Keep It Short and Simple

Easy UV Treatment

AquaCulture

Make life flow

Get the facts on UV water treatment

UV water treatment is an effective way of keeping your aquaculture operation flowing by eliminating unwanted microorganisms and pathogens, but how does it work, and how do you select a suitable solution?

This brochure aims to de-mystify, clarify, and simplify this complex subject. We give you a clear definition of the terms used, we discuss key aspects of the technology, and we offer methods for comparing UV systems and the results they can provide.

We hope this introduction will help you find a treatment solution that keeps your critical processes flowing. We have worked with the aquaculture industry for decades – contact us for more details or an in-depth discussion of UV technology.

CONTENT

Proven Technology

Terms & Definitions

To understand the requirements for eliminating microorganisms with UV-treatment an understanding of the terms and definitions used is required. The following **explains** the terms and definitions used.

Pathogen is any organism or agent that can produce disease. They may also be referred to as an infectious agent, or simply a germ.

Pathogenic organisms are of five main types: viruses, bacteria, fungi, protozoa, and worms. Fish Lice are not exactly a pathogen, but rather a parasite, and it often carries harmful pathogens such as virus and fungi.

In general, the higher number of cells and bigger the physical size of the organism the harder it is to kill with UV.

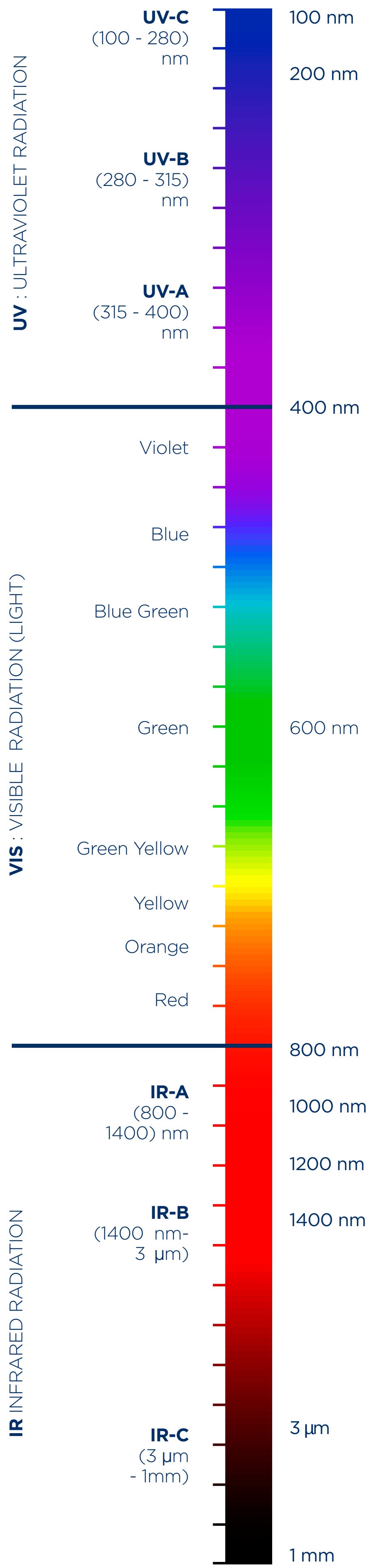
UV, also known as Ultraviolet light or radiation, is a range of “light” with shorter wavelengths than that of visible light, e.g. from the sun and is spilt into UV spectrum ranges.

UV-A –wavelength 315-400 nm, long-wave UV. Not absorbed by the ozone layer.

UV-B – wavelength 280-315 nm, medium-wave UV. Mostly absorbed by the ozone layer.

UV-C – wavelength 100-280 nm – short-wave UV. Completely absorbed by the ozone layer and atmosphere.

UV-C is the spectrum used for eliminating pathogens & other biological contaminants, i.e. microorganisms as exposure to this radiation is harmful to DNA. But recent research points to that UV-A and UV-B in combination with UV-C have a positive in reducing pathogens.



