

## Water disinfection using DabV

Tor-Henning Iversen dr.philos.,  
professor em. <https://bio-consult.net>

The issue of clean water is considered the most important problem facing mankind, and WHO defines water as the most important food product, essential for our health (Golovin et al. 2021).

To inactivate microbial pathogens and protect public health from infectious water-borne diseases, disinfection is necessary. Compared with the conventional chemical disinfection (e.g., chlorination or ozonation), UV disinfection can inactivate microbial pathogens with minimal production of toxic disinfection by-products and chemical residues. UV radiation may have both direct and indirect effects on aquatic microorganisms. Direct effects involve damage to biological molecules by direct absorption of UV radiation. UV energy penetrates the outer cell membrane, passes through the cell body and disrupts its DNA, preventing reproduction. Indirect effects alter water chemistry (e.g. formation of radicals and production of low-molecular-weight compounds). These indirect effects change the nature of organic matter, especially humic substances (Alkan et al. 2006).

However, drinking water treatments are challenged as the concentrations of natural organic materials and other compounds in raw waters are increasing (Alkan et al. 2006, Johansson et al. 2010). UV is light and light does not penetrate well through organic matters. Natural organic substances in water comes from degraded plant and animal material, and it can be characterized as yellow to black in colour. Zyara et al. (2016) investigated water disinfection by UV the combination of chlorine and UV disinfection treatment, and they concluded that if the watercolour is higher than 5 mg Pt/L there is a need for another disinfection treatment in addition to UV filtering.

DabV is a water improvement technology based on sound. In contrast to light, sound travels well through organic materials. The present study investigates the effects of DabV on water disinfection. In one experiment disinfection is performed by a combination of UV radiation and DabV, and in three experiments DabV is performed without UV disinfection treatment.

## **Material and methods**

DabV was used for water treatment for bacterial control in four different experiments.

### Experiment no 1

In experiment no 1, DabV was added as an additional disinfection treatment in water from a commercial water treatment plant after an outbreak of pathogen microbial contamination. The water treatment plant deliver water to approximately 140 destinations.

The plant routinely uses UV radiation for disinfection. The color number was high due to high levels of organic matter. DabV was mounted as an extra disinfection filter in addition to UV radiation with the hypothesis that DabV could control bacteria level even at high level of organic material in the water i.e. with high color number well above 20 mg Pt/L. DabV was mounted where the water enters the plant and after the UV filtering.

### Experiment no 2

Experiment no 2, is an old water treatment plant (AG-DF). The plant has a filter system but does not use UV radiation for disinfection. The destinations included one living house, a house with restaurants for guests and a stable for 30 horses. In total this resulted in high water consumption.

### Experiment no 3

Experiment no 3 is a very old water treatment plant (AGM), which delivers water to 14 houses with different working places, including cantina, office, hand craft companies etc. Due to covid-19, the activity was low in the companies and the water consumption was low leading to stagnated water challenges.

### Experiment no 4.

Experiment no 4 was a water well that has been left unused for a very long time. The initial bacterial content in the water was extremely high, above the range that could be measured.

## Results

### Experiment no 1

In experiment no 1, where DabV was mounted as an additional disinfection step to the routinely used UV radiation, resulted in bacteria disinfection even in water with color number in the range 38-48 Pt/L. The water after the disinfection and at two different destinations (Destination 1, a home for elderly and Destination 2 at an outdoor tap), was analysed every month and the raw water was analysed every second month.

At the site immediately after the UV+DabV disinfection all bacteria were under the detection limit of 1 MPN/100 ml. In the first time after mounting DabV, bacteria were detected at the destinations, whereas at the latter timepoint no bacteria could be detected at the destination positions.

Strikingly, the 16th of November 2020, the raw water had very high level of pathogen bacteria (110 MPN/100 ml *Coliform* bacteria, 4 MPN/100 ml *E.coli* and 3 MPN/100 ml *Enterococci*), and the color number was high (45 Pt/L). Yet, no bacteria were detected after UV+DabV disinfection or at any of the destination positions.

Our interpretation why initially bacteria could be detected at the destinations, but not at the position just after UV+DabV, is that there might have been bacteria resting in the water distribution system that was disinfected by DabV during the first period, but that over time these were removed by DabV.

