

WHITE PAPER
inTank versus inLine

THE BENEFITS OF BALLAST WATER TREATMENT DURING THE VOYAGE

An inTank solution for high
ballast dependent ships



Paper: inTankTS-2nd gen.
Version: F-01 Public
Date: 31-10-2018



An inTank™ solution for high ballast dependent ships

This paper discusses a common aspect of many Fully Type Approved inline ballast water treatment systems. Inline ballast water treatment systems interrupt main ballast water flow with a filtration mechanism.

This introduces operational and commercial challenges for time-critical high ballast dependent ships. Inline systems also treat ballast water in Port, an inconvenient time and place due to various factors in play during port calls. An alternative “second generation” solution is introduced. Treatment in the tanks during ships voyage elegantly avoids operational and commercial risks for high ballast dependent ships. An inTank treatment based on recirculation and active total residual oxidant (TRO) monitoring also introduces the ability to control regrowth.

The best confidence of regulatory compliance with the least impact on vessel operations.

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INTRODUCTION

About 90% of all cargo worldwide is moved over seas. Ships are designed to move cargo in the most efficient, cost effective and environmentally friendly manner. During a Port call cargo is discharged or loaded. The weight of cargo loaded or offloaded needs to be compensated for various purposes: stability, manoeuvrability, optimal propulsion (draft, trim) and to counter stress factors on the hull.

Ships therefore ballast or de-ballast water in Ports. The required volume of water is displaced by a pump and or by gravitational forces into or out of specific dedicated ballast tanks. Port water contains biological activity of marine species and pathogens. Therefore, treatment is required to avoid the introduction of invasive marine species and pathogens from one part of the world to another.

The ballast water industry has so far tackled this problem via treatment and disinfection of port water at intake – otherwise known as inline Ballast Water

Treatment Systems (BWTS).

This paper discusses the impact of the installation of ballast water treatment systems designed to treat water in Port, focusing mainly on cargo ships and the operational risks involved.

The latter part of the paper introduces a “second generation” solution, which treats ballast water in the tanks during ship’s voyage. Treatment of water in the tanks and during the voyage elegantly mitigates the risks associated with in Port water treatment and conditioning.

THE IMPACT OF TREATMENT OF WATER IN PORT FOR HIGH BALLAST DEPENDENT SHIPS

CARGO SHIPS, TANKERS, BULK AND GAS CARRIERS, HEAVY LIFT, SEMI-SUBMERSIBLES



In general, to date the treatment or disinfection of ballast water is directly connected and in parallel with cargo activities in Port. This timing seems logical as cargo is discharged or loaded and the weight differential must be compensated by port water pumped to the ballast tanks. In reality this practice poses some operational challenges for high ballast dependent ships.

1.1 INLINE SYSTEMS INTERRUPT FLOW

From a technical point of view the currently type approved ballast water treatment systems are “inline”. These solutions interrupt existing ballast water piping with a water treatment and conditioning plant.

There are two types of Inline solution set-ups. The first is a full-flow treatment, which is directly performed on the complete port water intake flow – all UV and chemical injection BWTS have this setup as well as some electro-chemical based systems. The other one is side- or slip-stream treatment, used mostly for electrochemical based BWTS. A side

stream BWTS is a hybrid set-up in which the port water intake flow is pre-treated by a filtration mechanism and at the discharge side of the filter a stream with a high concentration of active substances is dosed and then injected into the main flow.



1.2 FACTORS IN PLAY WHILST TREATING IN PORT

This method introduces various operational risks for high ballast dependent ships.

Timing

Foremost, in Port a cargo ship's crew is dedicated to the critical process of the cargo operation, monitoring flows continuously, loading and offloading plans, operating related machinery such as cranes or cargo pumps as well as the overall monitoring of ship's stability including the (de)ballasting.

Other port activities also put pressure on crew time, including maintenance and overhauls, Class and Port State inspections, vitals and shore leave.

Power

In Port power demand delivered by generators is at a peak due to demand

for cargo operations and auxiliary machinery as well as hotel load. This is usually is the peak load the vessel is designed for during Port – Terminal stays.

