PROPOSED AMENDMENTS IN SOLAS AND MARPOL CONVENTIONS TO LIMIT VOC EMISSION FROM OIL TANKER LOADING AND SHIP BUNKERING OPERATIONS

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SUMMARY

Exhaust gas emissions are regulated at international and national levels, but venting vapours from oil tanks is a cause of concern due to a lack of regulatory control. Oil tanker loading operations and ship bunkering operation results in a considerable amount of 'Volatile Organic Compound' (VOC) in the surrounding environment. The presence of toxic components in this VOC emission has the potential to affect the health of seafarers as well as local air quality. Numerous tankers engaged in loading operations within the same port has a solid potential to increase the toxic emission to a dangerous level locally. Loading ports near highly populated areas expose the local population to toxic VOC concentration. A few ports in Europe, the USA and South Korea have strict local environmental rules prohibiting VOC emission from oil tanker loading operations. There is a need for international and national regulations to limit or stop the release of VOCs from oil tankers and monitor VOC exposure risks at the local level. The research objective is to analyse the current status of international and national rules and regulations related to VOC emission and monitoring VOC exposure risks during loading operations in an oil tanker and ship bunkering operations. Existing international (SOLAS and MARPOL Conventions) and national regulations (EU, USA, Norway) are described and analysed regarding the contemporary tanker design and standard tanker operating practice. A critical analysis determines the effectiveness and adequacy of the current regulations and tanker industry working practices. Finally, amendments to existing international conventions are proposed to minimise or stop the VOC emission and monitor VOC exposure risks to seafarers and the surrounding population near tanker terminals and ports. Solutions are also proposed to amend the existing tanker design and operating practices to stop the VOC emission, including toxic hazard assessment in vapour vent design and prevent exposure to VOC emission.

KEYWORDS

Carbon emission, Toxic Hazard Assessment, Venting of oil vapours, VOC emission

NOMENCLATURE

BAT	Best Available Techniques
CAA	Clean Air Act
CFD	Computational Fluid Dynamics
CII	Carbon Intensity Indicator
CVE	Crude oil Vapour Emission
CVOC	Direct absorption of VOC in the crude oil
EEA	European Environmental Agency
ELSA	Emergency Life Support Apparatus
EPA	United States Environmental Pollution Agency
EU	European Union
HAP	Hazardous Air Pollutant
IAPH	International Association of Ports and Harbour
ICS	International Chamber of Shipping
IMO	International Maritime Organisation
ISGOTT	International Safety Guidelines for Oil Tankers and Terminals
MARPOL	International Convention for the Prevention of Pollution from Ships
KLIM	Norwegian Climate and Pollution Agency
KVOC	Cargo pipeline partial pressure control system
LRTAP	Convention on Long-Range Transboundary Air Pollution
MACT	Maximum Achievable Control Technology
MEPC	Maritime Environment Protection Committee
MSC	Maritime Safety Committee
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standard
NEA	Norwegian Environment Agency
NESHAP	National Emission Standards for Hazardous Air Pollutants
NMVOC	Non-methane Volatile Organic Compounds
OCIMF	Oil Companies International Marine Forum
OVE	Oil Vapour Emission
PGM	Personal Gas Monitor
PPE	Personal Protective Equipment
P-V	Pressure-Vacuum
RACT	Reasonably Available Control Technology
SEEMP	Shipboard Energy Efficiency Management Plan

SIRE	Ship Inspection Report programme
SOLAS	Convention on Safety of Life at Sea
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
UNO	United Nations Organization
VOC	Volatile Organic Compounds
VOCMP	VOC Management Plan
VOCON	VOC control
VOCTHA	VOC Toxicity Hazard Assessment

