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Review paper

Impact of the COVID–19 on Container Ships Efficiency

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Abstract: Coronavirus (COVID-19) has significantly slowed down the global economy, affecting global shipping and impacting all shipping sectors. COVID-19 slowdowns disrupt port operations and cause delays in planned schedules at major ports around the world. Around of 2,4 million TEUs (10 % of the Container fleet at the end of 2021) was waiting globally due to port´s congestion. Ship operators are facing increasing problems from biofouling, which occurs during idle periods. The considerable extent of hard fouling appears to be due to increasing idle time; COVID-19 shows the extent of unnecessarily increasing fuel consumption, emissions and speed losses due to increased hydrodynamic drag. Most antifouling paints are toxic and extremely harmful to the environment, and increasing idle time causes additional amounts of leached biocides in the port area. Ship operators are increasingly demanding antifouling paints that are suitable for specific ship routes as well as for the different activities of the ships. This paper focuses on the possibility of reviewing the impact of the COVID-19 crisis on the efficiency of container shipping. The authors emphasis the need for the use of a new environmentally friendly technology against biofouling, as container ship lay times increase significantly in the COVID-19 pandemic.

Keywords: COVID-19, Container shipping, Ship operators, Idle period, Antifouling coatings.

1. Introduction

The coronavirus (COVID-19) has significantly slacken not only the Chinese but also the global economy, affecting global shipping and impacting all shipping sectors. A noticeable fell in global real GDP by 3.6 %, the volume of global trade by 5.3 %, and foreign direct investment (FDI) by 42 % were recorded in 2020, in year which was declared the beginning of the COVID pandemic [1]. The ongoing coronavirus crisis escalated to unprecedented levels in Europe in March 2020, with severe health, human and economic impacts.

COVID-19 slowdowns in southern China are disrupting port operations and causing delays in planned schedules. This is causing massive delays at major Chinese ports and driving up the cost of shipping. According to analysts and representatives of the shipping industry, waiting times at berths have increased considerably. For example, waiting times for container ships at the Yantian International Container Terminal in Shenzhen have increased from an average of 0.5 days to 16 days [2].

Some regions of the world recovered from the pandemic in the last quarter of 2021, leading to a buying boom that caused a critical shortage of empty containers. This led to massive delays in shipping goods from China to all destinations, especially Europe and the US [3].

Container shipping slowed down considerably and container ships stayed longer at anchorages and ports. First it was COVID-19 slowdowns and a critical shortage of empty containers due to the pandemic. Then there was a massive blockage of the Suez Canal [4]. Ship operators faced increasing problems from biofouling that occurs during idle periods. More than 40 % of vessels were suffering from over 10 % hard fouling coverage on the underwater part of the hull even before the fleets were idled due to COVID-19 as per conducted [5]. The level of hard fouling could be responsible for at least 110 million tonnes of excess carbon emissions and an additional $ 6 billion a year in fuel costs for the global merchant fleet as per data taken from conducted study from 2011 [6]. Given the data on the increase in unused ships in 2021, it is reasonable to assume that the extent of fouling has increased significantly across the shipping industry. The significant extent of hard fouling appears to be due to the increase in idle time in the pandemic COVID-19. Hard fouling of underwater part of the ship has great impact on the unnecessary rise in fuel consumption, emissions and speed losses due to increased hydrodynamic drag.

The aim of this paper is to identify the possibility of reviewing the impact of the COVID-19 crisis on the efficiency of container shipping. The paper examines the impact of a pandemic on container ship lay times and the increasing problems caused by biofouling that occur during this time. Most antifouling paints are toxic and extremely harmful to the environment. Therefore, the authors emphasis the need to use a new environmentally friendly technology against biofouling to improve the efficiency of container shipping. In Section 2 is presented impact of the COVID-19 on the global economic, maritime trade and container shipping, while Section 3 analyzes the impact of the COVID-19 on port operations. Sections 4 and 5 describe the biofouling underwater part of ships due to ships idle and its consequences.

2. Impact of the COVID-19 on the Container Shipping

In today's economy, maritime trade plays an irreplaceable role, which is expressed in the amount of goods transported by sea - about 11 billion tonnes in recent years, which accounts for about 80 % of the global trade in goods [7]. Global trade in containers has grown by about 55 % in the last ten years, on average by about 5 % per year [8]. In the period under consideration, container trade accounted for 17 % of global maritime trade [9].

