerede tanke med en reserve på få timer og overdimensionerede tanke med en reserve på flere døgn. Det understreges, at en reserve på et antal timer (med middeltimeforbrug) rækker til et meget kortere tidsrum under en spidsbelastning.

$$450m^3 \times \frac{år}{660.000m^3} \times \frac{365d}{år} \times \frac{24t}{d} = 6{,}0t$$

4.3.14 Rentvandstankens udnyttelse

Rentvandstankens udnyttelse udtrykker (i %) i hvor høj grad rentvandstankens volumen bliver udnyttet på en daglig basis. Den defineres ud fra den laveste vandstand på en typisk dag (i cm) og den maksimale vandstand (i cm), der kan være i tanken. Hvis for lidt af rentvandstankens volumen udnyttes, er det sandsynligt, at der i perioder med højt vandforbrug skal anvendes et unødvendigt højt flow på filtrene for at følge med forbruget (i stedet for at forskelle i dag- og natforbrug udjævnes i produktionen). Lav udnyttelse af rentvandstanken medfører også større risiko for stagneret vand i tanken. Ved for høj udnyttelse er der risiko for, at man kan komme til at mangle vand til returskyl, brandslukning eller forsyningssikkerhed generelt.

$$\frac{385cm - 115cm}{385cm} \times 100\% = 70\%$$

TABEL 3. Oversigt over udvalgte DDP-Indikatorer for de 10 vandværker.

	Indikatornavn	Enhed	Målte værdier fra 10 vandværker					Målværdier		Kommentar
			Min	10%	Median	90%	Maks	Gul	Rød	
1	Filterudnyttelse	%	22	24	50	63	79	<50	<30	Produktion i forhold til maks. filterhastighed 24/7
2	Filter footprint	$\frac{m^2 filterareal}{10^6 m^3/år}$	48	48	59	93	101	>50	>80	Kun gravitationsfilter Ser bort fra råvandskvalitet
3	Maksimum filterhastighed	m/t	2,8	3,3	4,7	6,3	15,3	<4	<3	Maks. værdien gælder for et trykfilter
4	Minimum Empty Bed Contact Time (EBCT)	min	10	13	17	24	28	<15	<10	Skal være større, hvis råvandet indeholder meget ammonium
5	Gangtidens produktion (UFRV)	m^3/m^2	163	170	218	344	559	<250	<200	Ser bort fra råvandskvalitet; højere for trykfiltre end gravitationsfiltre
6	Gangtidens jernbelastning	$\frac{gFe}{m^2}$	160	180	260	700	820	<300	<600	Kun gravitationsfiltre

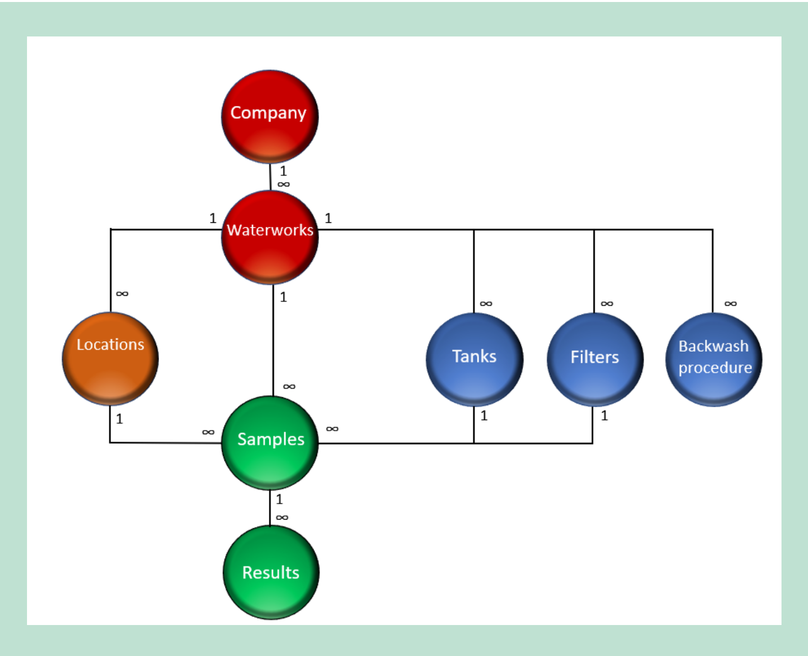
7	Maksimal ammoniumbelastning	$\frac{g_{amm}}{t \cdot m^3_{sand}}$	0,6	0,6	0,9	1,9	2,5	>2,0	>2,5	Kan også beregnes for jern og mangan
8	Hastighedskonstant for ammoniumfjernelse	min^{-1}	0,11	0,15	0,37	1,02	1,17	<0,5	<0,2	Kan også beregnes for mangan
9	Filtermediets coating, 0-20 cm	%	4	10	32	38	43	>20	>40	Varierer med filterdybde og mediealder
10	Filtermediets uensformighedstal (Cu), 0-20 cm	dimensionsløs	1,4	1,5	1,9	3,1	3,5	>2	>3	Varierer med filterdybde og mediealder
11	Returskyllets effektivitet	$\frac{g_{Fe}}{m^3_{skyllevand}}$	21	57	89	196	236	<100	<50	Ser bort fra hvor meget jern er fjernet i løbet af gangtiden
12	Filtermediets ekspansion	%	22	24	29	74	79	<15	<10	Usikkerhed i de målte tal som følge af lille skyl
13	Rentvandstankens reserve	$timer$	3,2	3,4	5,9	10,0	10,1	<6	<4	Baseret på maks. Filterhastighed
14	Rentvandstankens udnyttelse	%	35	37	68	94	95	<50	<25	Sikkerhedsvolumen til nødsituationer kan variere

5. Design af databasen

Databasen Merkur er en åben, webbaseret relationel database til vandbehandlingsdata udviklet på FileMaker 14 Platformen. FileMaker består af en databasemotor og en grafisk grænseflade til Windows og Mac. Ved udvikling af Merkur blev der anvendt Jupiter terminologien i den udstrækning, det gav mening. I dette kapitel beskrives Merkurs design.

5.1 Tabeller og deres indbyrdes relationer

Der findes otte hovedtabeller i Merkur, som alle er forbundet med én-til-mange relationer. Hovedtabellerne og deres relationer ses i FIGUR 6.



FIGUR 6. Hovedtabeller i databasen Merkur.

Hver hovedtabel er beskrevet i det følgende. Bilag 2 er en liste over tabellernes felter og tabellernes primære nøgler.

1. Company: Denne tabel angiver data om forsyningerne. Navnet "Company" stammer fra Jupiter terminologi. Én forsyning kan drive flere vandværker.
2. Waterworks: Denne tabel angiver data om de undersøgte vandværker. Ud over link til Company samt oplysninger om vandværkets geografiske placering, findes oplysninger om type af filtrering (tryk eller gravitation, enkelt eller dobbeltfiltrering) og beluftningsmetode.
3. Locations: Denne tabel angiver den placering på en PI-diagram, hvor prøven eller målingen hører hjemme.
4. Tanks: Denne tabel angiver data om kapaciteten af rentvandstanke, udførselsmateriale og min./maks. vandstand i tankene.
5. Filters: Denne tabel angiver de undersøgte filterbassiner/filterbeholdere med hensyn til dimensioner og de indsatte filtermedielag.
6. Backwash procedure: Denne tabel beskriver bl.a. de forskellige trin i returskylleproceduren, skyllevandsforbrug og hvilken trigger anvendes til at udløse et returskyl.

7. Samples: Denne tabel angiver prøvetypen (vand, skyllevand eller filtermedium), dato og klokkeslæt for prøvetagning samt diverse meta-data.
8. Results: Denne tabel angiver værdien af selve måleresultaterne, enheder, evt. ”<” tegn, m.m.

Ud over disse hovedtabeller findes følgende støttetabeller: History, Parameters, Municipality, Labs.

5.2 Brugerflade

En udførlig brugermanual (Merkur System User Manual) findes som Bilag 3.

Bruger adgangsniveau:

1. Høj: man kan se grafer, skifte mellem hvilken vandværk fremhæves i gul på grafer, indtaste/ændre data, downloade data
2. Mellem: man kan kun ses grafer og kun med 1 vandværk fremhævet i gul
3. Lav: man kan kun ses grafer, og ingen vandværker er fremhævet i gul

Medlemsniveau:

1. A: Vandværket bidrager både med Vingesus data samt felt/lab-data
2. B: Som A, dog uden dybdeprofiler (normalt fordi der er tale om trykfiltre uden haner på filtersiden
3. C: Vandværket bidrager kun med Vingesus data (dvs. uden prøvetagning og analyse)

Hver graf har et flag, der fortæller hvilke medlemsniveau den skal være tilgængelig for

Adgang til Merkurs brugerflade fås ved login på hjemmesiden www.ceath.merkur.com. Der er mulighed for login som følger:

1. Forsyning: giver adgang til grafer om det aktuelle vandværk samt sammenlignings-grafer, hvor det aktuelle vandværk er fremhævet.
2. Udefra: giver kun adgang til sammenligningsgrafer uden fremhævning.
3. Administrativ: giver adgang til at skifte frit mellem det vandværk, der er fremhævet.

Efter login præsenteres man for et skærmbillede med ti faneblade, hvor de første syv indeholder en række grafer (i parentes):

1. Anlæg (årsproduktion)
2. Hydraulik (filter footprint)
3. Vand (dybdeprofiler med Fe, Mn, NH_4, O_2, pH, redox)
4. Filter (enkelt/dobbelt, gravitation/tryk, filterudnyttelse, hydraulisk belastning/volumetrisk)
5. Filtermedie (kornstørrelsesfordeling, coating profil)
6. Returskyl (skylleeffektivitet, tidsserie med Fe og turbiditet, bed ekspansion, ekspansion/fribord-forhold)
7. Rentvandstank (reserve, udnyttelse)
8. Detaljeret data (grunddata samt mulighed for data download)
9. Min konto (skift af kodeord, valg af sprog)
10. Log ud

5.3 Visualisering af data

Der er udarbejdet 21 grafer til fremvisning i Merkur. Der er 11 grafer, der sammenligner data fra forskellige vandværker og yderligere 10 grafer, der viser data fra det aktuelle vandværk.

Der er anvendt histogrammer, punktdiagrammer og lagkagediagrammer.

Bilag 4 Description of graphs in Merkur giver en beskrivelse af alle graferne i Merkur.

5.4 Vandbehandlingsdata i Merkur

Metoderne, der blev anvendt til indsamling af prøver og målinger, er beskrevet i Rapport 1 om ”Dataindsamling”. Data for 10 vandværker blev indlæst i Merkur og kontrolleret for fejl. I skrivende stund ligger der over 200 resultater i tabellen ”Results” for hvert vandværk. Hertil kommer mange andre informationer om vandværket.

I en traditionel database identificeres prøver ofte med en lokalitet (f.eks. et boringsnummer eller en adresse) og en dato (med klokkeslæt). I Merkur databasen findes mange resultater, der ikke passer til denne simpel form for identifikation. Flere resultater i Merkur er grupperet i serier. Eksempler inkluderer tidsserier med skyllevandsprøver (hvor der udtages prøver hver 30 sekunder under et skyl) og dybdeprofiler (hvor vand- og filtermedieprøver udtages i hhv. 10 og 20 cm intervaller). I Merkur terminologien kaldes hver serie for en ”sample”, ligesom hver enkeltstående måling (non-series) kaldes for en ”sample”.

Resultater i Merkur kan også adskille sig fra en traditionel database i de metadata, der skal være forbundet til resultaterne. Her tænkes f.eks. på hvilket flow var gældende når et sæt jernprofilprøver blev udtaget.

Merkur indeholder også en del data, der er beregnede. For eksempel er alle DDP-Indikatorer beregnede. TABEL 3 viser en oversigt over DDP-Indikatorer.

6. Perspektiver

Den primære målgruppe for Merkur er det tekniske personale på vandbehandlingsanlæg i Danmark. Denne gruppe har brug for data til at kunne tage beslutninger baseret på evidens. I takt med, at flere vandværker bidrager med data til Merkur, vil databasen få større betydning for andre målgrupper. Her kan der f.eks. være tale om entreprenører og rådgivere, der designer vandværker, kommuner, der fører tilsyn med drikkevandskvalitet og forskere, der belyser vandbehandlingsprocessen. Merkur kan være med til at skabe et fælles sprog til at tale om vandbehandlingsudfordringer. En frugtbar vandbehandlingsdialog kan fremmes f.eks. ved en tilbagevendende Merkur-forum.

For at blive en succes i fremtiden er der behov for deltagelse af flere vandværker end de nuværende 10. Jo flere vandværker, jo stærkere og jo mere retvisende bliver de forskellige drift, design og performanceindikatorer. For at sikre Merkurs udbredelse er der også behov for at fastlægge en finansieringsmodel til hosting og vedligeholdelse af databasen.

På den lidt længere bane kan Merkur udvides til også at omfatte udenlandske vandværker med lignende forhold (dvs. vandbehandling baseret på grundvand og biofiltrering). Relevante lande og områder inkluderer f.eks. Holland, Nordtyskland, Baltikum, Canada.

7. Referencer

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Bilag 1. Lister over stoffer med drikkevands-kvalitetskrav

Fra Bekendtgørelse 1068 af 23. august, 2018.