1. INTRODUCTION

Recent studies have shown that large volumes of Volatile Organic Compounds (VOCs) are emitted into the surrounding air during marine oil tanker loading operations.(DeLuchi, 1993; Hansen *et al.*, 2008; Lee *et al.*, 2013; Tamaddoni *et al.*, 2014; Deligiannis *et al.*, 2016; Todd, 2016; Habiba *et al.*, 2017; Fetisov *et al.*, 2020; Hu *et al.*, 2020; Rajabi *et al.*, 2020). The resulting VOC emission is not only detrimental to local air quality but also affects the health of seafarers and marine personnel due to the presence of toxic components in this VOC emission (Paulauskiene *et al.*, 2009; Claxton, 2014; Mihajlović *et al.*, 2016; Milazzo *et al.*, 2017; Polvara *et al.*, 2021). To date, there are no regulations in international conventions such as SOLAS and MARPOL to limit or stop VOC emissions from oil tanker loading and ship bunkering operations to safeguard the health of seafarers and preserve air quality. Various regulations related to VOC emission from loading operations in oil tankers can be classified as international regulations, national regulations, and tanker industry-specific practices. The international regulations about tankers are covered under 'International Maritime Organization' (IMO) conventions such as 'Safety of Life at Sea' (SOLAS) and 'Prevention of Pollution from Ships' (MARPOL). The regional and national regulations related to tankers can be regional and local conventions and Acts such as the 'Long-Range Transboundary Air Pollution' (LRTAP) convention under 'United Nations Economic Commission for Europe' (UNECE) and 'Clean Air Act' (CAA) in the USA. The tanker industry-specific practices are related mainly due to commercial considerations to seek tanker business, such as 'Oil Companies International Marine Forum' (OCIMF) led 'Ship Inspection Report Programme' (SIRE) inspections and following industry best practices under 'International Safety Guide for Oil Tankers and Terminals' (ISGOTT) and the guidelines developed by the trade association such as 'International Association of Independent Tanker Owners' (Intertanko). The objective of the paper is to analyse the current status of international and national rules and regulations related to the VOC and hence carbon emission during oil tanker loading and ship bunkering operations and propose amendments in SOLAS and MARPOL conventions to minimise or stop VOC exposure to seafarers and preserve air quality during these operations.

The subsequent section provides a literature review of regulations related to VOC emission in international conventions such as SOLAS and MARPOL, national and regional regulations in the U.S.A, the E.U., and Norway. Discussion and the amendments proposed for the regulations in SOLAS and MARPOL convention are presented, followed by the conclusion.

2. LITERATURE REVIEW OF CURRENT REGULATIONS

2.1 INTERNATIONAL REGULATIONS

IMO is a specialised 'United Nations Organization' (UNO) agency to promote safe, secure, environmentally sound, efficient, and sustainable shipping through cooperation. IMO is improving safety at sea by developing international regulations that are followed by various treaties and conventions between different nations (IMO, 2020). The main conventions related to the design and operations of oil tankers are SOLAS and MARPOL conventions. SOLAS and MARPOL conventions are described and analysed as per the objective of the current study to assess the effectiveness of existing regulations regarding VOC and hence carbon emissions from oil tankers and bunkering operations.

2.1 (a) SOLAS Convention

The primary objective of the SOLAS convention is to specify the minimum standards for the ships' construction, equipment, and operations, compatible with safety. Safety onboard is understood to save the ship, human health, and the environment. The analysis of the SOLAS regulations related to the current study indicates that the regulations focus primarily on safety, less on the environment, and the least on health aspects of ship operations.

None of the regulations in SOLAS mentions the risk of inhaling oil vapours and its associated toxicity hazard of the carriage of oil as cargo or as fuel. As the current objective is to analyse the rules related to the carriage of oil and use of oil as fuel, it is observed that all the regulations associated with the design of ships and oil tankers address the flammability hazard of the oil, e.g., SOLAS Ch II-2 entirely deals with fire protection, fire detection and fire extinction issues. Ch II-2 Regulation 4.5.7, Gas measurement and detection, also details the carriage requirement to contain the flammability hazard of oil cargo.

A typical oil tanker loading, and ship bunkering operation involve either controlled or free vapour venting to the atmosphere and monitoring the oil level in the cargo or bunker tank using an ullage or sounding pipe. Vapour Vents and Sounding Pipes are generally located close to each other. Hence, seafarers onboard monitoring tank filling levels manually are regularly exposed to VOC emissions from the tank vapour vents. These vapour vents discharge freely to the surrounding air from the main deck. Current SOLAS regulations for cargo and bunker tank designs have no minimum safe distance requirement between air vents and the ullage or sounding pipe to prevent seafarers' inhalation of oil vapours. 'Ch II-2' 'Regulation 4.5.3' has detailed requirements for cargo tank venting, but the basis is only to address the flammability hazard(SOLAS, 2023).