The coronavirus crisis has reached unprecedented proportions in Europe and has serious health, population and economic implications. The ongoing global outbreak of COVID-19 has affected shipping worldwide and it has had a significant impact on all types of shipping.

The global economic slowdown has had a negative impact on maritime trade flows in the first two quarters of 2020. Despite the economic slowdown caused by COVID-19, overall global trade held up relatively well in the last quarter of 2020 [10]. The positive trends from the last quarter of 2020 grew stronger in early 2021 and the value of global trade in goods and services grew by about 4 % quarter-over-quarter and by about 10 % year-over-year. Importantly, global trade in Q1 2021 was above pre-crisis levels, with an increase of about 3 per cent compared to Q1 2019. The recovery in trade in Q1 2021 was driven by the strong export performance of East Asian economies [10]. World trade in goods 2021 remained strong and trade in services finally returned to its pre-COVID-19 levels. According to a report issued by the World Trade Organization world trade in goods 2022 will be expanded for a 3.5 % [11]. In the 2021 the Global Shipping Container Market size was approximately 13,856.42 million USD. In the 2022, an increase of 2.7 % is expected [12]. The expected improvement in the supply chain did not happen during 2022, which is evident from the sailing schedules published by Container Carriers [13]. During 2022, pressure on the maritime transport market has been continued due to port congestion and strong global demand in the consumer goods sector. It is assumed that freight rates will not fall to pre-COVID levels [14].

Analyses of the impact of COVID-19 on the development of maritime transport can be carried out using ship calls at EU ports. The data is based on information on ship calls provided by Member States to Safe Sea Net for the years 2019, 2020 and 2021 [15].

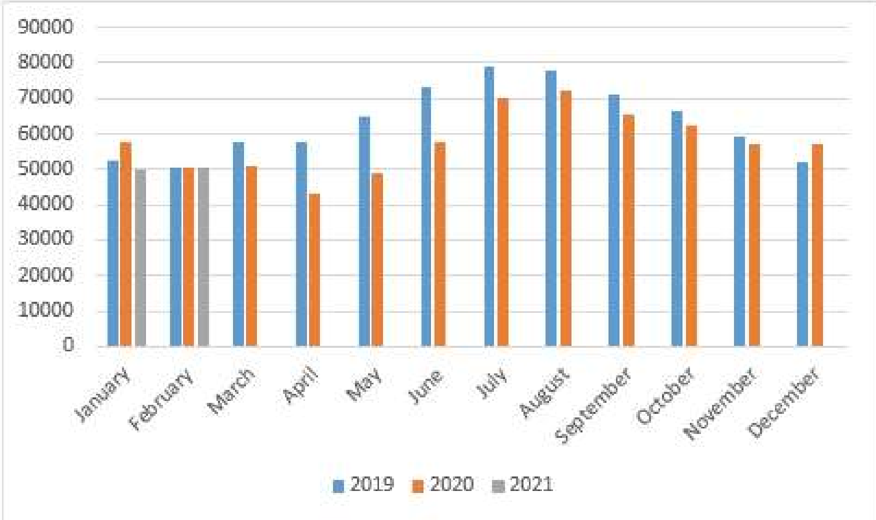

Fig. 1 – *Ships calls at EU ports in 2019, 2020, 2021 [15]*

The graph on Figure 1 shows the number of ship calls per month in 2019, 2020 and 2021. It was decided to use 2019 as a reference because it was the last year without COVID-19 in Europe. The trend of ship calls was negative and reflected in the maritime trade flows, especially in the second quarters of 2020. The positive trend was observed in the last quarter of 2020 and continues in the first quarter of 2021.

Cruise ships and passenger ships are the ship types where the greatest decrease in shipping traffic were observed [15]. During the same period (Figure 2), container ships were found to have experienced a 9 % decrease in shipping traffic.