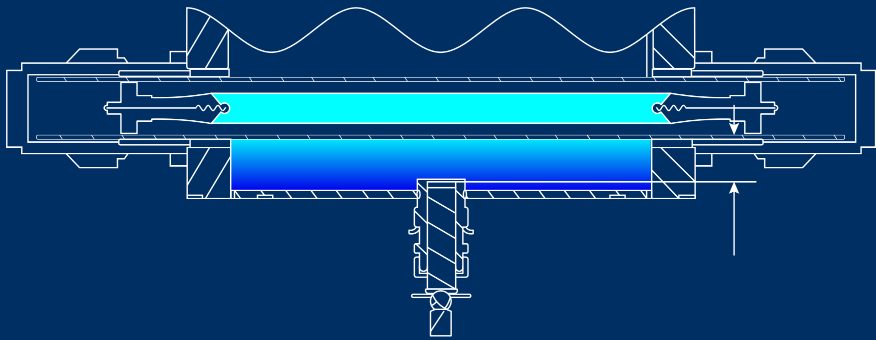
UV-I

also known as **U**ltra**v**iolet-**I**ntensity, is a measurement of how much light reaches a UV-I sensor.

To the right: Illustration showing the UV-I sensor and UV lamp for UV Intensity measurement.

- UV-I is generally measured in Watt/m2.
- UV-I is system specific and depends on the light source and distance.

- UV-I can NOT be used for comparing different systems.



UV-T

also known as **U**ltra-**v**iolet-**T**ransmission, is the percentage of UV-Light (254nm) remaining after travelling 1 cm through water.

This means that for a UV-T at e.g. 85% the amount of UV light will be reduced to 85% after penetrating 1 cm of water. When penetrating the next cm, the UV light will be reduced to 85% of the 85% etc.

- UV-T used in aquaculture are usually in the range of 85-97%, although RAS systems may experience lower values in the internal recirculation stream.
- UV-T states the clearness of the water the UV-Light is being passed through.
- UV-T is universal.
- UV-T is measured in %
- UV-T light source is defined as 254 nm.
- UV-T distance is defined at 1 cm.

- UV-T can be used for comparing different systems, to determine their disinfection in different environments. One system may be very effective at 97% UV-T but useless in 85% UV-T water.
- UV-T cannot be determined by eye, as UV-Light is invisible to human eyes.
- UV-T measurement is normally done across a band of wavelengths, but the numerical value referred to is normally the value at 254nm.

TSS

also known as **T**otal **S**uspended **S**olids, is often organic matter and minerals (sand/ silt) which is mostly present in river estuaries or in regions with a lot of variation in tidal water levels.

- It may also affect the UV-I reading and effectiveness of the UV light.
- Depending on the solids it may affect the UV-Transmission.
- Fine filtration may help increase the UV-Transmission if there is a high level of TSS.

- In general, Norwegian land-based Aqua-culture sites, with deep-water intakes are not prone to suffer from high level of TSS. Whereas tropical areas like South America or Southeast Asia where the basins are dug out in the ground may suffer from high TSS.

Log reduction is a measure of how much a specific pathogen is reduced. Each pathogen has its own action spectrum or sensitivity to UV-Light.

Log reduction is sometimes expressed as a percentage where the closer the value is to 100% **the better the reduction** of the contaminant.

LOG-1 REDUCTION	**90%** reduction of the contaminant, i.e. **10%** may remain
LOG-2 REDUCTION	**99%** reduction of the contaminant, i.e. **1%** may remain
LOG-3 REDUCTION	**99,9%** reduction of the contaminant, i.e. **0,1%** may remain
LOG-4 REDUCTION	**99,99%** reduction of the contaminant, i.e. **0,01%** may remain
LOG-5 REDUCTION	**99,999%** reduction of the contaminant, i.e. **0,001%** may remain

UV dosage is typically measured in mJ/cm2 and signifies the necessary irradiation of UV light for specific purposes, such as **eradicating microorganisms.**

Another unit of measurement is J/m², which is numerically ten times higher than mJ/cm²; for instance, 250 J/m2 equals 25mJ/cm². The required UV dosage varies depending on the pathogen targeted for elimination. Furthermore, different levels of UV dosage are necessary to achieve the desired reduction in contamination measured by log reduction.