Standatcode	Stofnavn	>	Kategori	Kvalitetskrav	Enhed
3670	1,2,4-triazol		Nedbrydningsprodukter	0,0001	mg/l
2688	2,4-dichlorphenol		Nedbrydningsprodukter	0,0001	mg/l
3548	2,6-DCPP		Nedbrydningsprodukter	0,0001	mg/l
2712	2,6-Dichlorbenzamid		Nedbrydningsprodukter	0,0001	mg/l
4014	2,6-dichlorbenzosyre		Nedbrydningsprodukter	0,0001	mg/l
2690	2,6-dichlorphenol		Nedbrydningsprodukter	0,0001	mg/l
3538	4-CPP		Nedbrydningsprodukter	0,0001	mg/l
3011	4-nitrophenol		Nedbrydningsprodukter	0,0001	mg/l
1584	Acrylamid		Materiale monomerer	0,0001	mg/l
3503	Aldrin		Pesticider	0,00003	mg/l
1501	Aluminium		Uorganiske sporstoffer	0,2	mg/l
1011	Ammoniak+ammonium		Hovedbestanddele	0,05	mg/l
4536	AMPA		Nedbrydningsprodukter	0,0001	mg/l
1506	Antimon		Uorganiske sporstoffer	0,005	mg/l
1511	Arsen		Uorganiske sporstoffer	0,005	mg/l
4515	Atrazin		Obligatoriske pesticider	0,0001	mg/l
3505	Atrazin, desethyl-		Nedbrydningsprodukter	0,0001	mg/l
3506	Atrazin, desisopropyl		Nedbrydningsprodukter	0,0001	mg/l
3507	Atrazin, hydroxy-		Nedbrydningsprodukter	0,0001	mg/l
9944	Bentazon		Obligatoriske pesticider	0,0001	mg/l
9824	Benz[a]pyren		PAH-forbindelser	0,00001	mg/l
662	Benzen		Olieprodukter	0,001	mg/l
1531	Bly		Uorganiske sporstoffer	0,005	mg/l
1536	Bor		Uorganiske sporstoffer	1	mg/l
1545	Bromat		Halogenholdige omdannel-sesprodukter	0,01	mg/l
1546	Cadmium		Uorganiske sporstoffer	0,003	mg/l
380	Carbon,org,NVOC		Hovedbestanddele	4	mg/l
1583	Chlorat		Halogenholdige omdannel-sesprodukter	0,05	mg/l
1591	Chlorid		Hovedbestanddele	250	mg/l
1582	Chlorit		Halogenholdige omdannel-sesprodukter	0,05	mg/l
2002	Chrom		Uorganiske sporstoffer	0,05	mg/l
9255	Clostridium perfringens, sporer		Mikrobiologiske parametre	0	antal/100 ml

2012	Cobalt,filt		Uorganiske sporstoffer	0,005	mg/l
9052	Coliforme Bakt. MP		Mikrobiologiske parametre	0	antal/100 ml
654	Cyanid, total		Uorganiske sporstoffer	0,05	mg/l
3755	Deisopropyl-hydroxyatra-zin		Nedbrydningsprodukter	0,0001	mg/l
	Desethyldesisopropyl-at-razin (DEIA)		Nedbrydningsprodukter	0,0001	mg/l
3754	Desethyl-hydroxy-atrazin		Nedbrydningsprodukter	0,0001	mg/l
4696	Desphenyl-chloridazon		Nedbrydningsprodukter	0,0001	mg/l
2627	Dichlobenil		Obligatoriske pesticider	0,0001	mg/l
4510	Dichlorprop		Obligatoriske pesticider	0,0001	mg/l
3756	Didealkyl-hydroxy-atrazin		Nedbrydningsprodukter	0,0001	mg/l
3134	Dieldrin		Pesticider	0,00003	mg/l
2628	Diuron		Obligatoriske pesticider	0,0001	mg/l
9186	E.coli		Mikrobiologiske parametre	0	antal/100 ml
9357	Enterokokker		Mikrobiologiske parametre	0	antal/100 ml
1585	Epichlorhydrin		Materiale monomerer	0,0001	mg/l
3573	Ethylenthiourea		Obligatoriske pesticider	0,0001	mg/l
61	Farvetal-Pt		Hovedbestanddele	15	Pt mg/l
2701	Fluoranthen		PAH-forbindelser	0,0001	mg/l
2022	Fluorid		Hovedbestanddele	1,5	mg/l
	flygtige organiske chlor-forbindelser		Opløsningsmidler - chlor-holdige	0,001	mg/l
3592	Glyphosat		Obligatoriske pesticider	0,0001	mg/l
3136	Heptachlor		Pesticider	0,00003	mg/l
3137	Heptachlorepoxid		Pesticider	0,00003	mg/l
3597	Hexazinon		Obligatoriske pesticider	0,0001	mg/l
2041	Jern		Hovedbestanddele	0,2	mg/l
8999	Kimtal		Mikrobiologiske parametre	200	antal/ml
9037	Kimtal 22 gr		Mikrobiologiske parametre	200	antal/ml
2061	Kobber		Uorganiske sporstoffer	2	mg/l
11	Konduktivitet		Hovedbestanddele	2500	µS/cm
2071	Kviksølv		Uorganiske sporstoffer	0,001	mg/l
2086	Mangan		Hovedbestanddele	0,05	mg/l
4511	MCPA		Obligatoriske pesticider	0,0001	mg/l
4512	Mechlorprop		Obligatoriske pesticider	0,0001	mg/l
3611	Metalaxyl		Obligatoriske pesticider	0,0001	mg/l
4717	Metalaxyl-M		Obligatoriske pesticider	0,0001	mg/l
	Methyl-desphenyl-chlori-dazon		Nedbrydningsprodukter	0,0001	mg/l
3683	Metribuz-desamino-di-keto		Nedbrydningsprodukter	0,0001	mg/l
3617	Metribuzin		Obligatoriske pesticider	0,0001	mg/l
3684	Metribuzin-desamino		Nedbrydningsprodukter	0,0001	mg/l

3685	Metribuzin-diketo		Nedbrydningsprodukter	0,0001	mg/l
	N-(2,6-dimethylphenyl)-N-(methoxyacetyl)alanin		Nedbrydningsprodukter	0,0001	mg/l
	N-(2-carboxy-6-methylphenyl)-N-(meth-oxyacetyl)alanin		Nedbrydningsprodukter	0,0001	mg/l
4743	N,N-dimethylsulfamid (DMS)		Nedbrydningsprodukter	0,0001	mg/l
2096	Natrium		Hovedbestanddele	175	mg/l
2101	Nikkel		Uorganiske sporstoffer	0,02	mg/l
1176	Nitrat		Hovedbestanddele	50	mg/l
1051	Nitrit		Hovedbestanddele	0,1	mg/l
2695	Pentachlorphenol		Chlorphenoler	0,00001	mg/l
41	pH		Hovedbestanddele	8,5	pH enhe-der
41	pH	>	Hovedbestanddele	7	pH enhe-der
4779	Radon		Radioaktivitetsindikatorer	100	Bq/l
2106	Selen		Uorganiske sporstoffer	0,01	mg/l
4516	Simazin		Obligatoriske pesticider	0,0001	mg/l
452	Simazin, hydroxy		Nedbrydningsprodukter	0,0001	mg/l
2142	Sulfat		Hovedbestanddele	250	mg/l
	sum af organiske chlor-forbindelser		Opløsningsmidler - chlor-holdige	0,003	mg/l
	sum af PAHer		PAH-forbindelser	0,0001	mg/l
	sum af pesticider		Pesticider	0,0005	mg/l
	sum af PFAS		PFAS-forbindelser	0,0001	mg/l
	sum af trihalomethaner		Opløsningsmidler - chlor-holdige	0,025	mg/l
1586	Sum chlorit/chlorat		Halogenholdige omdannel-sesprodukter	0,05	mg/l
2226	Sølv		Uorganiske sporstoffer	0,01	mg/l
422	Terbut.azin,desethyl		Nedbrydningsprodukter	0,0001	mg/l
	total indikativ dosis		Radioaktivitetsindikatorer	0,1	mSv/år
2245	Tritium		Radioaktivitetsindikatorer	100	Bq/l
46	Turbiditet		Hovedbestanddele	1	FNU
9946	Vinylchlorid		Materiale monomerer	0,0005	mg/l
2251	Zink		Uorganiske sporstoffer	3	mg/l

Bilag 2. Liste over Merkurs tabeller og felter

Table name	Field name	Data type	Pri-mary Key	Forei gn Key	Calcu-lated field
Company (T01)	Company_Key_Field	AutoIn-teger	X		
Fields=8	Company_Name	Text			
	Address Line 1	Text			
	Address Line 2	Text			
	City	Text			
	Pærovince	Text			
	Postal Code	Text			
	Country	Text			
Waterworks (T02)	Waterworks_Key_Field	AutoIn-teger	X		
Fields=80	General information	Text			
	Waterworks_Name	Text			
	Waterworks_Number	Integer			
	Address Line 1	Text			
	Address Line 2	Text			
	City	Text			
	Province	Text			
	Postal Code	Integer			
	Country	Integer			
	Company_Key_Field	Integer		X	
	Municipality	Integer			
	Comment_General_Merkur	Text			
	Comment_General_Vingesus	Text			
	Contact Information	Text			
	Name First	Text			
	Name Middle	Text			
	Name Last	Text			
	Email	Text			
	Phone	Text			
	Name First Alt A	Text			
	Name middel Alt A	Text			
	Name Last Alt A	Text			
	Email Alt A	Text			
	Phone Alt A	Text			
	Name First Alt B	Text			

	Name middel Alt AB	Text			
	Name Last Alt B	Text			
	Email Alt B	Text			
	Phone Alt B	Text			
	Map and Image Information	Text			
	Coordinate_X	Real number			
	Coordinate_Y	Real number			
	Lattitude	Real number			
	Longitude	Real number			
	Builder	Text			
	Builder_Descript_Other	Text			
	Image	Contai-ner			
	Aeration information	Text			
	Aeration_Type	Text			
	Aeration_Depth	Real number			
	Aeration_Other_Description	Text			
	Aeration_Lines	Integer			
	Reaction_Basin	Text			
	Reaction_Basin_Size	Integer			
	Comment_Aeration	Text			
	Filter Information	Text			
	Filtration_Type	Text			
	Filtration_Other_Description	Text			
	Filtration_Single_Double	Text			
	Filtration_Lines	Integer			
	Number_of_First_Filters	Integer			
	Total_Number_of_Filters	Integer			
	Filtration_Underdrain	Text			
	Filtration_Underdrain_Other_De-scription	Text			
	Filter for this investigation	Text			
	Comment_Filtration	Text			
	Filter_Key_of_Interest	Integer		x	
	Filter Media Information	Text			
	Comment_FilterMedia	Text			
	Backwash Information	Text			
	AirFlow	Text			
	AirFlow_scour_metric	Real number			
	AirFlow_with_water_metric	Real number			
	WaterFlow	Text			

	WaterFlow_alone_metric	Real number			
	WaterFlow_with_air_metric	Real number			
	FlushFrequency	Text			
	FlushFrequency_metric	Real number			
	Backwash_Run_Time_Volume	Real number			
	Comment_Backwash	Text			
	Tank Information	Text			
	Tank for this investigation	Text			
	Comment_Cleanwater_Tank	Text			
	Tank_Key_of_Interest	Integer		x	
	Other	Text			
	PI Diagram	Contai-ner			
	Result1_of_Interest	Integer			
	Result2_of_Interest	Integer			
	Result3_of_Interest	Integer			
Back-wash_Proce-dure (T02.1)	Backwash_Key_Field	AutoIn-teger	X		
Fields=10	Timestamp	Date/ti me			
	Waterworks_Key_Field	Integer		X	X
	Step_Number	Integer			
	Activity	Text			
	Duration	Se-conds			
	Flow_Rate_Water	Real number			
	Flow_Rate_Air	Real number			
	Backwash_Trigger	Text			
	Volume_of_Water_Used	Real number			
Locations (T03)	Location_Key_Field	AutoIn-teger	X		
Fields=13	Waterworks_Key_Field	Integer		X	
	Use this location in graphs	Integer			
	Sample_Key_Field	Integer		X	
	Local Identifier	Text			
	Unit_1_Type	Text			
	Unit_1_Number	Integer			
	Unit_1_Connection	Text			
	Unit_2_Type	Text			

	Unit_2_Number	Integer			
	cLocationToDisplay	Integer			x
	Filter_Key_Field	Integer		X	
	Tank_Key_Field	Integer		X	
Filter (T04.1)	Tank_Filter_Key_Field	AutoIn-teger	X		
Fields=23	Waterworks_Key_Field	Integer		X	
	Filter_Line_Number_from_Vingesus	Integer			
	Filter_Number	Integer			
	Fore_or_After_Filter	Text			
	Filter_Width	Real number			
	Filter_Length	Real number			
	Filter_Diameter	Real number			
	cFilter_Area	Real number			x
	Active_Medium_Depth	Real number			
	Method_of_Determination_of_Ac-tive_Medium_Depth	Text			
	Layer_1_Medium_Type	Text			
	Layer_1_Medium_Thickness	Real number			
	Layer_1_Medium_Grain_Size_High	Real number			
	Layer_1_Medium_Grain_Size_Low	Real number			
	Layer_2_Medium_Type	Text			
	Layer_2_Medium_Thickness	Real number			
	Layer_2_Medium_Grain_Size_High	Real number			
	Layer_2_Medium_Grain_Size_Low	Real number			
	cSingle_Dual_Media	Integer			X
	cActive_Filter_Volume	Real number			X
	Medium_Placement_Year	Integer			
	Comment	Text			
FilterMedia (T04.2)	Filter_Media_Key_Field	AutoIn-teger	X		
Fields=9	Filter_Key_Field	Integer		X	
	Waterworks_Key_Field	Integer		X	
	Layer_Number	Integer			
	Layer_Type	Text			

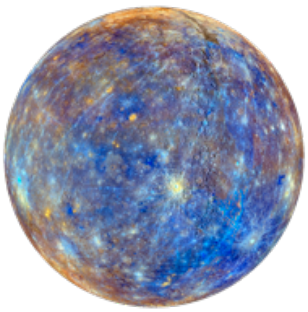
	Layer_Depth	Real Number			
	Layer_Grain_Size_Minimum	Real Number			
	Layer_Grain_Size_Maximum	Real number			
	Year	Integer			
Tank (T04.3)	Tank_Key_Field	AutoIn-teger	X		
Fields=11	Waterworks_Key_Field	Integer		X	
	Tank_Line_Number_From_Vingesus	Text			
	Tank_Number	Integer			
	Max_Level	Real number			
	Min_Level	Real number			
	Alarm_High	Real number			
	Level_Stop	Real number			
	Level_Start	Real number			
	Alarm_Low	Real number			
	cTank_Utilization	Real number			X
Sample (T05)	Sample_Key_Field	AutoIn-teger	X		
Fields=21	Waterworks_Key_Field	Integer		X	
	Sample_Type	Text			
	Location_Key_Field	AutoIn-teger		X	
	Medium	Text			
	Description	Text			
	Sample_Timestamp	Date/ti me			
	cSample_Year	Integer			x
	Use this data	Integer			
	Sampler_Name	Text			
	Remarks	Text			
	Metadata	Text			
	Timestamp_of_Last_Backwash	Date/ti me			
	cMinutes_Since_Last_Backwash	Real number			x
	Flow_including_Flow_Before	Real number			

	Flow_Rate	Real number			
	Christmas_Tree_Vertical_Offset	Real number			
	Christmas_Tree_Distance_from_In-take	Real number			
	Christmas_Tree_Dis-tance_from_Edge	Real number			
	Wells_Running	Text			
	Default_Lab_Key_for_Sample	Integer			
Result (T06)	Result_Key_Field	AutoIn-teger	X		
Fields=16	Sample_Key_Field	Integer		X	
	Parameter_Key_Field	Integer		X	
	Waterworks_Key_Field	Integer		X	
	Use_This_Data	Integer			
	Lab_Key_Field	Integer		X	
	External_ID	Text			
	Seconds				
	Depth	Real number			
	Low_Depth	Real number			
	High_Depth	Real number			
	Low_Grain_Size	Real number			
	High_Grain_Size	Real number			
	Attribute	Text			
	Amount	Real number			
	Remarks	Text			
Parameters (T06.1)	Parameter_Key_Field	AutoIn-teger	X		
Fields=6	Description	Text			
	Unit	Text			
	Short_Name	Text			
	Maksimum_Preferred_Value	Real number			
	Remarks	Text			
Labs (T06.2)	Lab_Key_Field	AutoIn-teger	X		
Fields=10	Name	Text			
	Contact_Person	Text			
	Contact_Person_Email	Text			

	Contact_Person_Phone	Text			
	Address_1	Text			
	Address_2	Text			
	Postal Code	Text			
	City	Text			
	Country	Text			
History (T07)	History_Key_Field	AutoIn-teger	X		
Fields=15	Waterworks_Key_Field	Integer		X	X
	Year	Date/time			
	This_is_the_most_recent_year	Integer			
	Recent_Year_Error_Message	Text			
	Annual_Production_Volume	Integer			
	Maximum_Hourly_Flow	Real number			
	Daily_Production_Max	Real number			
	Daily_Production_Min	Real number			
	cFilter_Utilization	Real number			X
	cTotal_Filter_Area	Real number			X
	cFilter_Footprint	Real number			X
	cTotal_Tank_Volume	Real number			X
	cAverage_Tank_Utilization	Real number			X
	cTotal_Tank_Reserve	Real number			X

Bilag 3. Merkur System User Manual

CEATH Company



Merkur System

User Manual

Client:

VIA University College
Chr. M. Oestergaards Vej 4
8700
Horsens
Danmark

Date:

January 2, 2019 (original)
January 9, 2019 (revision 1)

CEATH Company 1788 Hwy. 1016, Suite B, Berea, KY 40403-9110 USA **T** 1(859)986-8702 **W** www.ceath.com **E** mail@ceath.com

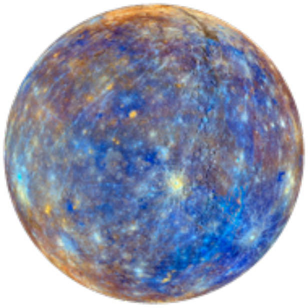
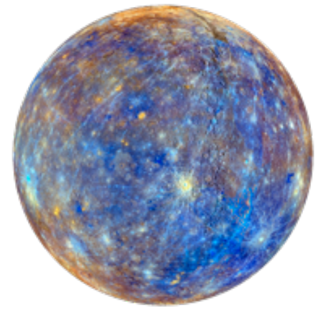


Table of Contents



Merkur System

User Manual

Merkur is a web-hosted computer system developed for VIA University College's MUDP project, "Re-design drinking water production". VIA University College designated staff serve as the Project Leaders.