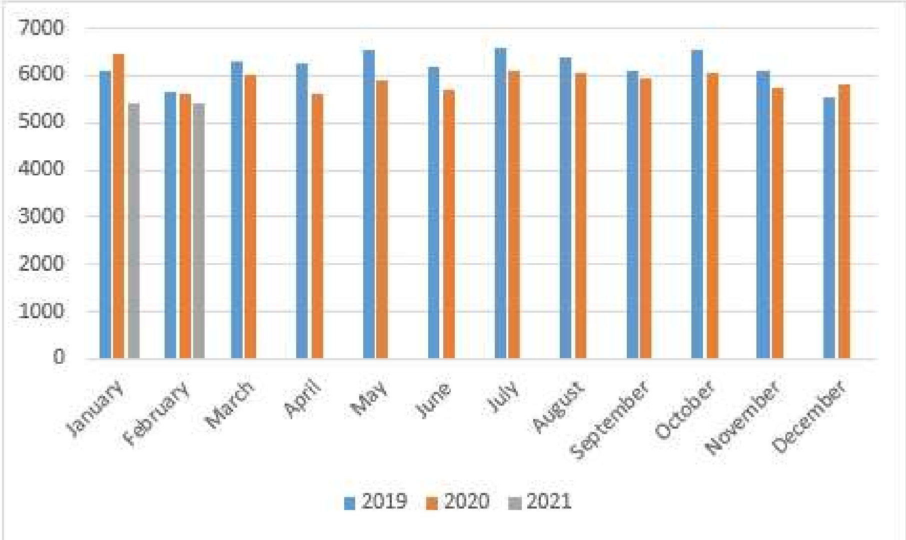

Fig. 2 –*Ship calls by container ships in EU ports (2019, 2020 and 2021) [15]*

The highest decreasing of container ship calls was happened in second quarter 2020. Container traffic was increased in last quarter booming global demand for COVID-19 related products. In the first quarter container traffic doesn′t reach expected vessel traffic due to congestion of main China′s, EU and USA ports.

3. Port′s Congestion due to pandemic COVID-19

Container ships were waiting in ports from Shenzhen to Los Angeles. The stoppage of ships was caused by storms, pandemics and a shortage of empty containers. A large number of container ships were waiting to be docked in ports around the world. At the beginning of 2021 port congestion was worsened by 14 % compared to the September same year [16]. Ships were arriving at the ports without interruption, which means there were no signs of improvement. An analysis carried out shows that a total of 427 container ships, with a capacity of 2,914,445 TEU, were on the roads of the world's ports.

The nearly 100 ships were waiting on the port area to dock at the container ports of Hong Kong and Shenzhen container ports indicate on problems whose disruption of global supply chains had led to shortages of goods in the US and Europe [17]. The container port in Long Beach, California, is one of the most congested container ports in the US. At the beginning of 2021 there were 67 ships waiting off Long Beach. The longest waiting vessel was idling for 22 days.

Asian ports were also affected by the pandemic COVID-19. A total of 74 ships anchored or drifted outside Ningbo/Zhoushan (306,538 TEU) [16]. An additional problem was a major shortage of container boxes in the export ports. Returning empty containers to be refilled with industrial goods also takes much longer than before the pandemic. The number of ships waiting at the ports were continue to increase, as many ships were still on their way to these places. For this reason, congestion was continuing for some time. It can be concluded that the problems in the considered period were arisen due to increased demand, closure of terminals, shortage of port workers, truck drivers, shortage of available empty containers and finally shortage of available container ships.

The ships also had to wait a long time in the European seaports. Even when ships do not have to wait for days at sea, there can be massive disruptions - as in the port of Rotterdam in the Netherlands, where a shortage of truck drivers or congested inland waterways slowed down the onward transport of cargo [17]. Figure 3 shows the ships that are idle in the world's major ports. Los Angeles is the least efficient major port as can be seen on Figure 3. Ships in the port area of LA were idle for an average of 6.5 days. Ships in Port Kelang and Tanjung Pelepas were the least idle, averaging 1.5 days [18].

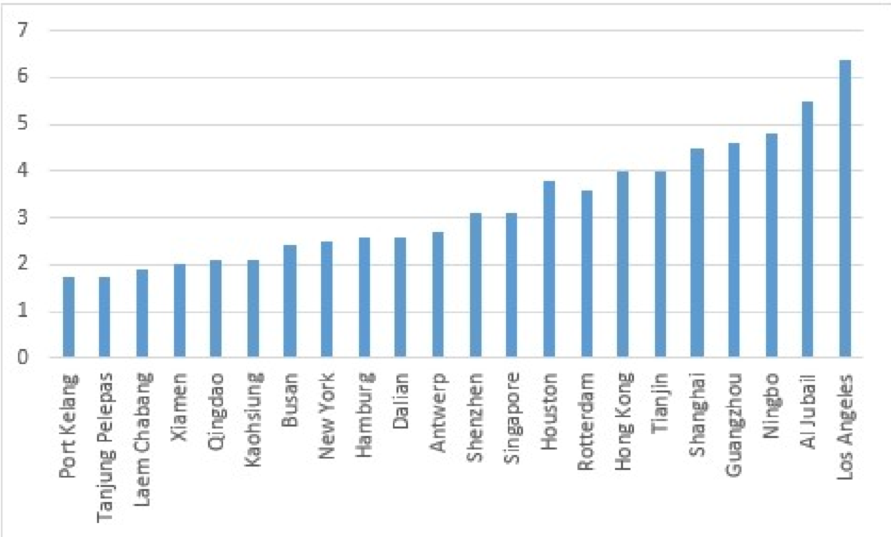

Fig. 3 – *Number of day ships remain in or near major world ports [19]*

The idle capacity of container ships reached a record high of 3 million TEU by the end of 2021. And it was the "worst capacity crisis the industry has ever seen," according to [20].