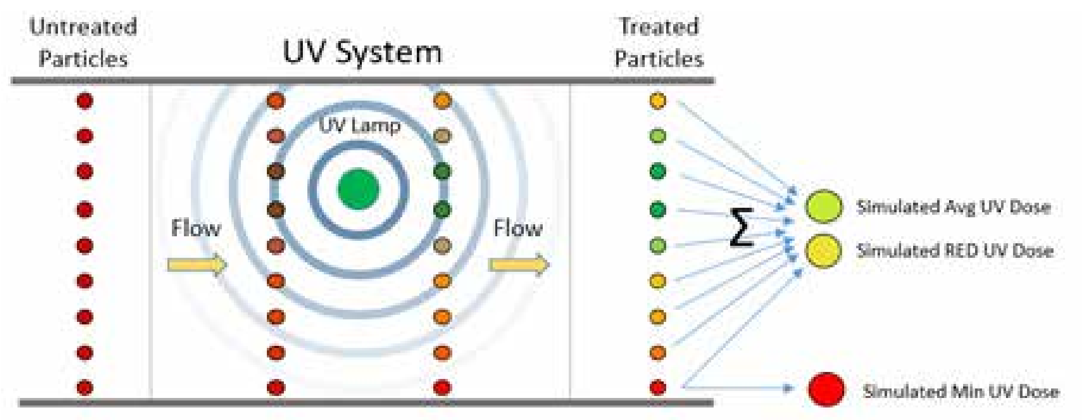
Dosage is often mentioned, but needs defining:

Minimum dose – the particle furthest away from the UV light source is considered ensuring that all microorganisms receive a minimum dose.

Average dose – averages the UV light between all the particles passing through the reactor at the distance furthest from the UV light source (lowest UV level) and the area immediately in front of the UV light source (highest UV level).

Reduction equivalent dose – considers the target microorganism's sensitivity to UV light, i.e. a specific UV dose for a specific log reduction. Ideally each UV-Unit should have a range of RED dose calculated for each specific pathogen, as they may have different sensitivity to different doses, and it may not necessarily be a linear reduction. This should be the type of dosage used when comparing UV-systems. In Bio-dosimetry testing, MS-2 bacteria are commonly used

Simulated



Bio Dosimetry Testing

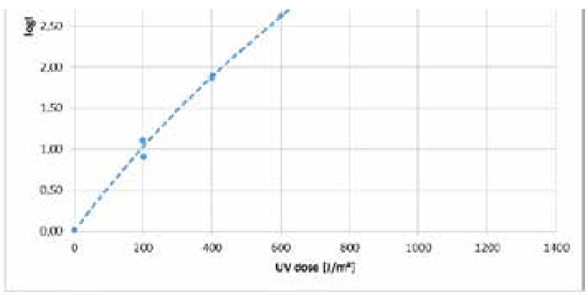
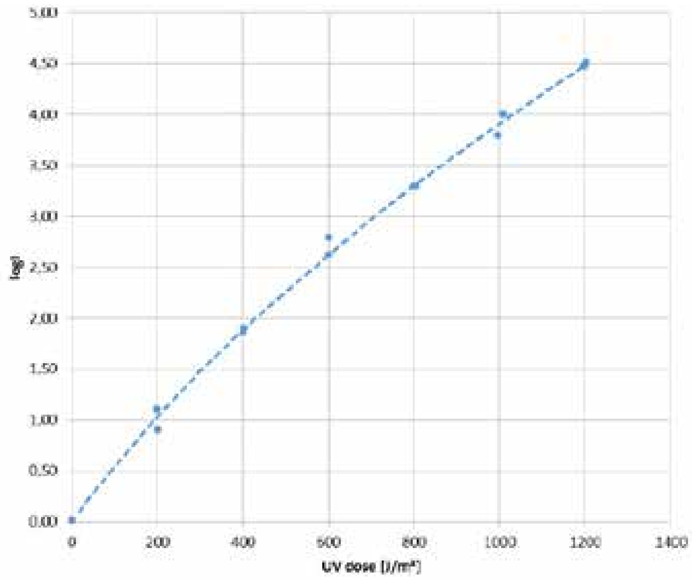


Figure 4: Dose-response curve of MS2.