Port water quality

The majority of BWTS are designed and optimised to deal with challenging in Port water qualities¹ during the ballasting operation. ABS reports this often causes slower than normal ballasting. Treatment at sea gives a BWTS time to handle any challenging ballast water. Treating in port might slow the vessels port operations and impacts BWTS reliability, efficacy and power consumption. Two specific challenges are detailed below:

Turbidity and Ultra Violet Transmittance

Suspended and dissolved matter in port water decreases light intensity, sometimes by over 50%. (See table: In Port water

In Port water quality parameters <small>source: Alfa Laval White paper, p12</small>	Salinity (PSU)	Temp (°C)	UVT (%)
Hamburg, Germany	0,1	2	69
Houghton, MI, USA	0,1	-0,1	91
Rotterdam, the Netherlands	0,3	5	93
Erie, PA, USA	0,3	-0,1	87
Shanghai, China	1,2	4	49
Bremerhaven, Germany	4	2	60
Antwerp, Belgium	6,5	5	66
Baltimore, MD, USA	12	11	83
Halifax, NS, Canada	20	0,8	94
Houston, TX, USA	20	11	74
Gothenburg, Sweden	20	0	85
Istanbul, Turkey	24	6	95
Southampton, England	32	5	51
San Pedro, CA, USA	32	2	95
Hong Kong, China	33	17	80
Lisbon, Portugal	35	14	53

¹ ABS, 10th of August 2017; Best Practices for operation of BWTS, Page 3. BWMS workshop, Houston. Results from a study questionnaire of 220 BWM Systems of 27 shipowners.

quality). In addition, the sediment load poses challenges to plants that require pre-filtration (see also section 1.3: Pre-filtration)

Salinity & temperature

Treatment technologies which rely on the availability of natural dissolved salts in the water to produce a disinfectant, active substance are de facto less efficient in comparison to open sea water intake. At sea but for some anomalies, salinity level is minimal: PSU 36.



1.3 PRE-FILTRATION TO REDUCE BIOLOGICAL LOAD

Ballast water treatment systems normally use a two-step treatment process: a pre-treatment and a main treatment event. The purpose of pre-treatment, such as filtration of port water flowing into a vessel's tank is primarily to remove larger organism and species.

Larger species will survive the main treatment step if the BWTS runs without a filter. The main factors behind the requirement to filter out larger species are a short contact time, flow rate and a practical decision: the impossibility to install the power required to neutralise larger species without filtration. A side-effect of filtration is the removal of larger sediments.

However, a small percentage of overall sediment particles which cause turbidity in Port water (silt, clay) are effectively

filtered out as the filter screen pore-size is normally above 30 micro (see table- Filter cut off value).

Pre-treatment is required to ensure the BWTS consistently meets the ballast discharge standards as set by regulatory bodies. Without it, most technology applied is not sufficiently effective to meet the discharge standards, in particular for larger species.

In general, cargo ships are high ballast dependent in conjunction with their cargo-offload flows (e.g. oil tankers). The point to consider for cargo ships is that pre-treatment (pre-filtration) to remove larger species introduces risks such as reduced ballast water intake, de-rated pumps due to saturation or shutdown of the filter mechanism².

Sediments scale and sizes source: University of Geosciences Edinburgh	uM (Micron)	Metric (mm)	Phi scale
Very coarse sand	> 1000	> 1	0
Coarse sand	> 500	> 1/2	1
Medium sand	> 250	> 1/4	2
Fine sand	> 125	> 1/8	3
Very fine sand	> 62,5	> 1/16	4
Pre-Filter size CUT OFF value	40 microns		
Coarse silt	> 31,25	> 1/32	5
Medium silt	>15,63	> 1/64	6
Fine silt	> 7,8	> 1/128	7
Very fine silt	> 3,9	> 1/256	8
Clay	< 3,9	< 1/256	

² ABS, 2017, Report on BWMS Workshop, Page 3: "Reduction of ballast water throughput both uptake and discharge are a recurring theme". In many cases this appears linked to filter clogging and cleaning"

1.4 BIOLOGICAL COMPLIANCE

The currently available USCG and IMO type approved solutions for treatment of ballast water have been tested to meet discharge standards as set by regulatory bodies.