The system was built for the project by CEATH Company. CEATH Company also serves as the hosting organisation and the Merkur system administrator.

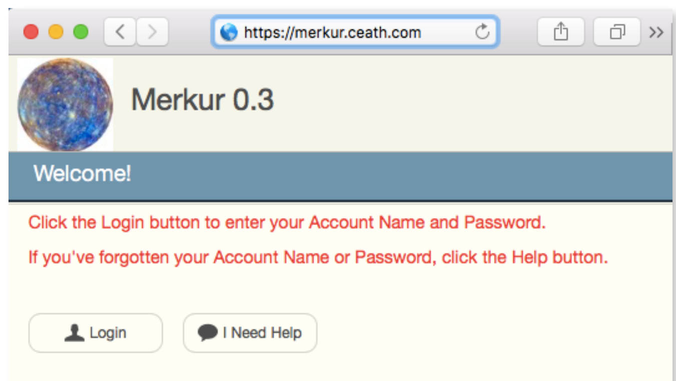
This document contains information for users about how to use the system effectively.

Accessing Merkur

1. Ensure that your computer is connected to the Internet
2. Open any modern browser
3. Browse to http://merkur.ceath.com
4. Click the Login button

Note:

- You may also browse to a secure connection, https://merkur.ceath.com .However, you may have to tell your browser that you "trust" the Merkur web site.
- Whether or not you browse to a secure site initially, Merkur will switch to a secure site with a valid SSL certificate.

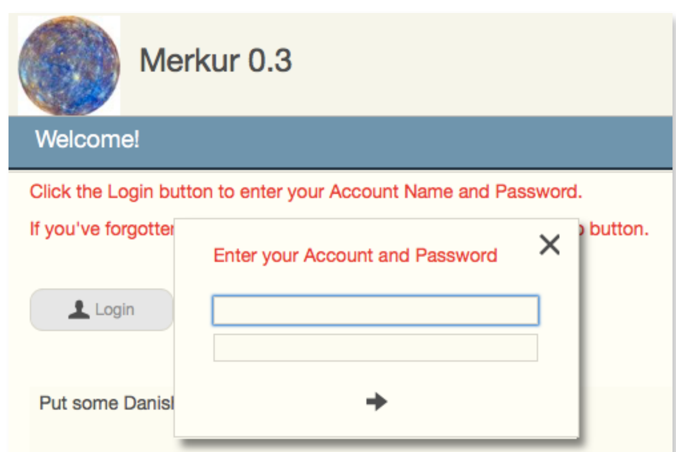


Logging In

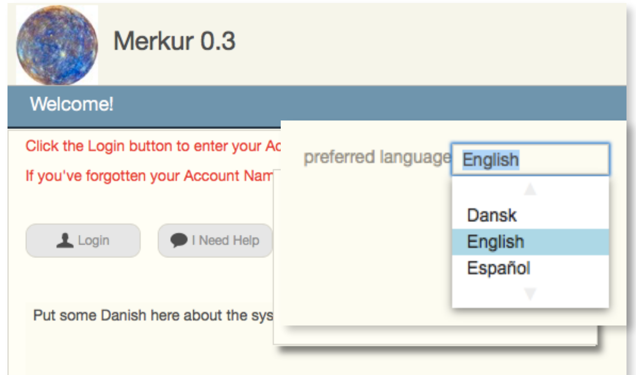
1. Enter your user Account in the first line of the Login box
2. Enter your Password in the second line of the Login box
3. Click the arrow at the bottom of the Login box

Note:

- If you do not know your user Account or Password, click the X in the upper right corner of the Login box to close the box.
- Then see If You Forget Your Password below.



If You Forget Your Password



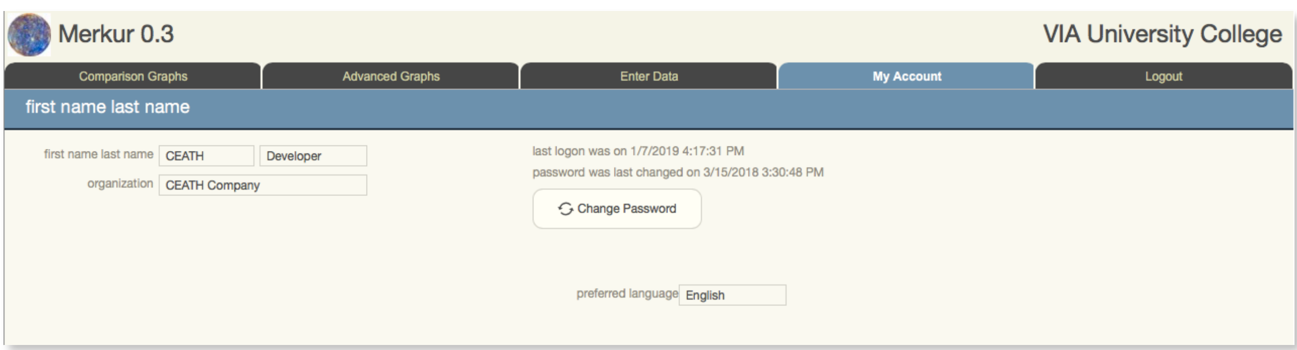
1. Click the I Need Help button
2. Enter the email address that is associated with your user Account
3. Click the arrow at the bottom of the I Need Help box
4. An email will be sent to your email address containing instructions for logging
5. Follow the instructions in that email for logging on

Note:

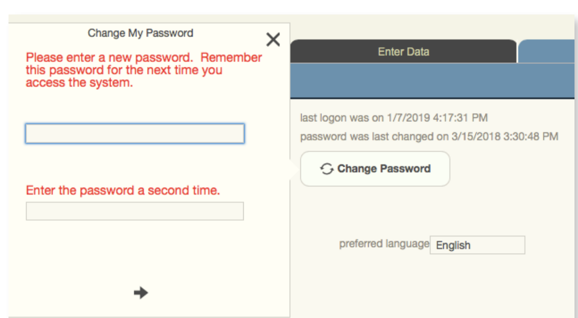
- You must use the email address associated with a valid user Account.
- If you do not have an account, or if you do not know the email address associated with your account, you must contact the Merkur system administrator to have your password reset manually.

Managing Your Account

1. Click the My Account tab



2. To change your name, enter a new first and/or last name
3. To change your organisation name, enter that name in the box indicated
4. To change your password, click on the Change Password button
5. In the resulting box, enter a new password (enter it twice)
6. Then click the arrow at the bottom of the password change box



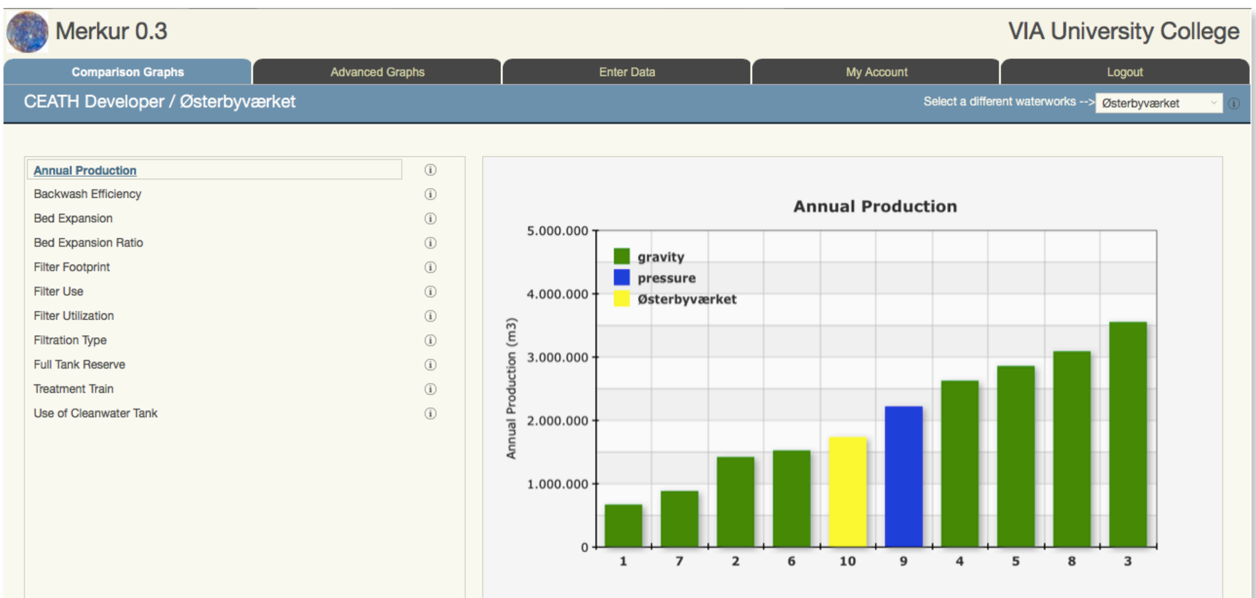
7. To change your preferred language, click on the preferred language box
8. Select a new language from those available in the drop down box

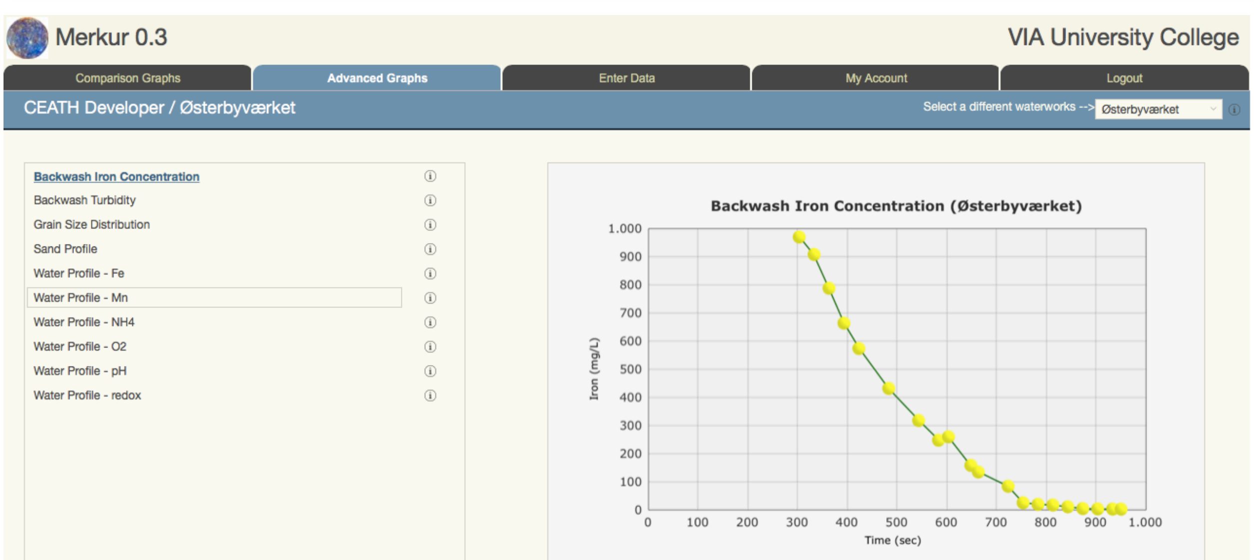
Note:

- The My Account tab shows the last time your user account was used to log on to Merkur. It also shows the last time your password was changed. Note that times are Eastern US time, where the Merkur server is located.
- Always follow good security protocols and do not share your password. Also take care where you write it down; it should not be easily accessible by anyone except you.
- You should change your password immediately if you believe it has been compromised in some way.
- When changing a password, the only requirement is that the two passwords match.
- When changing languages, be patient. Merkur must find and replace all text in one language with your newly selected language, and this can take a bit of time

Accessing Graphs

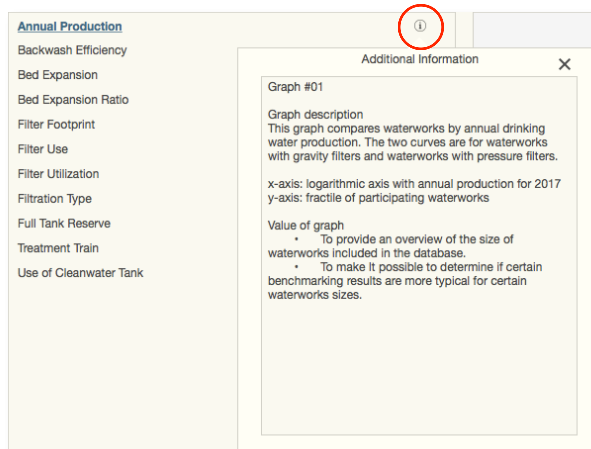
1. To access a graph of data about your waterworks, click on the Comparison Graphs or the Advanced Graphs tab
2. Then click on a specific graph to display it





Note:

- The Comparison Graphs are graphs that display all waterworks in the Merkur system, comparing one with another on a specific measurement.
- The Advanced Graphs are focused more on your individual waterworks, displaying data collected at your facility.
- A small letter "i" in a circle (for Information) is displayed to the right of each graph title. You may click on that information circle to display more information about the graph.
- Not all graphs are available to all users. Graphs that are not available to you will be a light gray color. See Access Level under Understanding User Management below for more information.
- The section below, Overview of the Graphs, provides more detailed information about each graph in Merkur and its utility for waterworks operators and others.
- Note that the header bar contains your name (your first name and last name as entered on the My Account tab) along with the name of the waterworks being displayed. This information is important for some specific users who may be able to access more than one waterworks. It is important to know which waterworks is being displayed in the graph.



Overview of the Graphs

This section describes each graph in Merkur and its significance for waterworks.