Dose simulation



Note that the unit used here for dose is J/m2, which numerically is x10 higher than mJ/cm2

Results

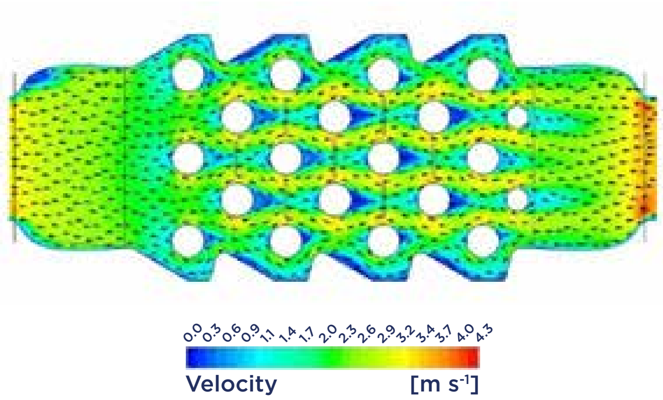
CompactClean™

BWTS | 2017

Plot of simulated log inactivation vs. UV-dose for MS2 microbe with exponential approximation (dotted line) and actual dosimetry data points.

	ID	UVT [%]	Flow [m³/h]	Logi [-]	Red [J/m²]
Test Results	MS2-1	64.7	340	4.15	1080
	MS2-2	59.8	288	4.14	1078
	MS2-3	55.3	216	4.25	1118
	MS2-4	44.4	122	4.51	1210
	MS2-5	40.6	91	4.71	1284
CDS Results	MS2-1	64.7	340	4.15	1083
	MS2-5	40.6	91	4.99	1392

Table: Comparison of measured data and CFD simulation



Tailoring Doses for Disease Control

In aquaculture different fish diseases require **different doses** for a given log reduction. Note that often doses found on google and in literature is based on Low-Pressure UV-Lamps, i.e. only 254nm, and medium-pressure UV-Lamps may require a significantly lower UV-C dose due to the wider spectrum.

Recent study from DTU suggest that DESMI Medium-pressure lamps only need to emit a UV-Dose (RED) of 60mJ/cm2 to generate a log-4 reduction of IPN-Virus.

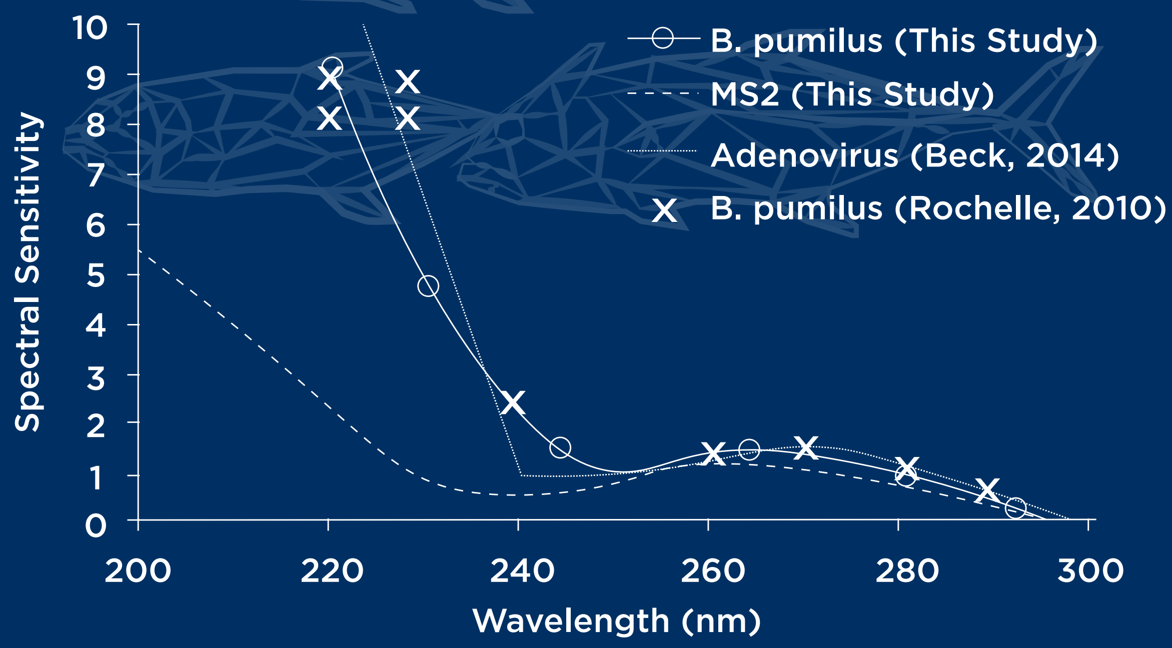
Depending on the specific pathogen it may be more sensitive to shorter wavelengths and the closer to 200nm the greater the effect. But as seen in the UV-T plot, shorter wavelengths are also greater absorbed by water (and the atmosphere as well).