The solutions are based on in-line water treatment event(s) on intake and also at discharge in the case of UV systems (see table: USCG type approved list).

Cargo ships, especially the larger ships, are designed for longer voyages. Voyage durations may exceed the time period applied and adhered to during both land- and shipboard testing for Type Approval certification.

Technical compliance of a ship with an

operable type-approved BWTS is not in discussion here, but uncertainty may rise on actual biological compliance for longer voyages. Potential risk on regrowth of marine species and pathogens during longer voyages might risk unwanted results from ballast water sampling by Port State Control. No Fully Type Approved BWTS on the market is designed to control and prevent regrowth on longer voyages.

Current Type approved BWMS all work around these fundamental aspects of treating ballast in port, in line. Treating in the ballast tank during the voyage elegantly bypasses these fundamental issues and provides many benefits.

APPROVED							
Application Received	Manufacturer	Model	Independent Laboratory	Capacity	System Type	Certificate Issued*	HTime
20 Sep 2016	Optimarin, Norway	OBS/OBS Ex	DNV GL	167 - 3,000 m ³ /h	Filtration + Ultraviolet	02 Dec 2016 (03 Nov 2017)	> 72 Hrs
21 Sep 2016	Alfa Laval, Sweden	Pure Ballast 3	DNV GL	150 - 3,000 m ³ /h	Filtration + Ultraviolet	23 Dec 2016 (21 Nov 2017)	> 72 Hrs
23 Sep 2016	TeamTee OceanSaver AS, Norway	OceanSaver MK II	DNV GL	200 - 7,200 m ³ /h	Filtration + Electrodialysis	23 Dec 2016 (18 Oct 2017)	N/A
24 Jan 2017	Sunrui, China	BalClor	DNV GL	50 - 8,500 m ³ /h	Filtration + Electrolysis	06 Jun 2017 (05 Jan 2018)	N/A
31 Mar 2017	Ecochlor Inc., USA	Ecochlor BWTS	DNV GL	500 - 16,200 m ³ /h	Filtration + Chemical inject.	10 Aug 2017 (26 Apr 2018)	> 24 Hrs
02 May 2017	Erma First, Greece	Erma First FIT	Lloyd's Register	100 - 3,740 m ³ /h	Filtration + Electrolysis	18 Oct 2017	N/A
28 Sep 2017	Techcross Inc. Republic of Korea	Electro-Clean	Korean Register	150 - 12,000 m ³ /h	Electrolysis	05 Jun 2018	120 Hrs
31 Oct 2017	Samsung Heavy Ind. Co. Ltd., Republic of Korea	Purimar	Korean Register	250 - 10,000 m ³ /h	Filtration + Electrolysis	15 Jun 2018 (20 Jul 2018)	N/A - Fw 24
12 Mar 2018	BIO-UV Group, France	BIO-SEA B	DNV GL	55 - 1,400 m ³ /h	Filtration + Ultraviolet	20 Jun 2018	24 - 72 Hrs
09 Apr 2018	Wärtsilä Water Systems Ltd., England	Aquarius EC	DNV GL	250 - 4,000 m ³ /h	Filtration + Electrolysis	30 Aug 2018	24 Hrs

*Some manufactures have requested multiple amendments to their Type Approval Certificates. The first date is the date when the original certificate was issued, and the date in parentheses is the date of the current amendment. Copies of Type Approval Certificates [can be found here](#) or by visiting the [USCG Approved Equipment List](#).

TREATING inTank™ DURING THE VOYAGE

A SECOND GENERATION, IMPROVED
APPROACH TO THE PROBLEM OF BALLAST
WATER TREATMENT.