Annual Production

what it shows

how the data is obtained/derived

why it is significant

Backwash Efficiency

what it shows

how the data is obtained/derived

why it is significant

Bed Expansion

what it shows

how the data is obtained/derived

why it is significant

Bed Expansion Ratio

what it shows

how the data is obtained/derived

why it is significant

Filter Footprint

what it shows

how the data is obtained/derived

why it is significant

Filter Use

what it shows

how the data is obtained/derived

why it is significant

Filter Utilization

what it shows

how the data is obtained/derived

why it is significant

Filtration Type

what it shows

how the data is obtained/derived

why it is significant

Full Tank Reserve

what it shows

how the data is obtained/derived

why it is significant

Treatment Train

what it shows

how the data is obtained/derived

why it is significant

Use of Cleanwater Tank

what it shows

how the data is obtained/derived

why it is significant

Backwash Iron Concentration

what it shows

how the data is obtained/derived

why it is significant

Backwash Turbidity

what it shows

how the data is obtained/derived

why it is significant

Grain Size Distribution (not complete)

what it shows

how the data is obtained/derived

why it is significant

Sand Profile

what it shows

how the data is obtained/derived

why it is significant

Water Profile - Fe

what it shows

how the data is obtained/derived

why it is significant

Water Profile - Mn

what it shows

how the data is obtained/derived

why it is significant

Water Profile - NH_4

what it shows

how the data is obtained/derived

why it is significant

Water Profile - O_2

what it shows

how the data is obtained/derived

why it is significant

Water Profile - pH

what it shows

how the data is obtained/derived

why it is significant

Water Profile - redox

what it shows
how the data is obtained/derived
why it is significant

Graph Name	Tab	Graph Number	Access Level
Annual Production	Comparison Graph	1	C
Filter Utilization	Comparison Graph	2	C
Use of Cleanwater Tank	Comparison Graph	3	C
Filter Use	Comparison Graph	4	B
Filter Footprint	Comparison Graph	5	C
Full Tank Reserve	Comparison Graph	6	C
Treatment Train	Comparison Graph	7	C
Filtration Type	Comparison Graph	8	C
Bed Expansion	Comparison Graph	9	A
Bed Expansion Ratio	Comparison Graph	10	A
Backwash Efficiency	Comparison Graph	11	B
Water Profile - Fe	Advanced Graph	12	A
Water Profile - NH4	Advanced Graph	13	A
Water Profile - Mn	Advanced Graph	14	A
Water Profile - O2	Advanced Graph	15	A
Water Profile - redox	Advanced Graph	16	A
Water Profile - pH	Advanced Graph	17	A
Sand Profile	Advanced Graph	18	A
Backwash Iron Concentration	Advanced Graph	19	A
Backwash Turbidity	Advanced Graph	20	A
Grain Size Distribution	Advanced Graph	21	A

Understanding the Graph Contents

Note:

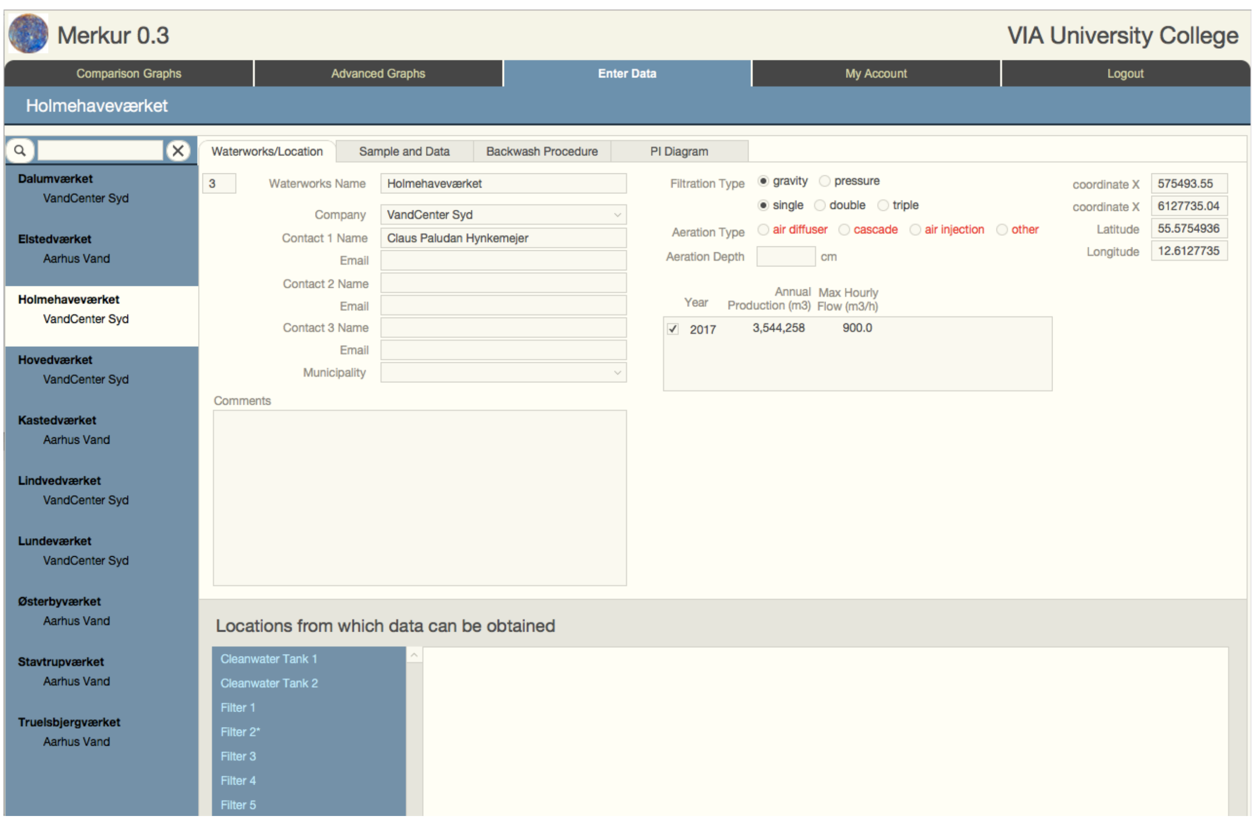
- In the Comparison Graphs, your waterworks will be shown in yellow. The other waterworks will be shown in green (and, if a second color is needed for some graphs, blue). You can always identify where your waterworks stands in comparison with the other waterworks.
- Some graphs include a legend identifying the meaning of the different colors, and also identifying the yellow data point as "your" waterworks by name.
- By default, waterworks other than your own are anonymous. In other words, you are not able to specifically identify them by name or number. However, some users have an ability that allows them to identify other waterworks. This is done through a "can view organizations" flag. If this flag is turned on for your user account, you will see a number identifying each waterworks on a Comparison Graph. A number is assigned to each waterworks and is used consistently throughout the Merkur system. A report identifying waterworks by number is available from the Project Leaders.
- If the "can view organizations" flag is set for your user account, you will also see a "Select a different waterworks" drop down menu in the upper right corner of the screen. This can be used, both on the Comparison Graphs tab and on the Advanced Graphs tab, to change which waterworks is being viewed. On a Comparison Graph, selecting a different waterworks from the drop down list has the effect of changing which waterworks is indicated by the yellow color. On an Advanced Graph, selecting a different waterworks changes the data being displayed to that waterworks.
- On the Advanced Graphs, the waterworks being displayed is included in the title of the graph.

Entering Data

The Enter Data tab is only available to VIA University College users. See Understanding Access Groups below for more information.

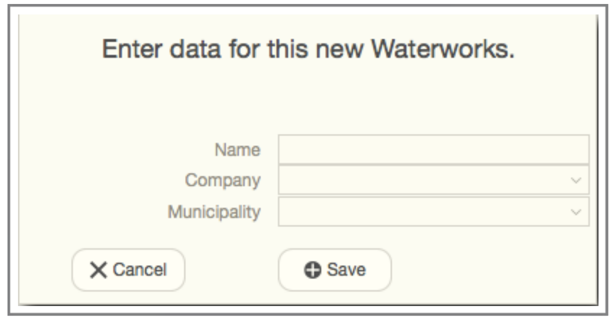
The Enter Data tab allows a user to enter data for a specific waterworks. Capabilities include:

- Adding a new waterworks
- Entering or editing general information about the waterworks such as the parent company with which it is affiliated and the type of filtration it employs
- Adding a new parent company or editing data about an existing parent company
- Adding locations from which data samples may be obtained
- Adding or specific editing information about those sample locations, such as the size of a filter or the capacity of a clearwater tank
- Creating a new sample
- Entering or editing specific data from that sample, including importing a series of data points obtained from a sample
- Entering or editing the steps involved in a backwash procedure at the waterworks
- Entering or editing an image representing the PI diagram for the waterworks



To Add a New Waterworks

1. Click on the Add a New Waterworks button in the bottom of the list of waterworks.
2. In the box that displays, enter the name of the waterworks.
3. Enter the parent company name by selecting it from the drop down list. Note that, if a new parent company needs to be added to the list, click in the company box again (to make the drop down list go away) and manually enter the name of the new parent company. In the future, the new company name will be included in the drop down list.



4. Enter the municipality by selecting it from the drop down list. Note that, if a municipality needs to be added to the list, click in the municipality box again (to make the drop down list go away) and manually enter the name of the new municipality In the future, the new municipality name will be included in the drop down list.
5. Click the Save button.

To Select a Different Waterworks

1. Click on the name of the waterworks in the left hand column.
2. The selected waterworks will be highlighted. All actions will pertain to this waterworks until a different waterworks is selected.

To Search for a Specific Waterworks

1. Type some text in the Search box at the top of the list of waterworks.
2. Click on the magnifying glass icon to the left of the Search box.
3. Any waterworks name containing the text that you type will be displayed and the others will be eliminated from the list.
4. To return to displaying all waterworks in Merkur, click the X button to the right of the Search box.

To Add Information about a Specific Waterworks

1. Ensure that the waterworks of interest is highlighted in the left hand column.
2. You can add or update the following information:
   - Waterworks name
   - Parent company
   - Contact names and email addresses at the parent company (up to three)
   - Municipality
   - Comments about the waterworks
   - Filtration type (gravity or pressure; single, double or triple)
   - Aeration type (air diffuser, cascade, air injection, or other)
   - Aeration depth (in cm)
   - X and Y coordinates for the geographic location

- Latitude and longitude for the geographic location

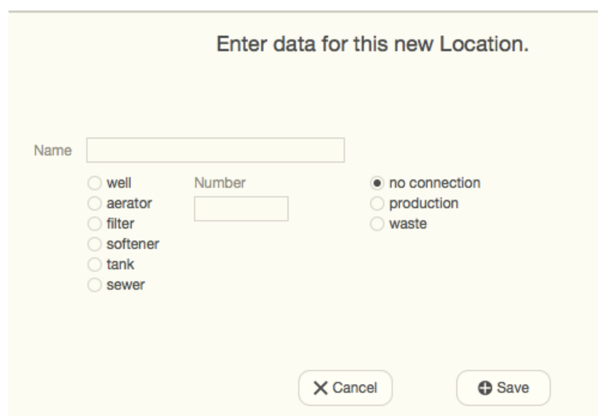
Note:

- There is no Save button to click once a waterworks has been created. Your data is automatically saved when you enter it.
- This screen displays History data showing the year, annual production, and maximum hourly flow. This data can also be updated, but new history records cannot currently be created.
- The check box to the left of the year in the History table indicates which year should be used for building graphs. This allows new data to be entered each year with the old data kept for historical or trend analysis. Only one year should be checked at a time Checking more than one year will result in erroneous data being displayed on some graphs.

To Add a New Location

Locations are physical locations within a waterworks from which a sample may be obtained. Most frequently, these are filters and clearwater tanks. But they can also be wells, aerators, softeners, and even sewers. In addition, a location can be a "pipe" that connects two elements (for example, the connection between a filter and a clearwater tank). Adding a new location allows the user to create any location within the waterworks for which data may be obtained and entered into Merkur.

1. Ensure that the Waterworks/Location tab is selected toward the top of the screen.
2. Click on the Add a New Location button at the bottom of the list of locations.
3. In the box that displays, enter the name of the location. This name can be any text that is commonly and locally used to identify the location within the waterworks. For example, "western clearwater tank" or "blue pipe in the ceiling" are perfectly acceptable as descriptions.
4. Indicate what type of location this is: well, aerator, filter, softener, tank or sewer. If the location is a "pipe" indicate the "upstream" or "first" element that the pipe connects.

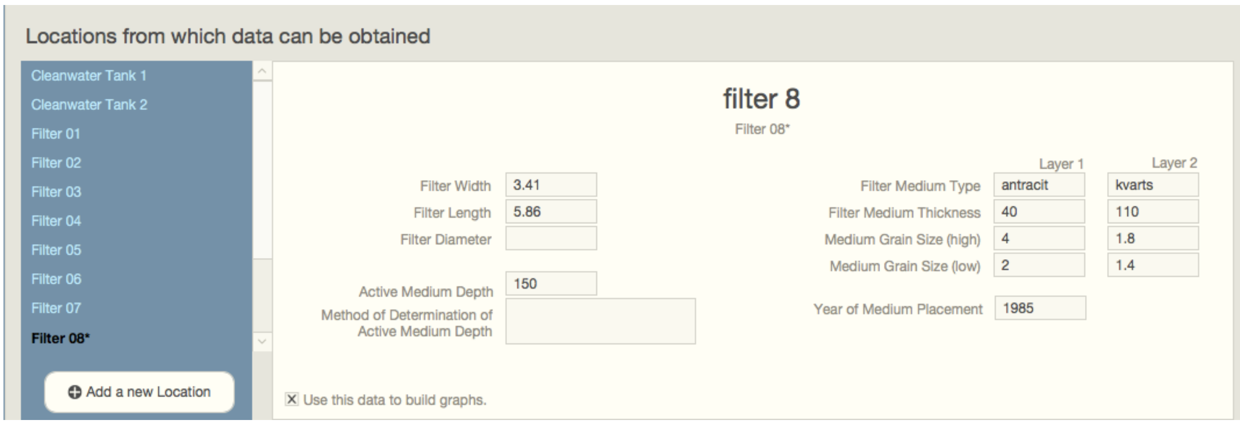


5. Give the location a number. This can be any number, but is most commonly used to more precisely designate the location. For example, a 3 could be entered for the third filter in a row of six.
6. If the location is an element (well, aerator, filter, softener, tank or sewer), leave the default "no conversion" selected. If the location is a "pipe," select either "production" (indicating that the output of the element you just entered is considered "good" or "useful") or "waste" (indicating the output is considered to be "bad").
7. If you select "production" or "waste" (in other words, this is a "pipe" location), Merkur displays a second element to the right with arrows indicating the flow from the left element to the right element.
8. Just as you did for the left element, describe the right element, indicating its type and number.
9. Click the Save button.