**Table 1. Amount of bacteria before and after UV + DabV disinfection after an outbreak of pathogen bacteria in water with high color number. The unit of color number is mg Pt/L and the units of all bacteria is [MPN/100 ml]**

Date	Ref.number	Raw water				After UV+DabV				Destination 1				Destination 2			
		Color number	Coliform	E.coli	Enterococci	Color number	Coliform	E.coli	Enterococci	Color number	Coliform	E.coli	Enterococci	Color number	Coliform	E.coli	Enterococci
24.08.2020	EUNOBE-0042149					33	<1	<1	<1	32	11	<1	<1	31	4	<1	<1
21.09.2020	EUNOBE-0042757	38	24	<1	<1	38	<1	<1	<1	40	3	<1	<1	39	<1	<1	<1
19.10.2020	EUNOBE-0043349					37	<1	<1	<1	40	1	<1	<1	37	<1	<1	<1
16.11.2020	EUNOBE-0043946	45	110	4	3	44	<1	<1	<1	46	<1	<1	<1	45	<1	<1	<1
21.12.2020	EUNOBE-004748					52	<1	<1	<1	56	<1	<1	<1	54	<1	<1	<1
18.01.2021	EUNOBE-0045097					55	<1	<1	<1	57	<1	<1	<1	56	<1	<1	<1
15.02.2021	EUNOBE-0046537	48	1	<1	<1	49	<1	<1	<1	50	2	<1	<1	52	<1	<1	<1
15.03.2021	EUNOBE-0046264					48	<1	<1	<1	50	<1	<1	<1	48	<1	<1	<1

## Experiment no 2

In experiment no 2, DabV was used as the only water disinfection treatment and the bacteria challenge of this water was severe. The results of the bacteria analyses are shown in Table 2.

**Table 2. Amount of bacteria before and after DabV disinfection. The unit of color number is mg Pt/L and the units of all bacteria is [MPN/100 ml]**

Date	Ref.number	Raw water			After DabV			Destignation 1			Destignation 2			Destignation 3		
		Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli
26.11.2020	EUNOBE-0044152		78	4					11	5					4	<1
30.11.2020	EUNOBE-0044194	25	80	4	24	56	<1	25	56	4	24	32	<1	24	14	<1
12.01.2020	EUNOBE-0044990		8	1		6	1		1	<1					1	1
23.02.2021	EUNOBE-0044782	6	12	1		1	2		1	1		<1	<1		<1	<1

## Experiment no 3

In experiment no 3, DabV was used as the only water disinfection treatment in an old water treatment plant. The water flow was low and the bacteria challenge of this water was severe. The results of the bacteria analysis are shown in Table 3. In this experiment, analyses were not observed immediately after the water treatment. However, based on the fact that some of the destination positions did not have any detectable bacteria level, our interpretation is that the bacteria observed at some destination positions was a result of bacteria film inside the pipe in the water distribution system. The time period from the first analysis of the water (01.12.2020) until the second time point (02.02.2021) when most bacteria were removed was two months.

**Table 3. Amount of bacteria before and after DabV disinfection. The unit of color number is mg Pt/L and the units of all bacteria is [MPN/100 ml]**

Date	Ref.number	Raw water			After DabV			Destignation 1			Destignation 2			Destignation 3			Destignation 4		
		Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli
01.12.2020	EUNOBE-0044237	25	78	5	Not observed			25	4	<1	11	<1	<1	18	<1	<1	25	15	2
02.02.2021	EUNOBE-0044399	24	3	<1				22	1	1				15	<1	<1	22	1	<1
06.04.2021	EUNOBE-0046655	29	1	<1					<1	<1		<1	<1		<1	<1		<1	<1
Date	Ref.number							Destignation 5			Destignation 6			Destignation 7			Destignation 8		
		Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli
01.12.2020	EUNOBE-0044237							25	12	5	26	10	3	26	32	2	25	16	1
02.02.2021	EUNOBE-0044399							21	1	1	23	2	<1	23	<1	<1	17	<1	<1
06.04.2021	EUNOBE-0046655								1	<1		<1	<1		1	<1		1	<1

#### Experiment no 4

Experiment no 4, which was a water well that has been left unused for a very long time (**Figure 1**). Initial analysis results of bacteria level were so high that quantification was not possible. The accredited laboratory therefore reported “overload” on all bacteria analysed. DabV was left in the well for one and a half months.

When the water in the well was analysed after one and a half months with DabV in the well, no bacteria could be detected (**Table 4**). The color number of the water in the well was very high (78), which shows the effectiveness in disinfecting water even at a high content of dissolved organic matters in the water. An extra DabV treatment was performed as it was not surprisingly expected that the water from the well did not have any bacteria as a result of DabV places in the well. This analysis also showed that no bacteria was detected.



Figure 1. Experiment no 4 of a water well that had been left unused **for** a very long time.

Table 4. Amount of bacteria before and after DabV disinfection. The unit of color number is mg Pt/L and the units of all bacteria is [MPN/100 ml]

Date	Ref.number	Water in the well before DabV			Water in the well after DabV			Water from the well after DabV plus an extra DabV treatment		
		Color number	Coliform	E.coli	Color number	Coliform	E.coli	Color number	Coliform	E.coli
19.01.2021		Overload								
02.03.2021	EUNOBE-00445958				87	<1	<1		<1	<1

## **Conclusion**

Experiments focusing on bacteria removal by DabV show that DabV has a bactericidal effect even when applied in water with high level of organic materials and other compounds that result in coloured water. DabV can also contribute to cleaning the insides of the pipes in the water distribution system.

DabV may be used as an additional treatment device for water treatment, or in combination with other disinfection treatments.

## **References**

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