The idea to treat ballast water in the tank during ships voyage is not new nor very innovative. However, the inTank solution introduced by Envirocleanse LLC is remarkably different from the existing standards and configurations of inline flow treatment solutions.

2.1 FOUR FUNDAMENTAL DIFFERENCES

Current technologies and systems are designed and optimised for a specific ballast pump flow rate to handle directly the challenging biological load of Port water.

Designing a solution for inactivation of marine species and pathogens inside a ballast tank poses challenges as well. Fortunately, treatment in the Tanks is very similar to widely applied municipal water treatment technology methods.

The solution presented is close to a water conditioning method used to keep large swimming pools free of “invasive

species”. The fundamental differences are listed below.

Volume versus Flow

inTank treatment is designed to disinfect a specific water volume and not the flow.

Increased Contact time with oxidant

In contrast to inline flow treatment where fluid velocity (2.5 - 3 m/sec) is a major factor, treating in the tank is all about prolonged oxidant contact time. Therefore, the treatment event includes a minimum required time (in hrs) and disinfectant dosage-level (in mg/ltr) to effectively disinfect.



Re-circulation for dosing and neutralisation

A circulation loop on each tank is required to dose, mix-in an active substance and closely monitor the target dosage-level reached. The recirculation loop is also the means for neutralisation events.

Active control on regrowth

Once disinfected the BWT solution should provide a means to maintain, control the water volume free of species and pathogens.

2.2 THE inTank™ TREATMENT PROCESS EXPLAINED

The design solution in principle is simple and robust. When a vessel uses the inTank solution water is taken up into the ballast tanks in Port without any treatment and no changes to existing procedure. The treatment process occurs during the voyage. A small portion of ballast is circulated from one ballast tank at a time, passed through a dosing module and returned to the same tank through inTank patented mixing nozzles.

This circulation loop provides the means of applying and mixing in oxidants. The oxidant used is sodium hypochlorite (NaOCL) or commonly known as bleach. NaOCL can be generated on board via

an electrochemical generator or liquid bulk dosed.

The circulation loop also enables monitoring of TRO levels inside each tank and a means for injection of a neutraliser solution prior to discharge.

The consistency and successful inactivation of target organism and pathogens is verified by and controlled via a employed municipal waste water treatment metric: Concentration-Time dosing (CT dosing).

2.3 A NEW METRIC: CONCENTRATION -TIME

CT is a metric used in the waste water industry and by municipalities ensuring safe drinking water. CT is defined as the product of:

- Concentration of disinfectant (in mg/ltr)
- Contact Time (in Hours)

CT is measured as Total Residual Oxidant [TRO] x Exposure Time [HRS]. Envirocleanse has found that effective and complete treatment of ballast water

is ensured with a target CT value of 120.³

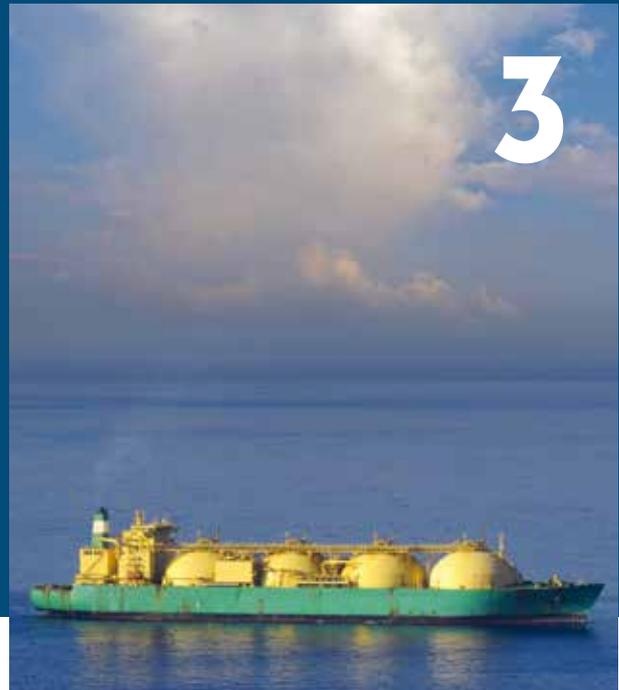
The CT approach ensures complete disinfection of ballast water and piping independent from ballast water quality and composition. Therefore, this approach also accounts for the quality of ballasted water. Recirculation and TRO measurements per tank also ensure the appropriate level of oxidant is dosed in line with the oxidant demand of the ballast water.