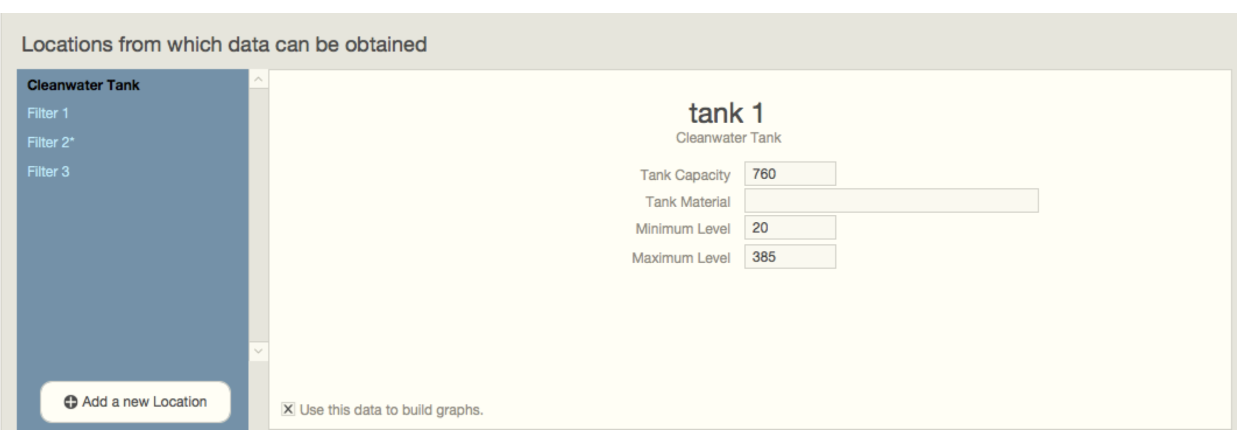
To Add or Update Data About a Location

Once a location has been added, information about the location should be added to Merkur. The information needed depends very much on the type of location it is. For example, filter locations require very different information from clearwater tank locations.

1. Ensure that the Waterworks/Location tab is selected toward the top of the screen.
2. Click on the location from the location list toward the bottom of the screen and ensure it is highlighted.



3. If the location is a Filter location, enter or update the following data:
    - Filter width and length, if the filter is rectangular in shape, or diameter, if the filter is circular, in meters
    - Active medium depth in centimeters
    - Notes about the method for determining the active medium depth
    - For each layer (up to two) of the filter medium:
        - The filter medium type
        - The thickness of the medium (in cm)
        - The high and low grain size (not sure of the dimensions here)
    - The year the filter medium was placed into service



4. If the location is a Tank location, enter or update the following data:

- Tank capacity (in m^3)
- Tank material (this is a free-form field, it can be any text desired)
- Minimum level of the tank (in cm)
- Maximum level of the tank (in cm)

5. If the location is some other type of location, enter or update the data as indicated.
6. For each location, you can check a box indicating if the location is to be used when building graphs. Note that some graphs should focus on an individual location in a series (for example, a specific filter from which data was obtained in a series of six). Failing to indicate which location of a type (usually only one) should be used for graphing purposes can create unpredictable results in some graphs.

Note:

- There is no Save button to click once a location has been created. Your data is automatically saved as you enter it.

To Add a New Sample

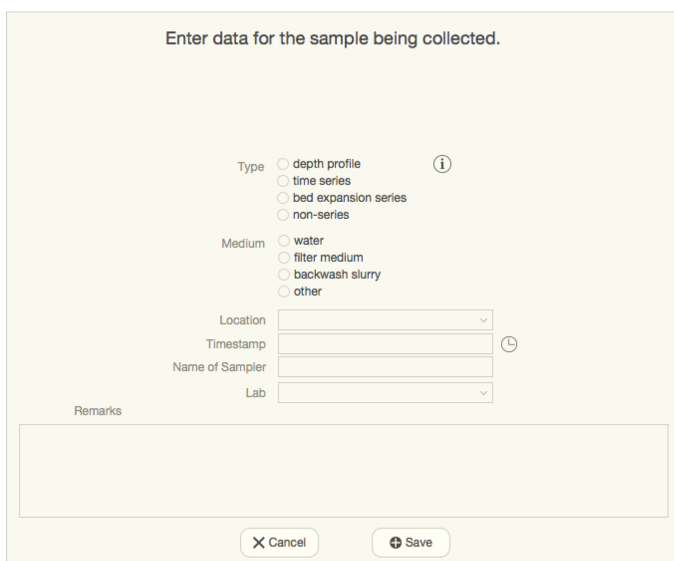
Samples in Merkur require a careful explanation. Often a sample is thought of as a collected representative specimen, such as water collected in a flask from the overflow of a filter during a backwash operation. From that single collection flask, one might run several tests, such as iron concentration or turbidity.

In Merkur, a sample can mean that kind of collection. It can mean the collection of a single container of some material that is then analyzed for one or more attributes. In Merkur, however, “sample” can also have a broader meaning. For example, if water is collected during a backwash operation every minute over the course of the operation, a series of flasks would be used, one for each minute during the process. All of those individual flasks together are considered to be one *sample* — a sample *series*, collected over time. Thus a sample can be a single collection, but it can be a series of collections as well.

A different kind of sample series is related to position. For example, filter media might be obtained from different depths in a filter. An individual flask would be used to gather filter media from a depth of 10 cm, 20 cm, 30 cm, and so on. As with a backwash operation, that series of flasks are considered to be one *sample*, but this time the sample is a *series* based on depth in the filter.

Another positional series is related to filter bed expansion during a backwash procedure. Instead of gathering material at different depths in the filter, the backwash slurry is collected at different heights above the top of the filter bed as it is being expanded by air and/or water. Again, this is a single *sample*, even though there are different containers of backwash slurry obtained from different heights. In other words, this is a bed expansion *series*.

Further, a sample might not actually be a physical specimen the can be collected in a container. It might simply be a measurement, such as the



amount of water used during a backwash procedure, or the freeboard height in a specific filter. In Merkur, these types of samples are called non-series samples to differentiate them from series samples such as time series, depth profiles, and bed expansion series.

1. Ensure that the Enter Data tab is selected at the top of the screen.
2. Ensure that the waterworks with which you want to work is selected on the left side of the screen.
3. Click on the Sample and Data tab toward the top of the screen. This displays a list of the samples already in Merkur for the selected Waterworks, if any.
4. Click on the Add a New Sample button at the bottom of the list of samples.
5. In the box that is revealed, select the type of sample that is being added.
   - depth profile — used for a series of collections of filter media at varying depth in a filter
   - time series — used for a series of collections over time, such as during a backwash procedure
   - bed expansion series — used for a series of collections of filter media slurry collected during a backwash procedure at different heights above the filter bed
   - non-series — used for all other data collections that are not one of the three series types
6. Select the medium of the sample that is being added.
   - water — broadly used for any aqueous sample
   - filter medium — used when the actual filter medium grains are collected
   - backwash slurry — used when the collection involves the mixture of water and filter medium stirred up during a backwash procedure
   - other — used when none of the above three categories apply
7. Select the location from which the sample was obtained. Merkur will provide a drop down list of locations that have been set up for this waterworks. Thus, prior to entering information about a specific sample, it is important that the location within the waterworks has first been created.
8. Enter the timestamp when the sample was collected. The “watch” icon to the right of the timestamp field can be clicked to insert the current server date and time (which is based on eastern US time). If you want to manually enter some other time, make sure the syntax matches the following: MM/DD/YYYY hh:mm:ss, where MM is the month, DD is the date, YYYY is the four digit year, hh is the hours, mm is the minutes, and ss is the seconds. Note that the date syntax follows the US month-then-day format rather than the European day-then-month format.
9. Enter the name of the sampler. Merkur maintains a list of all previous samplers, making it easy to select a sampler from the drop down list that is revealed. Alternatively, you can enter a new name by clicking in the field box again and typing in the name.
10. Enter the name of the default lab where the testing of this sample will occur. Merkur maintains a list of valid labs that can be selected from the drop down list that is revealed. The Merkur system administrator must add any new labs that you need added. Note that this is the default lab; you can override the lab for individual results analysis.
11. Optionally, enter any remarks about this particular sample.
12. Click the Save button.

To Add Results for a Sample

In Merkur, the specific measurement from a sample is called a *result*. An individual sample can have many results, because one might measure the iron, manganese, oxygen, ammonium, and other concentrations from a single flask. Further, when the sample is a sample series, multiple measurements might be taken from each individual flask in the series. Thus a large number of results can be recorded for an individual sample, especially if the sample is a series.

What is being measured for an individual result is called, in Merkur, a measurement *parameter*. Merkur includes a large but limited number of parameters, defining what specifically might be measured as a part of a data collection effort for a waterworks. The number of these parameters may increase over time as Merkur expands, but this method of being very specific about which parameter an individual results is measuring helps ensure that there is never any confusion about what the data represents.

When adding results, the type of sample (depth profile, time series, bed expansion series, or non-series) and the sample medium (water, filter medium, backwash slurry, or other) makes a difference as to how results are entered. Thus the data entry screens for entering results in Merkur will differ, depending on the sample type selected.

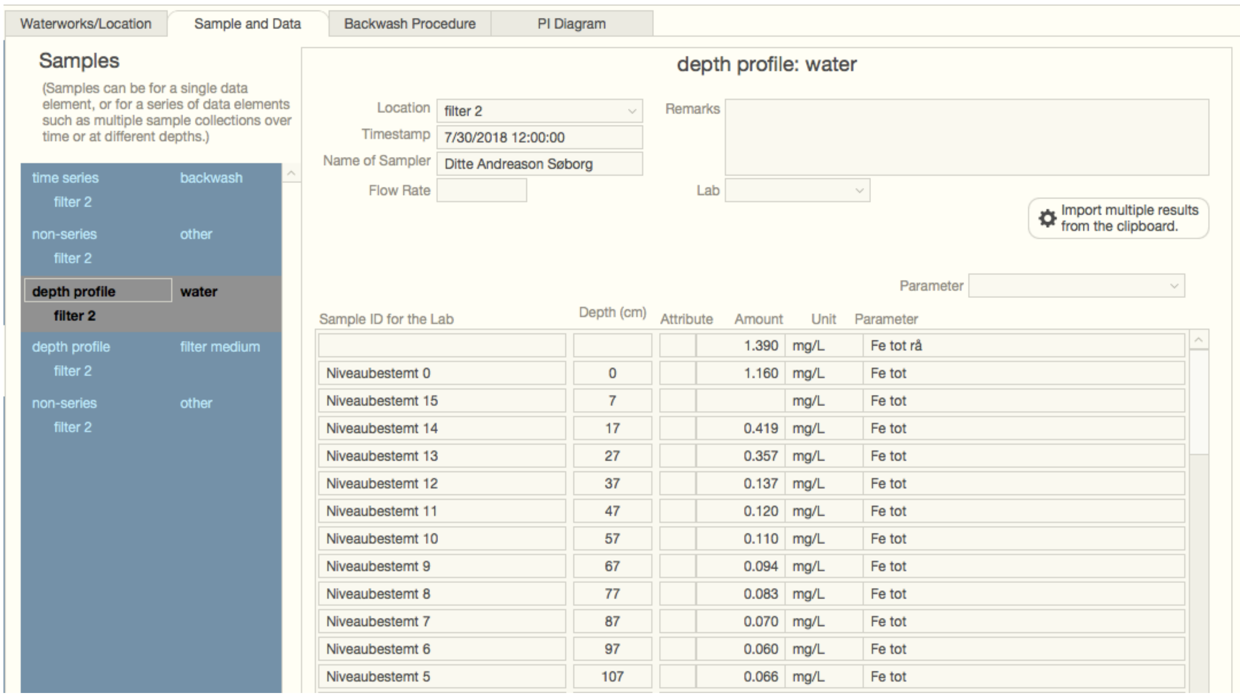
The following table shows the valid combinations of sample type and medium that Merkur accepts. The table also indicates the collection methodologies used by VIA University College in collecting various kinds of samples. You can learn more about the vapors collection methodologies from the VIA University College staff.

	depth profile	time series	bed expansion series	non-series
water	Christmas Tree			
filter medium	Proton Pack CamSizer			
backwash slurry		individual flasks	Organ Pipes	
other				observation measurement waterworks reporting

1. Ensure that the Enter Data tab is selected at the top of the screen.
2. Ensure that the waterworks with which you want to work is selected on the left side of the screen.
3. Click on the Sample and Data tab toward the top of the screen. This displays a list of the samples already in Merkur for the selected Waterworks.
4. Click on the sample with which you want to work in the list of samples. If no samples are listed, use the procedure to add a new sample before attempting to enter results.
5. The screen that is revealed will be based on the combination of sample type and medium. Each type will be discussed below.

To Add Results for a Depth Profile Water Sample

These results are commonly obtained using VIA University College's "Christmas tree" technology.

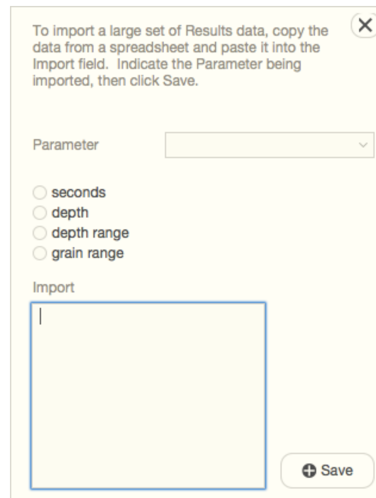


6. Information about the sample is shown at the top of the screen. This information can be updated if an error is found.
7. The lower part of the screen shows information about the individual results for the sample. The data shown includes:
    - Sample ID for the Lab — This is an optional free form text field that can used to identify the individual sample/result combination.
    - Depth — The depth (in cm) from which the sample was obtained.
    - Attribute — Optionally used to modify the amount. Typically this might be the less than (<) or greater than (>) symbol.
    - Amount — The actual measurement for the result.
    - Unit — The unit of measure for the result. Note that the unit is provided automatically by the parameter and is not modifiable.
    - Parameter — The thing being measured. (See the discussion above about parameters under To Add Results for a Sample.) Note that this is not modifiable.

    You may modify Sample ID for the Lab, Depth, Attribute and Amount if an error is found.
8. Because there can be a large number of results for a sample, you may optionally select a parameter in the Parameter box above the Parameter column. Selecting a parameter from the drop down list of parameters will limit the results that are displayed to only that parameter. Display all results again by deleting the entry in the Parameter box.