ISA — **Infectious Salmon Anemia**
10 mJ/cm² for log-3 reduction

ICH — **Ichthyophthirius Multifiliis**
100 mJ/cm² for log-3 reduction

SP — **Streptococcus sp. (seawater)**
45 mJ/cm² for log-3 reduction

IPN — **Infectious Pancreatic Necrosis**
250 mJ/cm² for log-3 reduction



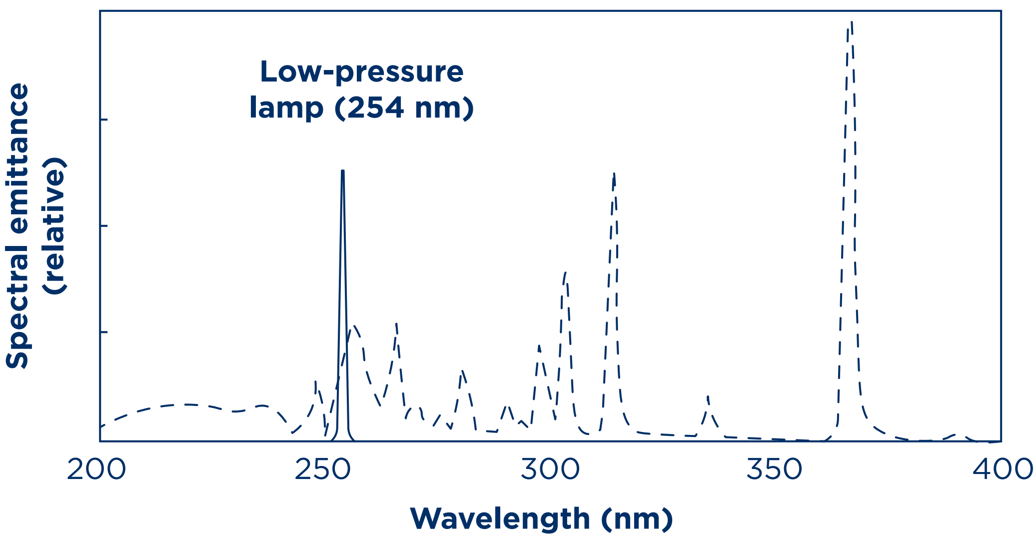
UV-Lamps (UV Light sources)

Generally, two different UV-light sources are used in aquaculture:

Low pressure lamps – output UVC light at 254 nm and in some cases also 185 nm depending on the type. The metal inside is amalgam.

Medium-pressure lamps – output UVC light at 200-400 nm. The metal inside is mercury.

The "pressure" refers to the internal pressure of the lamp when the metal inside vaporizes.



Spectral output of low-and medium-pressure UV lamps. Low-pressure bulbs (solid line) are monochromatic (UV 254), whereas medium-pressure lamps (dashed line) are polychromatic (200-400 nm). Figure adapted from Bolten and Linden (2003). Reprinted by permission of the publisher.

- Generally low-pressure UV lamps convert ~32% of the energy input to useful UVC whereas medium-pressure lamps convert ~14% of the energy input to useful UVC. This means that low pressure lamps are more efficient at converting power to UVC.
- The dose-values in literature regarding IPN virus are based on Low-Pressure UV-Lamps, where a dose of 250mJ/ cm^2 is required to achieve a LOG-3 reduction of IPN-Virus.
- Initial test results by independent laboratories indicate that using medium pressure lamps (with a broader UV light spectrum) with a dosage of 60 mJ/cm2 will generate a LOG-4 reduction of IPN.
- This means that while medium pressure lamps are less effective at converting power to UVC light in comparison to low-pressure UV lamps they have a much better elimination effectiveness on IPN (due to the broader spectrum) and can therefore be considered more efficient than low pressure lamps in eliminating pathogens for aquaculture using IPN Virus as the base for the reduction equivalent dosage.