SOLAS Chapter VI, 'Carriage of cargoes', 'Regulation 3' deals with the carriage of Oxygen analysis and gas detection equipment to be carried when transporting bulk cargo. The regulation is applicable for the cargo liable to emit toxic or flammable gas; the regulation is not applicable for the carriage of liquids in bulk. This means that the regulations are for bulk solid cargoes and not for the carriage of oil as cargo.

Tanker loading and ship bunkering operations emit flammable and toxic vapours during loading and bunkering operations and in transit. There are no regulations to check the presence of VOCs, including toxic gases when oil vapours are vented during the routine loading in oil tankers and ship bunkering operations. Further, Chapter VI, 'Carriage of Cargoes and Oil Fuels', 'Regulation 3', 'Oxygen analysis and Gas detection equipment', requires ships carrying solid bulk cargo to have an appropriate instrument for measuring the concentration of gas or oxygen in the air when carrying cargo which is liable to emit toxic or flammable gas.

'Regulation 5-1' of this 'Chapter VI' only mentions the ships to be supplied with appropriate 'Material Safety Data Sheet' for oil as cargo or oil as fuel before loading such cargoes. Though the regulation does not state the purpose of the requirement, a detailed analysis of the related IMO MSC (Maritime Safety Committee) Resolution states the purpose as recognising the importance of providing seafarers with clear, concise, and accurate information on the health and the environmental effects of toxic substances carried on board tankers (MSC.286(86), 2009). It has been reported in various research papers about the toxic components in vapours emitted from crude oil and gasoline (Hansen *et al.*, 2008; Claxton, 2014; Milazzo *et al.*, 2017; Rajabi *et al.*, 2020; Virdi *et al.*, 2021). There is no regulation in SOLAS prohibiting or limiting VOC emission during loading operations in oil tankers or any bunkering operations. Moreover, this regulation does not specify any reason for the mandatory carriage of MSDS, unlike SOLAS 'Chapter VI Regulation 5', which defines the basis for compliance as cargo carriage is liable to emit toxic or flammable gas.

A similar inhalation risk is present in oil cargo and bunker fuels, but there is no regulation for such requirements during their handling. The mandatory carriage of MSDS does not ensure that the ship operator will necessarily provide additional safeguards to protect the health of seafarers from toxic vapour exposure. There is a clear gap in connecting the carriage of MSDS with the provision of personal gas measuring instruments in SOLAS regulations.

SOLAS Chapter XI-1 'Special measures to enhance maritime safety' mandate that all ships carry an appropriate portable atmosphere testing instrument, with a minimum capability of measuring oxygen concentrations, flammable gases or vapours, and hydrogen sulphide and carbon monoxide before entry into enclosed spaces (SOLAS, 2023). No such instrument is specified for oil loading or bunkering operations, which pose oil vapour inhalation risks.

Another regulation in SOLAS which addresses any health-related aspect of seafarers is the guidelines for controlling the noise from ship machinery, commonly referred to as 'The Noise Code', under 'Chapter II-1', 'Regulation 3-12' (SOLAS, 2023). The 'Noise Code' issuance under SOLAS mentions that high noise levels on board ships could affect seafarers' health and impair the ship's safety (MSC.337(91), 2012). No health issue in any regulation has been documented for handling oil as cargo or fuel.

From the above analysis, it can be deduced that only two regulations deal with the protection of the health of seafarers, one related to noise and one about MSDS, to inform about the toxicity hazard of oil. No regulations expressly acknowledge the inhalation risk and associated toxicity hazard from oil as liquid and the resulting oil vapour emission (OVE) when tanks are filled up, e.g., oil tanker loading operations or ship bunkering operations.

It can be concluded from the above analyses that the inhalation risk and toxicity hazard of OVE needs to be included in the SOLAS regulations related to the ship design; in the same way, the flammability hazard is addressed in various regulations in the SOLAS convention.