Parameter	Limits	Example 1	Example 2
Tank hold time	24 hours minimum	24 hours	60 hours
Residual oxidant level	8 mg/L	5 mg/L average	2 mg/L average
Concentration-time (CT)	120 mg-hours/L minimum	120 mg-hours/L	120 mg-hours/L

³ CT Parameter: inTank™ BWTS Concentration-Time (CT) Parameters

OPERATIONAL BENEFITS OF inTank™ TREATMENT

SOLUTION SIMPLY DIVERTS THE COMPLETE
TREATMENT PROCESS TO THE VOYAGE



The inTank™ ballast water treatment solution elegantly eliminates various operational constraints related to in Port treatment. The solution simply diverts the complete treatment process to the voyage, effectively mitigating all in Port operational risks identified previously.

3.1 AVOIDANCE OF OPERATIONAL RISK FACTORS WITH INTANK SOLUTION

We return to the beforementioned factors at play for inline BWTS in relation to in voyage treatment of ballast water in the tanks.

Timing

Obviously, as we do not treat in Port, all critical cargo operations, cargo and ballast pumps, aux. machinery are NOT affected. Also, the vessel is always able to ballast or deballast as required without any interruption from an intermediate water treatment plant.

Power

The power load for cargo ships in transit

is low and sufficient installed generator capacity is available for a water treatment plant. In addition, the inTank solution continuously monitors the total residual oxidant on the recirculation line to ensure optimal dosage of oxidant. The elimination of the risk of over- or underdosing oxidants benefits the overall efficiency and power consumption.

Port water quality

Treatment at sea and in the ballast tank alleviates time pressure as well as flow constraints: a common concern for effective operation of ballast water treatment plants taking in water in Port

due to various challenging factors including turbidity, salinity and water temperature .

Turbidity (sediment loads)

It is well documented that EC-generated oxidants such as sodium hypochlorite are effective and less prone to efficacy drops caused by turbidity. Furthermore, the C/T model of a treatment event enables monitoring and re-dosing to meet the target combination of TRO dose and hold time. The ability to re-dose as needed ensures effective treatment regardless of organic and inorganic loads. In particular, the system is effective for treating organisms in sediment, as the re-application of disinfectant and in-tank mixing counteracts the ability of sediment to buffer chemicals.

Salinity & temperature

The inTank solution requires a small draw of seawater to the Electro-chemical generator for the production of active substance sodium hypochlorite [NaOCL]. The generator is effective with a minimum seawater-temperature combination of 10 PSU @ 10 °C. As a contingency and to normalise power consumption, vessels might opt for a simple pre-heater, brine injection or select a liquid bulk dosing module.

It is to be noted that the start of the treatment process is flexible for the operator considering the available time in conjunction with vessel's route. This flexibility also reduces concerns about salinity levels as ships predominantly sail in saline waters along the voyage.





3.2 NO FILTER

The inTank™ solution does NOT require a filter mechanism. Port water taken in flows uninterrupted to the ballast tanks, distinguishing it from most conventional in-line systems.

Due to the applied method of CT-dosing inTank™ also inactivates larger species and pathogens, removing the requirement for pre-treatment such as filters.

A filter-free solution eliminates the risk of ballast inflow reduction, or shutdown, a widely reported negative spin-off of in line BWTS.

3.3 BIOLOGICAL COMPLIANCE: IN CONTROL

The main objective of any BWTS is to meet IMO and USCG standards. The proof of the pudding is by regulation at the moment of discharge of ballasted water in Port.