4. Biofouling Impact on Shipping Industry

Biofouling is one of the problems that has plagued the shipping industry from the beginning. A biofouled ship consumes more fuel to maintain the same speed through the water. This leads to higher fuel consumption. A heavy fouled ship's hull also has a significant impact on maintenance costs, resulting in higher vessel operating costs. Due to the current situation, which has a strong impact on ships idle, biofouling risk increases and hull cleaning is likely to be required more frequently. The fouling risk can vary depending on the location. This means that, if possible, a lower risk location can be chosen.

Underwater hull cleaning can also remove layers of antifouling paint, which shortens the life of the paint and increases maintenance costs. Hull cleaning is not cheap, each cleaning can cost between $ 15,000 and $ 45,000 depending on the size of the vessel [20].

The negative impact of biofouling on the hydrodynamic performance of the hull has significant financial and environmental consequences for the shipping industry. According to [21], approximately 9 % of total ship fuel consumption is due to the effects of biofouling. Based on this assumption, a container ship with a length of 400 m will theoretically consume about 250 tonnes of heavy fuel oil per day if the hull is clean. The same ship will consume another 22.5 tonnes per day if it is fouled. This would equate to an additional operating cost of about $ 11,000, assuming a heavy oil price of $ 500 per tonne. Assuming that liner container ships spend 85 % of the time in transit each year (310 days), this would represent an additional expenditure of $ 3,410,000.

Research in the field of underwater protection of ship hulls has shown that ships idling for 14 days or more are highly exposed to the risk of barnacle growth. The risk and also the extent of biofouling increases in warm waters, especially when water temperatures exceed 25 degrees. This type of fouling can have a significant impact on the performance of the vessel.

Most antifouling paints protect the underwater hulls between 14 and 21 days at idle. Premium grade antifouling paints guarantee up to 30 days of no-use protection, and few offer more than 30 days of no-use guarantee. However, in difficult market conditions, such as during the current COVID-19 pandemic, it has been demonstrated in conducted research that it is not uncommon for a vessel to be idle for longer than 30 days and in some cases even longer than 45 days. Long idle periods are a challenge for foul-release and biocidal coatings. For these types of coatings, the idling guarantee is 14-21 days in most cases [20].

The shipping industry is essential to the global economy, but it is also a major contributor to global air pollution. Around 80 % of the world's goods are transported by ships, and compared to other modes of transport, shipping is the most energy-efficient way to move large amounts of cargo [10].

In general, two main methods are used to determine emissions from the shipping industry: a bottom-up and a top-down method. The top-down method determines total emissions without considering the characteristics of individual ships. This method is based on data on the total amount of marine fuel sold and the specific fuel emission factor [22]. The bottom-up method is based on pollution data from a single ship at a specific location. This method takes into consideration all the ship particulars important for air pollution and ship condition data.

Emissions estimation from fossil fuel combustion in navigation was provided by the Intergovernmental Panel on Climate Change (IPCC) Guidelines. According to [8] basic equation is:

$$Emissions = \Sigma\ (Fuel\ Consumed\ ab * \ Emission\ Factor\ ab) \quad (1)$$

Where:

a - fuel type (diesel, gasoline, LPG, heavy oil, etc.),

b - water-borne navigation type (i.e. ship or boat, and possibly engine type).

Biofouling has the greatest impact on a vessel's performance in navigation so it will be discussed below. The propulsion system of most ships consists of one or two main engines (rarely more) and two or more auxiliary engines connected to a generator. The emissions for a ship in navigation with steaming speed for the aforementioned machinery are expressed as follows [22]:

$$Em(steam) = \frac{D}{V(steam)} * (P_{ME} * L_{ME} * EF_{Steam} \ + P_{Ax} \ * L_{Ax} * EF_{Ax} \quad (2)$$

Where:

P_{ME} - main engine power (kW),

P_{Ax} - power (kW) of auxiliary engines driving the generators,

v - ship's average speed (steaming or manoeuvring (km/h),

D - distance passed with steaming speed (km),

L_{ME} - main engine load factor (%),

L_{Ax} - the load factor of auxiliary engines driving the generators during steaming (%),

EF_{Steam} - main engine emission factor in steaming (g/kWh),

EF_{Ax} - emission factor of engines driving the generators in steaming (g/kWh).