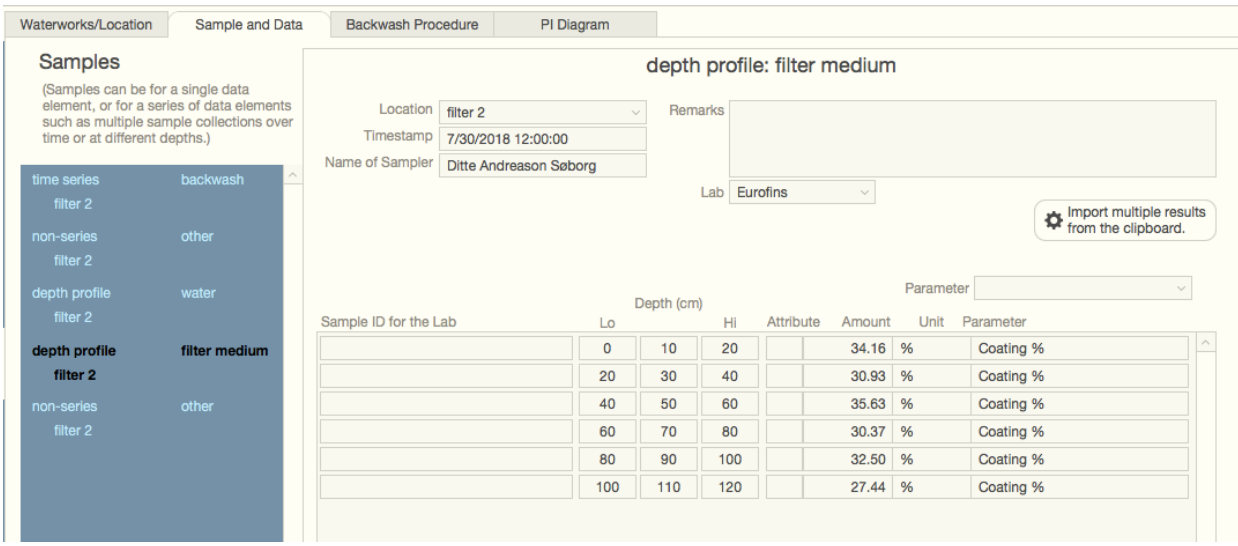
9. To import at “batch” of data (that is, an entire series of results of a single parameter for this sample), ensure that your data is in the proper format. This is best accomplished by preparing a spreadsheet containing the data in three adjacent columns:
    - Column A — Sample ID for the LAB
    - Column B — Depth
    - Column C — Amount

    The data should be lined up in rows, one row for each depth. Merkur can handle as many rows as needed.
10. In the spreadsheet, select the three columns and all of the rows containing data. Then, in the spreadsheet software, execute a Copy command. This will place the data in your computer’s clipboard.
11. In Merkur, click on the Import Multiple Results from the Clipboard button.
12. This will open up a data entry box. First, select the parameter you are importing from the drop down list of parameters.
13. Select the type of import you are doing. For a depth profile water sample, select “depth”.
14. Click inside the Import box and execute a Paste command. This will place the contents of your clipboard (the data you copied from the spreadsheet) into this box. Scan the data to make sure the data you expected has been pasted in. (Note, for example, that there should be an invisible “tab” character between each column of data with an invisible “return” character at the end of each row.)
15. Click Save.
16. Merkur will then process the batch of data, creating a Result entry for each row in your data. This may take some time, depending on the volume of data. Once the data has imported, review it to make sure that it has imported as expected.



To Add Results for a Depth Profile Filter Medium Sample

These results are commonly obtained using VIA University College's "Proton Pack" technology.



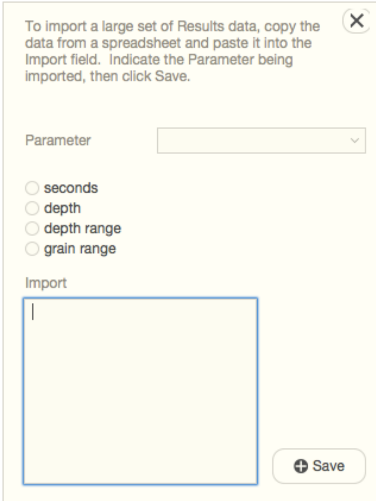
6. Information about the sample is shown at the top of the screen. This information can be updated if an error is found.
7. The lower part of the screen shows information about the individual results for the sample. The data shown includes:
    - Sample ID for the Lab — This is an optional free form text field that can used to identify the individual sample/result combination.
    - Depth Lo — The low end of the depth (in cm) of the range from which the filter media sample was collected. Note that, here, low means the smaller number. In terms of depth, this would be physically above the high number.
    - Depth — The depth (in cm) to be used when graphing this data. Typically this is the midpoint between the Lo and the Hi depths.
    - Depth Hi — The high end of the depth (in cm) of the range from which the filter media sample was collected. Note that, here, high means the larger number. In terms of depth, this would be physically below the low number.
    - Attribute — Optionally used to modify the amount. Typically this might be the less than (<) or greater than (>) symbol.
    - Amount — The actual measurement for the result.
    - Unit — The unit of measure for the result. Note that the unit is provided automatically by the parameter and is not modifiable.
    - Parameter — The thing being measured. (See the discussion above about parameters under To Add Results for a Sample.) Note that this is not modifiable.

    You may modify Sample ID for the Lab, Depth (Lo, mean and Hi), Attribute and Amount if an error is found.
8. Because there can be a large number of results for a sample, you may optionally select a parameter in the Parameter box above the Parameter column. Selecting a parameter from the drop down list of parameters will limit

the results that are displayed to only that parameter. Display all results again by deleting the entry in the Parameter box.

9. To import at "batch" of data (that is, an entire series of results of a single parameter for this sample), ensure that your data is in the proper format. This is best accomplished by preparing a spreadsheet containing the data in four adjacent columns:
    - Column A — Lo Depth
    - Column B — Hi Depth
    - Column C — Depth (typically midway between the Lo and Hi depths)
    - Column E — Amount

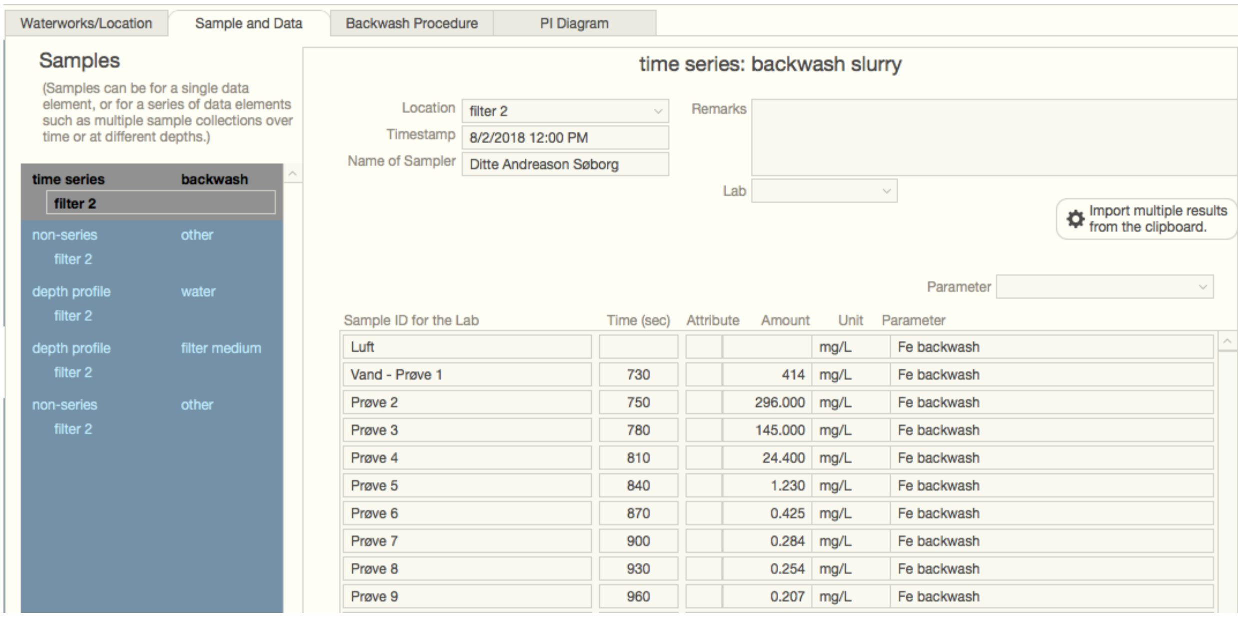
    The data should be lined up in rows, one row for each depth. Merkur can handle as many rows as needed.
10. In the spreadsheet, select the four columns and all of the rows containing data. Then, in the spreadsheet software, execute a Copy command. This will place the data in your computer's clipboard.
11. In Merkur, click on the Import Multiple Results from the Clipboard button.



12. This will open up a data entry box. First, select the parameter you are importing from the drop down list of parameters.
13. Select the type of import you are doing. For a depth profile filter medium sample, select "depth range".
14. Click inside the Import box and execute a Paste command. This will place the contents of your clipboard (the data you copied from the spreadsheet) into this box. Scan the data to make sure the data you expected has been pasted in. (Note, for example, that there should be an invisible "tab" character between each column of data with an invisible "return" character at the end of each row.)
15. Click Save.
16. Merkur will then process the batch of data, creating a Result entry for each row in your data. This may take some time, depending on the volume of data. Once the data has imported, review it to make sure that it has imported as expected.

To Add Results for a Time Series Sample

These results are commonly obtained by periodically collecting backwash slurry samples in individual flasks during a backwash procedure.

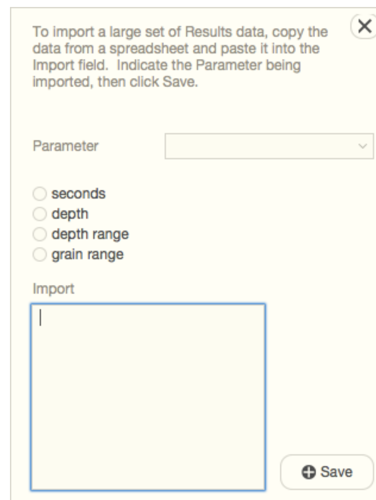


6. Information about the sample is shown at the top of the screen. This information can be updated if an error is found.
7. The lower part of the screen shows information about the individual results for the sample. The data shown includes:
   - Sample ID for the Lab — This is an optional free form text field that can used to identify the individual sample/result combination.
   - Time — The time (in seconds) after the process began at which the individual sample was collected.
   - Attribute — Optionally used to modify the amount. Typically this might be the less than (<) or greater than (>) symbol.
   - Amount — The actual measurement for the result.
   - Unit — The unit of measure for the result. Note that the unit is provided automatically by the parameter and is not modifiable.
   - Parameter — The thing being measured. (See the discussion above about parameters under To Add Results for a Sample.) Note that this is not modifiable.

   You may modify Sample ID for the Lab, Time, Attribute and Amount if an error is found.
8. Because there can be a large number of results for a sample, you may optionally select a parameter in the Parameter box above the Parameter column. Selecting a parameter from the drop down list of parameters will limit the results that are displayed to only that parameter. Display all results again by deleting the entry in the Parameter box.

9. To import at “batch” of data (that is, an entire series of results of a single parameter for this sample), ensure that your data is in the proper format. This is best accomplished by preparing a spreadsheet containing the data in three adjacent columns:
   - Column A — Sample ID for the LAB
   - Column B — Time
   - Column C — Amount

   The data should be lined up in rows, one row for each timed collection. Merkur can handle as many rows as needed.
10. In the spreadsheet, select the three columns and all of the rows containing data. Then, in the spreadsheet software, execute a Copy command. This will place the data in your computer’s clipboard.
11. In Merkur, click on the Import Multiple Results from the Clipboard button.



12. This will open up a data entry box. First, select the parameter you are importing from the drop down list of parameters.
13. Select the type of import you are doing. For a time series sample, select “seconds”.
14. Click inside the Import box and execute a Paste command. This will place the contents of your clipboard (the data you copied from the spreadsheet) into this box. Scan the data to make sure the data you expected has been pasted in. (Note, for example, that there should be an invisible “tab” character between each column of data with an invisible “return” character at the end of each row.)
15. Click Save.
16. Merkur will then process the batch of data, creating a Result entry for each row in your data. This may take some time, depending on the volume of data. Once the data has imported, review it to make sure that it has imported as expected.

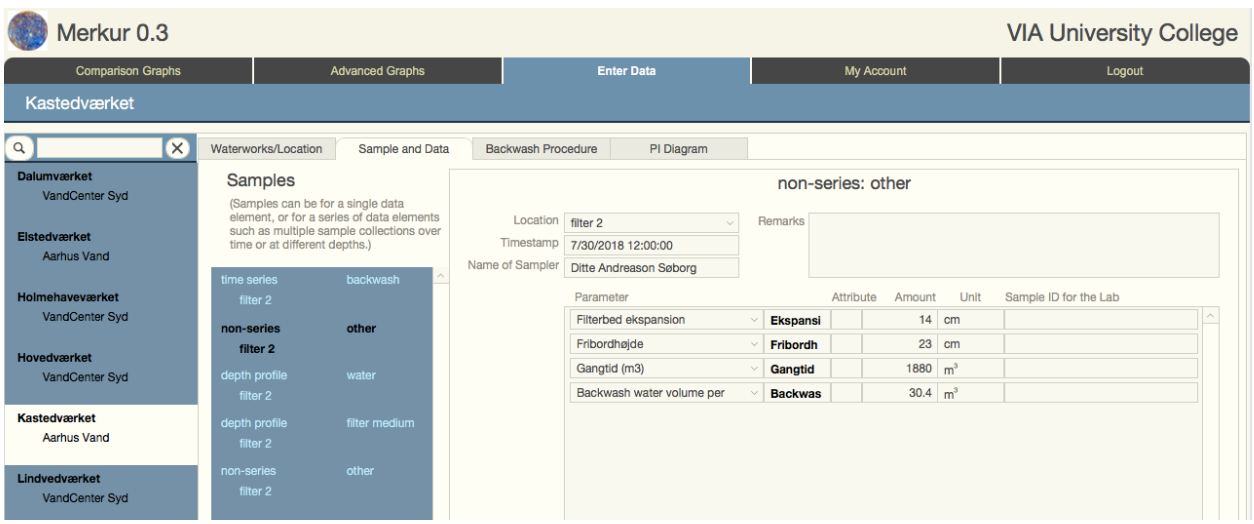
To Add Results for a Bed Expansion Series Sample

These results are commonly obtained using VIA University College's "Organ Pipe" technology. Currently the organ pipe data is expressed as a single number (the height) and is entered as a non-series result (see below).

In the future, Merkur may be expanded to receive multiple rows of bed expansion series data.

To Add Results for a Non-Series Sample

These results are obtained by a variety of methods, including direct observation, measurement of a parameter, accepting data reported by the waterworks to the researcher, and others. Currently the "Organ Pipe" data is reported as a single non-series number.



6. Information about the sample is shown at the top of the screen. This information can be updated if an error is found.
7. Currently non-series data must be added by the Merkur system administrator.

Understanding Access Groups

User accounts in the Merkur system are divided into two groups: waterworks users and VIA University College users.

Waterworks Users

Waterworks users have access to the two pages of graphs, the Comparison Graphs and the Advanced Graphs. All available graphs within the system are displayed on these to pages. These pages allow the waterworks user to display graphs showing their waterworks in comparison to all other waterworks in the Merkur system (Comparison Graphs) or specific series data from their own waterworks (Advanced Graphs).

Not all users will have access to display data for every graph. Access depends on the user's access level (see Understanding User Management below).

VIA University College Users

VIA University College users have access to one additional page, the Data Entry page. The Data Entry page allows the user to enter and update individual data results for a specific waterworks. In this way, VIA University College user can keep data for the waterworks updated as new information becomes available.

Understanding User Management

These additional ways of managing users are controlled by the Merkur system administrator. Each of the following also affect the way the system works for individual users.

Status

Individual user accounts can be active or inactive. This gives the Merkur system administrator the ability, at the direction of the Project Leaders, to activate or inactivate individual user accounts. An account that has been inactivated is no longer allowed to log on to the Merkur system.

The Merkur system administrator can also create new user accounts as directed by the Project Leaders.