When comparing different UV systems, it is very important to understand the importance of comparing the same parameters to ensure that the same result can be achieved, i.e. the required contaminant elimination at the same log reduction thus ensuring safe, clean water and healthy fish.

UV-I vs. UV-T

- UV-I is a measurement of how much light reaches a UV Sensor and is system specific and can therefore not be used to compare UV Treatment systems.
- UV-T expresses the clearness of the water and is the percentage of UV-Light at a given wavelength (254nm) after traveling 1 cm through water.
- UV-T can be used to compare UV Treatment systems, e.g. one UV Treatment system might be effective with water at 97% UV-T, but the same system might be useless for water with a UV-T of 85%.

Min. Dose vs. Avg. Dose vs. RED Dose

- Understand the type of dosage given by the UV-Treatment system manufacturer is paramount to the result.
- If, e.g. the manufacturer is stating a 250mJ/m^2 then it is important to understand whether it is the minimum or the average or the RED dosage that they refer to.
- If the stated dose is RED, understand for which pathogen the bio-dosimetry was used.

Low pressure vs. medium pressure UV lights

- Tests by independent third-party research centres indicate that the broader UV spectrum of medium pressure lamps are capable of a LOG-4 (99.99%) reduction of IPN virus with a dosage og 60 mJ/m^2, whereas literature for low pressure lamps define 250 mJ/m2 for a LOG-3 (99.9%) reduction of IPN virus.

CAPEX & OPEX for different lamp types

- Generally, the power density of a 50 CM medium pressure lamp is 6 kW, whereas the power density of a low-pressure lamp might be 500 W for a 160 cm lamp. The price between the two is comparable
- Less physical space is required for medium pressure lamps.
- Medium pressure lamps = potentially higher log reduction with lower dosage and lower power consumption.
- Low pressure lamps = lower log reduction with higher dosage and possible higher power consumption.
- Due to the potential for higher IPN reduction with lower dosage in comparison to low pressure lamps, medium pressure lamps and the reduced physical space requirements then.
- Less physical space is required for medium pressure lamps reducing CAPEX.
- Power consumption is lower for IPN virus for medium pressure lamps reducing OPEX.
- Higher log reduction of IPN virus for medium pressure lamps ensures higher safety.

Cleaning of UV-Unit (Chemical vs. mechanical wiper)

- UV Lamps generate heat, and this heat creates fouling – Look into how the UV lamps in the UV Treatment system are kept clean. By far the two most common cleaning methods used are mechanical wiping and CIP (Cleaning In Place).
- Mechanical wiping utilises physical brushes or scrapers to remove fouling from the surface of the lamps.
- CIP, recommended by DESMI, utilises circulating cleaning agents (like DESMI's citric acid) through a closed loop system ensuring optimal performance and safety.
- Refer to the technical document from DESMI comparing these two cleaning methods.

We exist to keep your business flowing

DESMI works closely with aquaculture engineers, designers, and owners to keep critical production processes flowing reliably and efficiently on fish farms on land and at sea, anywhere on the planet. Our pumps, UV treatment systems, IoT offerings, and after-sales service are trusted worldwide for dependability and the lowest total cost of ownership.

At DESMI, our focus has never been on discovering what we can do – it's about pushing the boundaries of what we can do for you, no matter which type of facility and what species you work with. We help you ensure optimal production environments that keep fish stocks healthy and safe and keep your business profitable.
Founded in Denmark in 1834, we have provided the expertise, solutions, and aftermarket support our customers need for nearly two centuries. We help you operate more efficiently and reliably, enabling your ambitions for performance, food safety, and growth whilst helping you reduce your climate impact.

Together, we can make a difference, whatever the future holds. Because we, like you, are here to make life flow.
For more information, visit **desmi.com**

DESMI A/S
Tagholm 1
DK-9400 Nørresundby
Tel.: +45 96 32 81 11

DESMI
Make life flow