The load factor of the engine plays an important role in the emissions of a ship. The load factor can be defined as the percentage of the current load in relation to the maximum power of the main and auxiliary engines. Normally, ships sail with a load factor of the main engine between 75 % and 90 % [22]. Research by the IMO has shown that 9 % of the total fuel consumption of ships is due to the effects of biofouling. To achieve the same speed, a fouled ship increases the load factor of the main engine. As can be seen from expression 2, the load factor has a direct effect on emissions. Fouling has no influence on the load factor of the auxiliary engines.

The air quality in the port area and the surrounding area may deteriorate due to air pollution from idle vessels. This type of pollution is directly related to the number of ships at anchor and the power of their auxiliary engines. The load factor of the auxiliary engines depends on the type of vessel and the activity, assuming that the auxiliary engines are always in operation. The emissions for an anchored vessel are expressed as follows:

$$Em\,(anchoring) = tm_{anchoring} * (P_{Ax} * L_{Ax} * EF_{Ax}) \qquad (3)$$

Where:

P_{Ax} - power (kW) of auxiliary engines driving the generators,

L_{Ax} - the load factor of auxiliary engines driving the generators for anchored ship (%),

EF_{Ax} - emission factor of engines driving the generators for anchored ship (g/kWh).

It can be assumed that the ship at anchor has a lower demand for electricity than when steaming or manoeuvring. The load factors of auxiliary engines for anchored vessels are approximately the same as for moored vessels. The values for the load factor depend on the type of ship and range from 17 % for a container ship to 80 % for a passenger ship [23].

5. Anti-fouling Coating Impact on Marine Environment and Alternative Methods for Environmentally-save Fouling Control

Fouling is the growth and settlement of various biological species on underwater surfaces such as ship hulls, piers and other underwater structures. It starts with the settlement of microscopic animal larvae or weeds. These form an adhesive surface to which larger organisms can later attach. In seawater, these include barnacles, algae, mussels and hydroids [24]. When an artificial structure is placed in seawater, fouling very soon occurs and plant and animal species begin to cause serious technical and economic problems [25].

The International Maritime Organization (IMO) uses the term 'antifouling system', which is defined as 'a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent the attachment of unwanted organisms' [26]. During the Second World War, copper-based synthetic paints became the most popular. In the late 1950s, a coating containing tributyltin (TBT) came into use. While this seems ideal, environmental studies provided evidence that organotin compounds from TBT coatings remain in the water and sediments, killing marine life and potentially entering the food chain. For this reason, tin-based antifouling paints were banned worldwide by the International Maritime Organization (IMO). In 2003, the International Convention on the Control of Harmful Anti-Fouling Systems on Ships entered into force. The Convention stipulates that all ships shall not apply or reapply organotin compounds in antifouling systems.

After the use of TBT compounds was banned, various methods were tested to find an effective substitute. Currently, the development of commercial AF coatings is generally based on following main types:

– non-biocide coatings,

– gradual biocide release coatings, and

– non-biocide-release based AF coatings.

Biocidal antifouling coatings generally contain slow-release toxic substances. Biocide-based AF coatings work on the same principle as TBT-based systems, but contain a different type of toxic component. The most common biocidal antifouling coatings are copper and zinc-based compounds [27]. Currently, there are three main biocidal antifouling technologies:

– Controlled Depletion Polymer soluble coatings (CDP),

– Self-polishing Copolymer (SPC),

– coatings with contact release of biocides.

CDP technology works by allowing water to penetrate the paint film, while dissolved rosin and biocides seep into the sea. The self-polishing copolymers react with the seawater, resulting in thinner leached coatings with excellent biocide release control. The reaction continues with the film becoming thinner as it is polished with seawater.

Non-biocide release-based AF coatings generally can be divided into two main types according to their mechanism of action: 'detachment of biofouling' and 'prevention of attachment' of biofouling. The 'prevention of attachment' strategy aims to prevent settlement, while the 'detachment of biofoulants' aims to reduce the adhesion force as much as possible to efficiently remove the settled organisms [28].