Access Level

Each graph on the Comparison Graphs and Advanced Graphs pages are keyed with an access level: A, B, or C. Each user is than given a designated access level, providing access to a limited set or all graphs. A is the most limited access level. Access level A users only have access to graphs designated as A graphs. Access level B users have access to both A and B designated graphs. Access level C users have access to all graphs.

This feature gives the Project Leaders the ability to designate which graphs should be seen by which users. The plan is to have the project evolve to the point that some waterworks join at a very basic level (A), while others join at higher access levels (B or C). Further, C level graphs most likely will require collection of very detailed data by VIA University College itself, so the C access level would be reserved for waterworks from which such data has been obtained.

Can View Organizations

Each waterworks is given a waterworks number that is consistent throughout the system. Where appropriate, these numbers can be indicate on graphs, particularly Comparison Graphs, so that data points on the graph belonging to individual waterworks can be designated. However, it may be appropriate to only allow some users to view the data point is their own organisation's, leaving the other data point on the graph, but anonymous as to their source.

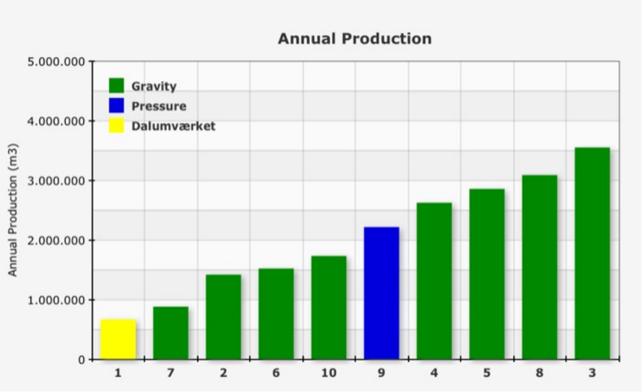
Each user can be identified as one that can view other organisations or that cannot.

Bilag 4. Description of graphs in Merkur

Comparison graphs

In all comparison graphs, your own waterworks is shown in yellow. Graphs are shown in alphabetical order.

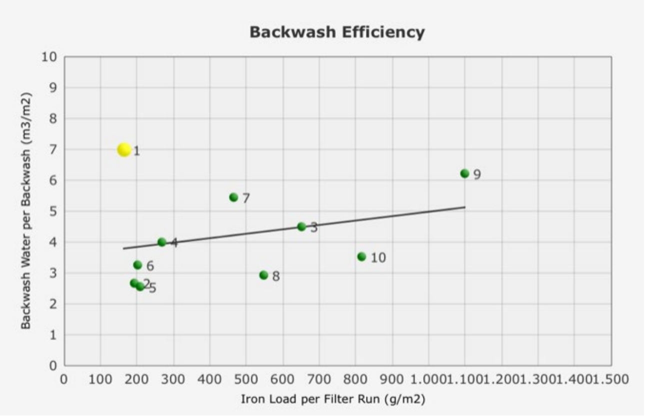
Annual Production (Årsproduktion)



Graph description
This bar chart compares waterworks according to annual drinking water production. Gravity filters are shown in green, and pressure filters are shown in blue.

Value of graph
• To provide an overview of the size of waterworks included in the database.
• To make it possible to determine if benchmarking results are more typical for certain waterworks sizes.

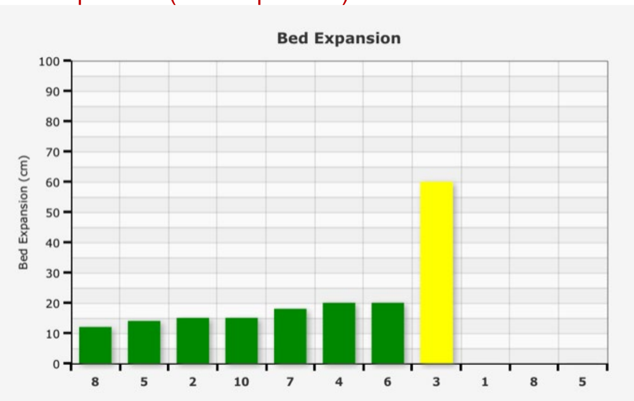
Backwash Efficiency (Skylleeffektivitet)



Graph description
This scatter plot shows how much backwash water is used (per square meter filter area) in comparison to how much iron has been removed during a single filter run (between one backwash and the next). The Y-axis sums the water used in the water-only step and water/air-combined step (if used).

Value of graph
- To show how efficient the backwash is
- To give an indication of the iron concentration in the backwash water

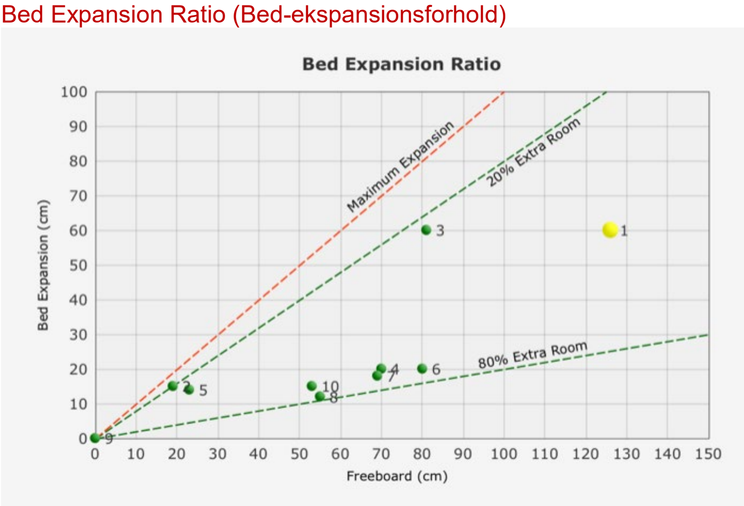
Bed Expansion (Bedekspansion)



Graph description
This bar chart shows the height to which filter media is lifted during the backwash. It is measured using an “organ pipe” fixed in place on the top of the sand bed prior to backwashing. The Y-axis gives the height of the allest organ pipe into which media grains fell during backwash.

Value of graph
- To determine if the filter media is sufficiently expanded to enhance cleaning during backwash
- To enable comparisons between bed expansion, medium grains and water flow

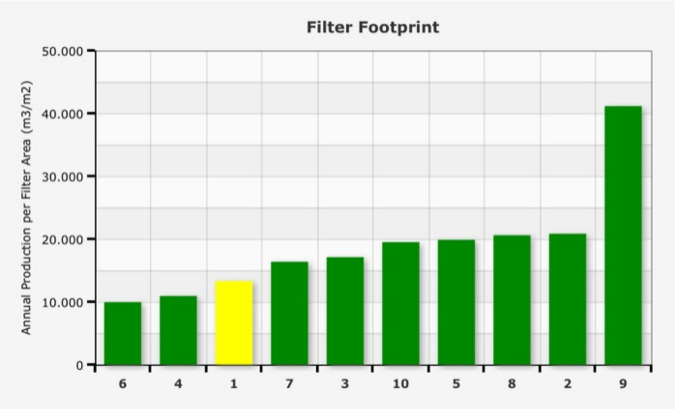
Bed Expansion Ratio (Bed-ekspansionsforhold)



Graph description
This scatter plot shows the ratio between bed expansion during backwash and the available freeboard built into the filter.

Value of graph
- To determine if there is risk of losing filter media to the trough during backwash
- To determine if the filter bed design creates an unnecessary volume of backwash water following backwash that must be discharged before good water quality can be obtained

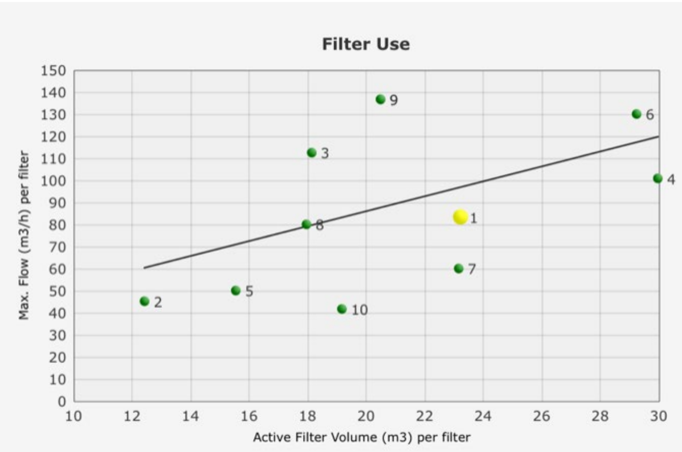
Filter Footprint (Filter footprint)



Graph description
This bar chart shows how much water is produced on an annual basis per m2 filter area (and is therefore the reciprocal of filter footprint). Note that this graph ignores the fact that waterworks with poor raw water quality would be expected to show lower values. Note also that pressure filters are expected to have higher values than gravitational filters (made possible due to higher filter velocity and thicker media layers).

Value of graph
- To give an indication of whether the waterworks is over-dimensioned

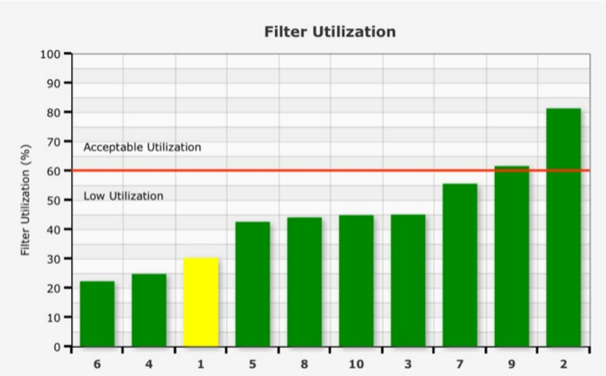
Filter Use (Filterudnyttelse)



Graph description
This scatter plot compares individual filters between waterworks to see how much flow can be put onto a certain amount of sand. When double filtration is used, the sum of the active filter volumes in both filters is used. Note that this graph ignores the effect of raw water quality. For example, raw water with high ammonium concentrations would naturally call for more sand than raw water with low ammonium concentrations. The maximum hourly flow is defined as the maximum flow sustained for at least one hour per weekday.

Value of graph
- To determine if the volume of the filter medium is larger than typical (over dimensioned) or smaller than typical (under dimensioned). These judgements must then be compared to the treatment difficulty of the actual raw water quality.

Filter Utilization (Filterudnyttelse)

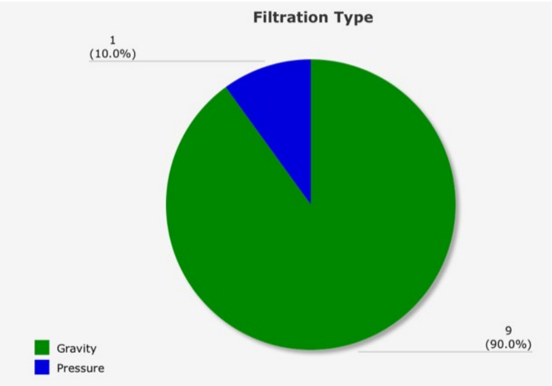


Graph description
This bar chart shows the drinking water production balance by comparing the annual production to the potential maximum annual production assuming the maximum filtration flow is maintained 24/7. Note that the need for production stop for backwashing is ignored, meaning that 100% production is never possible. The maximum filtration is defined ass the maximum flow sustained for at least one hour per weekday. The area above the red line represents acceptable filter utilization and is only obtainable for waterworks where production is virtually continuous for 16 or more hours per day. A continuous (Danish = grundlast) waterworks can reach approximately 98% utilization The area below the line represents low utilization where lowering the maximum hourly flow should be considered, assuming there is sufficient clean water tank capacity.

Value of graph

- To identify waterworks with potential for lowering the maximum hourly flow (which can improve water quality).
- To identify waterworks with potential to produce more drinking water, if needed.

Filtration Type (Filtertype)

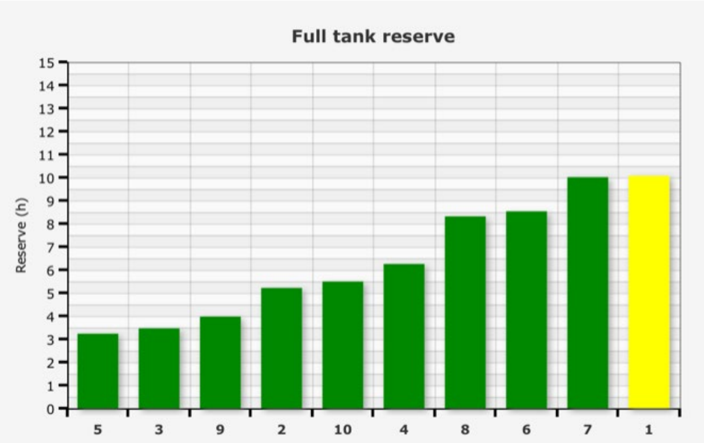


Graph description
This pie diagram classifies the participating waterworks as to whether they are gravity filters or pressure filters.

Value of graph

- To provide an overview of which waterworks are included in Merkur.

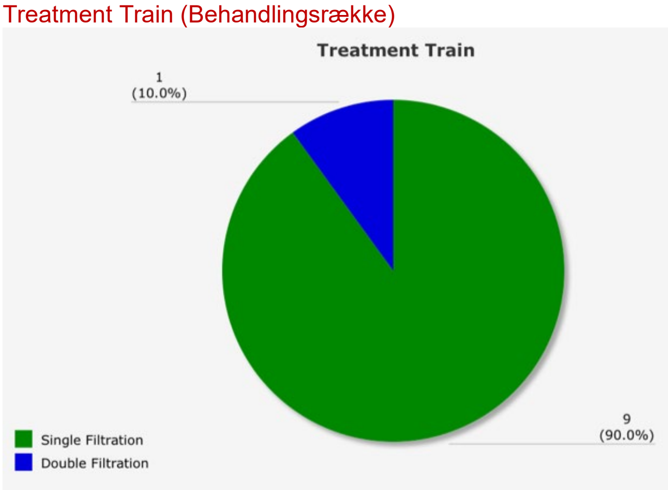
Full Tank Reserve (Reserve i rentvandstanken)



Graph description
This bar chart shows how many hours of reserve capacity that the waterworks have, assuming that the clean water tank is full, that no additional water is produced and that water is consumed at the annual average rate.

Value of graph
- To show if the risk for stagnated water in the clean water tank is too high due to a large tank capacity.
- To show if there is too little drinking water reserve in a filled clean water tank in case of fire.

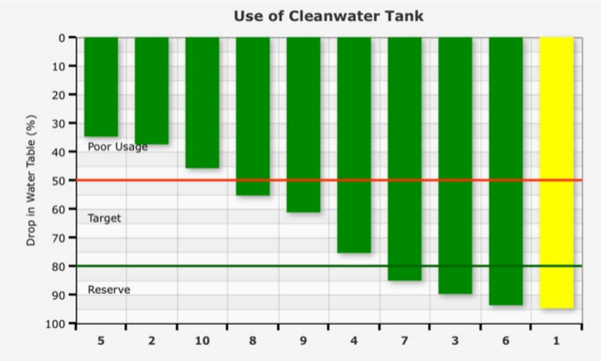
Treatment Train (Behandlingsrække)



Graph description
This pie diagram classifies the participating waterworks according to whether single or double filtration is utilized.