EPA's Vessel General Permit requires indicator sampling and analysis of "Total Heterotrophic Bacteria" counts. Conventional inline systems treat in Port, therefore ships with longer voyages might have surprises with regards to the biological activity and compliance in next Port call. Not with inTank™. The solution introduces both active control as well as flexibility for the ship. The start of the treatment pro-

cess can be decided freely by the ship's crew. This might be at the very end of ships voyage, considering the required treatment time. The flexibility mitigates before-mentioned risk as the overall hold time after treatment is reduced significantly. In addition, inTank™ facilitates active control and monitoring of each tank through the ability to sample and recirculate water in ballast tanks. When required, a regrowth suppressing maintenance dose can be applied. The ability to re-apply a controlled maintenance dose of active substance to ballasted tanks is the best guarantee for biological compliance, as long as ballast water remains in the tank.

3.4 TECHNICAL COMPLIANCE

It is to be noted that with regards to technical compliance the inTank solution is based on active registration of the treatment events per Tank and these are finished before discharge.

Many BWTS on the market to date require conditioning treatment at the moment of discharge or must sample ballast water on the way out to ensure regulatory limits are not surpassed.

This is not necessary with inTank. Technical compliance is guaranteed because treatment is performed, verified and recorded by the system before discharge begins. The vessel therefore is flexible to take measures as required during cargo operations without intervention of a BWTS.

3.5 ELEGANT SOLUTION FOR UNIQUE TREATMENT CHALLENGES

inTank's recirculation-based ballast water treatment is fully completed during the voyage. This implies that inTank does not intervene, nor interrupt any ballast flow during cargo operation whilst in Port, at the Terminal. Many Type Approved BWTS require obligatory discharge monitoring and sometimes a secondary treatment such as UV to reach performance standard D2. This poses operational challenges for time-critical high ballast dependent ships: bulk carriers, tankers and gas carriers. Certain vessel types also have unique design aspects in support of their cargo operations. For such ships the installation of inline BWTS is more complicated in comparison to inTank.

Bulk carriers with isolated top side tanks

A large part of the bulk carrier fleet uses energy efficient top side gravity discharge tanks. Top side tanks are normally filled by fire- and general service pump main piping and not the ballast piping system, which complicates inline BWTS integration.

With the inTank solution the top side tanks are treated via a simple recirculation loop, using a section of the existing piping for suction to the dosing module whilst a new small diameter header is branched off for redelivery to each isolated top side tank. As the complete treatment cycle is performed and recorded by the system,

including neutralisation, the ships are flexible to ballast and gravity de-ballast as required without any interruption in Port.

Tankers with submerged ballast pumps

Tankers with submerged ballast pumps must install a large part of the BWTS on deck in a house enclosing for most inline system filters and neutralisation units. For high ballast dependent ships the overall deck space required and delivery pressure to the tanks are impacted. The only component the inTank solution requires in a deck house is the small recirculation dosing module.

Heavy-lifters, semi-submersibles and specialised offshore ships

Obviously for this type of ships ballast and deballast operations are crucial and in direct connection to their lifting

activities. InTank does not interrupt ballast flow during loading or offloading. In addition, ships at work may ballast and deballast local water as needed, as long as the inTank system treatment is completed before arrival at work site.

Barges and Pontoons

These assets normally are used for specific jobs. Installing a permanent BWTS is not a logical option. The inTank solution of treatment per tank provides flexibility for a fleet of barges -a containerised version can be used for several barges, at the time that treatment is necessary.



CONCLUSION

The purpose of this paper was to present risk factors introduced to the operations of high ballast dependent cargo ships because of the installation of in line BWTS.

In line systems treat water in Port and at intake of Port water. A fit-for-purpose alternative solution was introduced.

Treatment of ballast water whilst a ship is in transit effectively eliminates many of the associated risks related to in Port treatment, especially for high ballast dependent ships, such as cargo ships.



**For more
information
contact us!**



For Global contact:
+1 713 840 0404
info@eco-enviro.com
www.eco-enviro.com



For Europe contact:
+31 (0) 10 4363 188
info@marshipengineering.com
www.marshipengineering.com