Silicone compounds are biocide-free coatings. When applied to the surface of the hull, they form a smooth and slippery surface that reduces surface energy, thus deterring organisms from initially attaching. Their disadvantages are resistance to physical wear and mechanical contact, higher price and the reasonable speed required for the coating to be effective. A novel alternative that shows competitive results for similar tasks is ceramic enamel coatings, which have excellent chemical and abrasion resistance. This type of antifouling coating minimises the adhesion of biofilms to the surface.

Some innovative techniques that may be used in the future to prevent biofouling are antifouling systems inspired by floating seeds and special molecules of bacteria.

The availability of more data on the risks of biofouling and the effectiveness of coatings could lead to a method for including the choice of coating in the calculations for the new measures. In the review of the two systems planned for 2026, there is a possibility that antifouling measures will become a factor to be included in the regulations.

The data on the ship's performance is regularly analyzed by Shipowners. If the underwater part of hull is fouled, it will be cleaned in dry dock or by the drivers using special equipment. The condition of the hull can be monitored regularly by divers.

Ship operators require antifouling systems that not only protect against all types of fouling, but are also suitable for specific trade routes and different ship activities (steaming, anchoring and mooring). Ships that are laid up for any reason are naturally at higher risk of fouling by marine organisms. Modern antifouling systems should ensure that the vessel is protected whether it is in constant operation or at rest for extended periods.

Researchers have made progress in this field. It needs to be found a suitable model for risk prediction of fouling of the ship's hull. Also environmentally friendly marine antifouling systems suitable for protect against all types of fouling specific trade routes and different ship activities should be developed.

6. Conclusion

The COVID-19 pandemic has had a major impact on global shipping markets, having a ripple effect on global shipping. The ongoing coronavirus crisis has serious health, human and economic implications. It has had a major negative impact on global supply chains and international trade. According to analysts and stakeholders in the shipping industry, idle times have increased significantly. In addition, 2021 saw massive delays in shipping goods from China in all directions, especially to Europe and the US, as the buying boom led to a critical shortage of empty containers.

Container ships were staying longer at anchor and in ports, and container shipping was slowed significantly due to COVID-19 and the critical shortage of empty containers. Ship operators were faced with increasing idle time in the considered period, leading to a significant increase in pollution across the shipping industry.

Maritime trade plays an important role in the global economy, transporting around 11 billion tonnes in recent years. Global container trade has seen annual growth of around 5 % over the last decade.

The spreading coronavirus is having a serious impact on health, people and the economy, and it is affecting global shipping. Economic cycles have had a direct impact on demand in maritime trade. Maritime trade flows were negative globally in the first two quarters of 2020 due to the economic downturn. In the 2021, global trade recovered and returned to its pre-crisis levels. In the 2022 it will be expanded for 3,5 %. The negative trend in maritime trade was reflected in a lower number of ship calls, especially in the second quarters of 2020. A positive trend was observed in the last quarter of 2020 and during 2021, which is continuing in 2022 (an increase of 2.7 % is expected).

Container ships were waiting in ports from Shenzhen to Los Angeles due to storms, pandemics and lack of empty containers. A total of 427 container ships, equivalent to a capacity of 2,914,445 TEUs, are currently lying idle in ports around the world, according to an analysis conducted by Vessels Value. Due to port´s congestion around 2,4 million TEUs was waiting globally at the end of 2021. The situation where ships are idle increases the risk of biofouling and hull cleaning is likely to be required more frequently. A heavily fouled hull has a significant impact on maintenance costs and engine consumption, resulting in higher operating costs for the ship and significant financial and environmental implications for the shipping industry. More fuel burnt due to fouling also leads to higher air pollution.

Hull fouling protection is the protection of the hull from fouling by the application of a protective coating or other antifouling protection system.

Antifouling systems can generally be divided into antifouling systems containing biocides that seep through the paint and create a toxic environment, and systems that create a surface that marine organisms cannot attach to when vessels are in motion.

Most antifouling paints are toxic and extremely harmful to the environment. Research in the paint industry is trying to find antifouling ingredients for their paints that will leave both the ships and the marine ecosystem unharmed. Some innovative techniques that may be used in the future to prevent biofouling are antifouling systems inspired by nature, but more research is needed to use them effectively on a ship's hull.

Ship owners and operators need to take the next step in prevention when considering the antifouling components of the paints on offer and potential downtime. The paints offered should meet the requirements and protect their vessel from hard fouling during unforeseen long downtimes.

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