Value of graph
- To provide an overview of which waterworks are included in Merkur

Use of Clean Water Tank (Udnyttelse af rentvandstanken)



Graph description
This bar chart shows the water level in the clean water tank measured as the minimum level experienced during a one-week period. Depending on circumstances, a value of 80% or so should not be exceeded to ensure adequate water in case of fire and for backwashing filters. Values below 50% or so indicate that more even flow could be achieved.

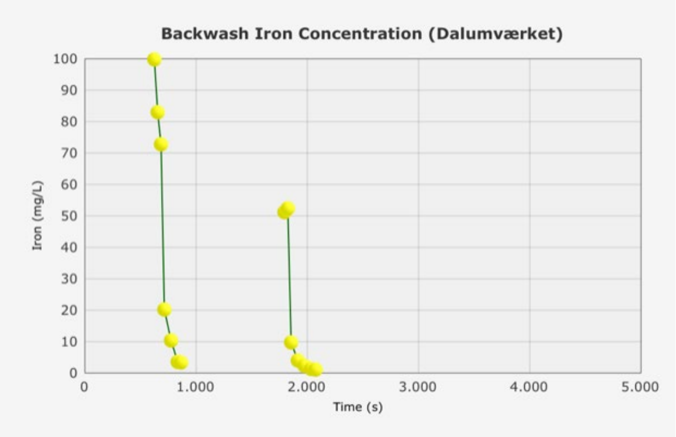
Value of graph

- To determine if the clean water tank is being used to even out day and night water production and give the lowest possible maximum hourly flow.
- To determine if there is likely to be a lot of stagnant water in the clean water tank.

Advanced graphs

Advanced graphs show results for one waterworks only. Graphs are shown in alphabetical order.

Backwash Iron Concentration (Skyllevandets jernkoncentration)

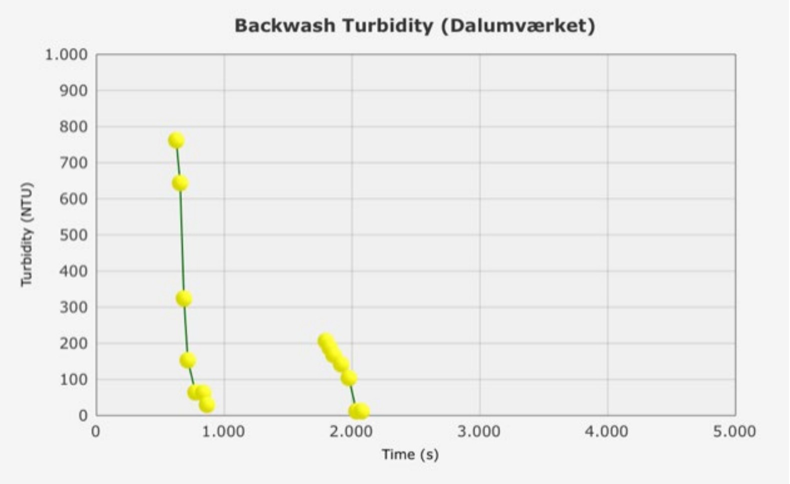


Graph description
This time series shows the iron concentration in water samples collected manually once or twice a minute from a backwash at one of the participating waterworks.

Value of graph

- To assist in optimizing the backwash procedure by indicating whether the backwash continues long after the iron oxides are removed or whether the backwash water is still heavily influenced at the end of the backwash.

Backwash Turbidity (Skyllevandets turbiditet)



Graph description
This time series shows the turbidity in water samples collected manually once or twice a minute from a backwash at one of the participating waterworks.

Value of graph

- To assist in optimizing the backwash procedure by indicating whether the backwash continues long after the turbidity is removed or whether the backwash water is still heavily influenced at the end of the backwash.

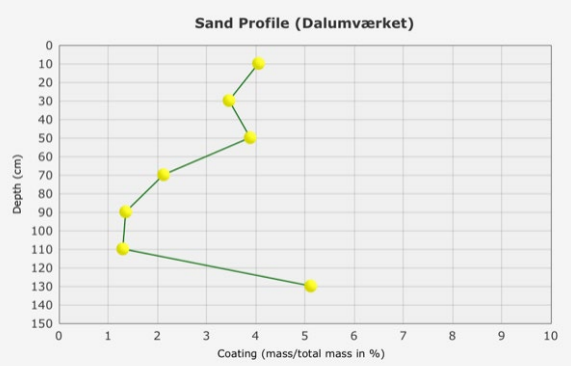
Grain Size Distribution (Kornstørrelsesfordeling)

Graph description
This cumulative distribution graph shows the grain size in filter medium samples collected at various depths at one of the participating waterworks.

Value of graph

- To show the interval of grain sizes in a filter. Due to coating with iron oxides, grain sizes often increase over time. Fragile media grains such as anthracite may break (attrition) thereby decreasing the grain size over time.
- To determine if the grain size in a filter is stratified. Smaller grains may mobilize to the top of a filter during backwash. In dual media, larger and less dense anthracite may remain at the top of a filter. The backwash process may also cause mixing such that any stratification is destroyed.

Sand Profile (sandprofil)

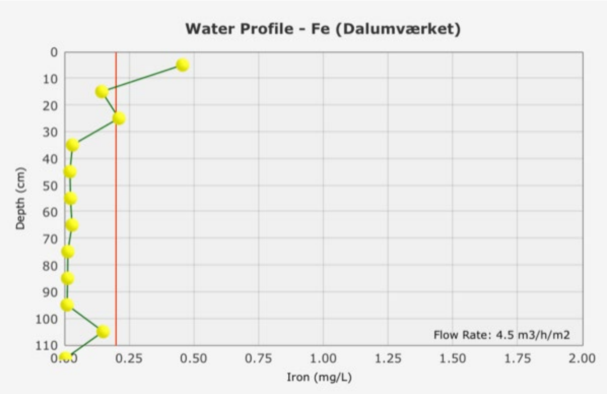


Graph description
This depth profile shows results from sand samples collected over 20 cm intervals from one of the participating waterworks using special sampling equipment. Depth in the filter starts with the top of the filter medium as 0. The graph point shows the middle of the depth interval that was sampled. In this graph, the relative mass of the media grains coating to the total mass (media grain plus coating) is shown in percent.

Value of graph

- Visualizes the stratification of the filter media. The coating may be greatest at the top of the filter. This is because iron (which causes the coating) is removed near the top of the filter and that the density of coating is greater than that of quartz, which may mobilize grains with more coating to the top of the filter during backwash.

Water Profile – Fe (Vandprofil - Fe)

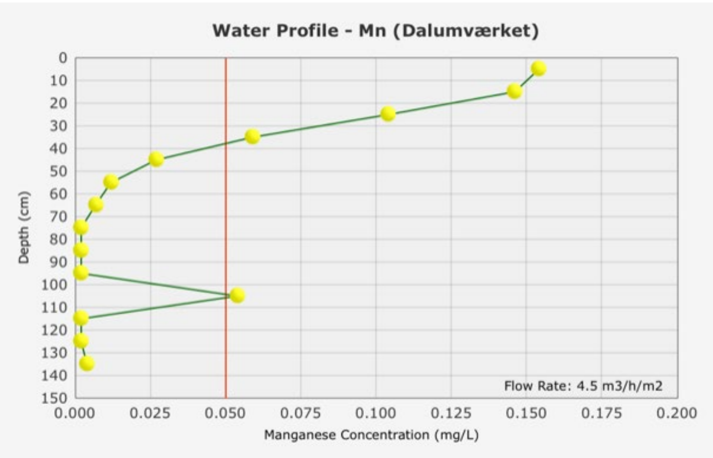


Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, the concentration of iron is shown in mg/L. The drinking water criteria is shown as a red line. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes removal through the depth of the filter.
- The steepest part of the curve can be used to determine the maximum volumetric removal rate.

Water Profile – Mn (Vandprofil - Mn)

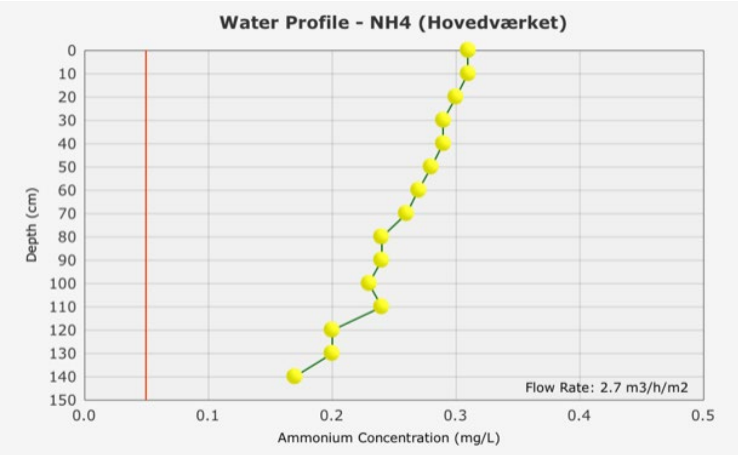


Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, the concentration of manganese is shown in mg/L. The drinking water criteria is shown as a red line. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes removal through the depth of the filter.
- The steepest part of the curve can be used to determine the maximum volumetric removal rate.

Water Profile – NH4 (Vandprofil – NH4)

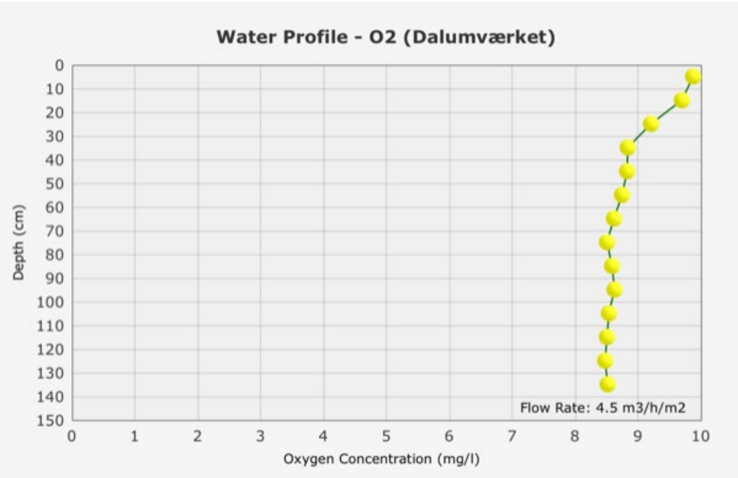


Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, the concentration of ammonium is shown in mg/L. The drinking water criteria is shown as a red line. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes removal through the depth of the filter.
- The steepest part of the curve can be used to determine the maximum volumetric removal rate.

Water Profile – O2 (Vandprofil – O2)

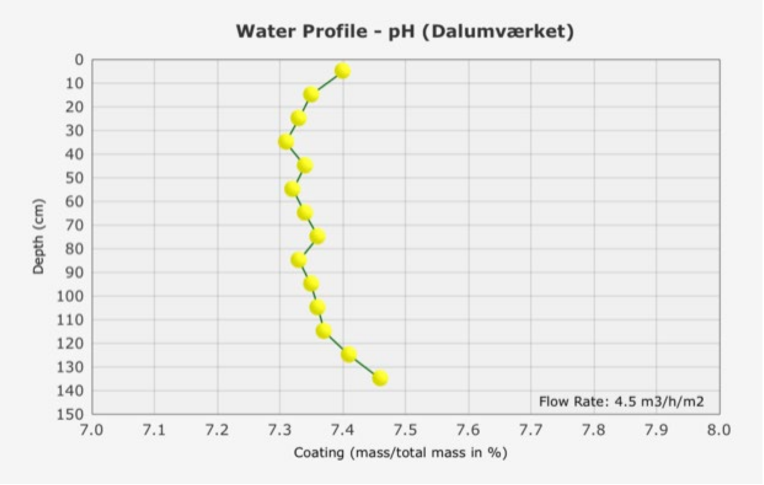


Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, the concentration of oxygen is shown in mg/L. The drinking water criteria is shown as a red line. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes removal through the depth of the filter.
- The steepest part of the curve is generally the layer where ammonium is being removed most rapidly.

Water Profile – pH (Vandprofil - pH)

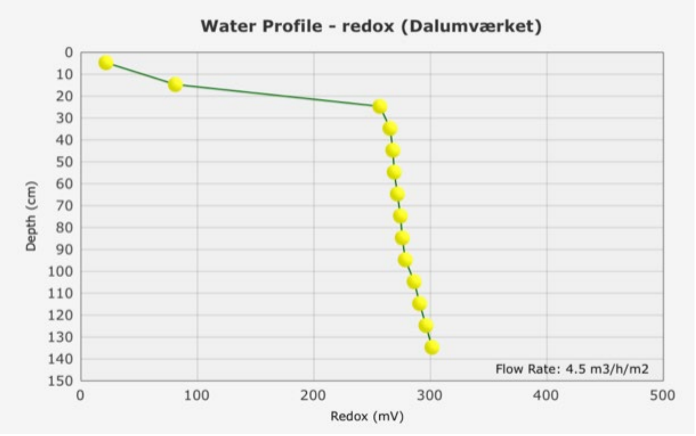


Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, pH measurements are shown. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes pH changes through the depth of the filter.

Water Profile – Redox (Vandprofil - redox)



Graph description
This depth profile shows results from water samples collected at 10 cm intervals from one of the participating waterworks using special sampling equipment. In this graph, the redox value is shown in mV. Depth in the filter starts with the top of the filter medium as 0.

Value of graph

- Visualizes changes in redox through the depth of the filter.
- The greatest redox increase is often seen at the depth where the majority of iron has been removed.

Merkur: Web-baseret platform til vandbehandlingsdata

I Danmark er drikkevandsproduktion baseret på grundvand, der behandles ved en enkel proces, der består af iltning af vandet efterfulgt af en biofiltrering med gravitations- eller trykfiltre. Herved fjernes eller omdannes jern, ammonium og mangan. Design og drift af biofiltrering, som er hjertet i vandbehandlingen, har ikke ændret sig væsentligt i mere end 100 år. Fremskridt i prøvetagning og måleteknikker i forbindelse med biofiltrering har imidlertid medført ny viden og mulighed for at undersøge, forstå og manipulere de kemiske, mikrobiologiske, fysiske og procesteknologiske elementer i drikkevandsbehandling. Vandkvaliteten er under pres, og der er en erkendelse af, at mange af de nuværende overskridelser af vandkvalitetskrav på landsplan kunne undgås ved en bedre vandbehandling.

Projektets formål er at re-designe vandbehandling fra bunden ved radikal nytænkning af drikkevandsproduktionen, hvormed der kan ske en optimering af nye og eksisterende vandværker, herunder reduktion af vandspildet ved returskyl, forkortelse af indkøringen af nye filtre samt større bæredygtighed i drikkevandsproduktion.
Projektet har resulteret i formulering af 18 ”redesign-principper”, der handler om design og drift af drikkevandsbehandling. Principperne blev testet ved fuldskala demonstration af ny filterbeholderdesign samt ny indkøringsprocedure med SmartSand. Endvidere blev principperne udviklet på basis af ny viden om jern- og ammoniumfjernelse samt returskylleprocessen. Projektet har desuden påbegyndt udvikling af den åbne dataplatform ”Merkur” til vandbehandlingsdata samt en matematisk model til at belyse virkningen af forskellige filterkonstruktioner.

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