2.1 (b) MARPOL Convention

Regulations covering the various sources of ship-generated pollution are contained in the six annexes of the MARPOL convention. The regulations related to the prevention of air pollution, contained in Annex VI of the MARPOL, are the latest addition to this

convention, which entered into force on 19th May 2005. As vapour emission from oil loading operations and ship bunkering contributes to air pollution, the related regulations are discussed in MARPOL Annex VI. MARPOL Annex VI 'Regulations for preventing air pollution from ships' 'Regulation 15' 'Volatile Organic Compounds' (VOCs)' provides detailed guidance and requirements for regulating VOC emission from tankers. The current text leaves the decision to control VOC emission on individual tanker terminals per applicable local rules where the port or terminal is situated.

The countries ratifying the convention must report to IMO where such VOC regulations are being imposed (MEPC.509, 2006). Currently, South Korea and the Netherlands are the only countries worldwide that have officially notified IMO about the list of ports and terminals where VOC regulation is in force (GISIS, 2020).

As per Regulation 15.6, every crude oil tanker shall have and implement a 'VOC Management Plan', which is approved by the administration, taking into account the relevant IMO guidelines (MEPC.1/Circ.680, 2009; MEPC.185(59), 2009; MEPC.1/Circ.719, 2010). There is no requirement to control VOC emissions as per this regulation. The analysis of MEPC guidelines leaves the decision with the ship operator about the scope of minimising or stopping the VOC emission by optimising operational procedures or providing devices to prevent VOC emission.

Cargo onboard clean petroleum tankers are more readily prone to evaporation and can introduce more toxic VOCs into the environment. Still, there is no regulation to include such clean petroleum tankers to have any VOC Management plan. Moreover, Regulation 15.6 does not apply to tankers carrying clean oil products such as Gasoline, Kerosene, and Naphtha and does not cover VOC emissions during ship bunkering operations.

During oil tanker loading operations, any excess pressure above the safe pressure limit of a cargo tank is vented to the atmosphere via approved venting devices such as 'Mast Risers' or 'P-V Valves'. Oil tankers carrying clean petroleum products vent the cargo vapours freely from P-V Valves. There is considerable VOC volume released in the environment during this venting as this emission may contain 30 – 60% hydrocarbons, especially when the tank level is between 50% to being full, as shown in Figure 1 (MEPC.1/Circ.680, 2009).

The literature review of various approved 'VOC Management Plans' (VOCMP, 1999; VOCMP, 2010; VOCMP, 2015) for different crude oil tankers concludes that crude oil tankers usually maintain 108 to 110 kPa tank pressure in their cargo tanks during loading operations.

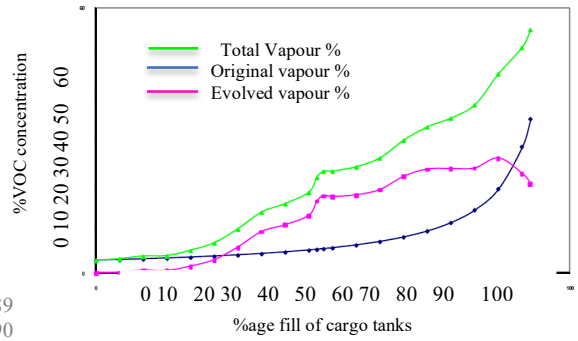

Figure 1: Hydrocarbon vapour concentration in the vapour phase during the loading operation (MEPC.1/Circ.680, 2009)

Any excess tank pressure is released into the atmosphere during loading operations via the 'Mast Riser'.

This current tanker loading and bunkering practice keep introducing VOCs into the surrounding environment, leading to local air pollution and exposing the ship personnel to toxic VOCs. There is an urgent need to limit or stop such OVE, contributing to continued VOC emissions daily in petroleum exporting terminals and bunkering locations worldwide.

MARPOL' Annex VI' 'Regulation 26' requires ships to have a specific 'Ship Energy Efficiency Management Plan' (SEEMP) (MARPOL, 2023; MEPC.328(76), 2023). This plan is developed as per IMO guidelines (MSC.282(70), 2016). SEEMP aims to have a ship management plan for improving energy efficiency, guidance on best practices for fuel-efficient operations, collect fuel oil consumption data and calculate direct CO_2 emissions due to ship operations. The factors to optimise efficiency include optimum use of ship machinery, propeller and hull cleaning, cargo and fuel heating, draft and trim optimisation, weather routeing and speed optimisation. The standardised data reporting format for CO_2 emissions focuses only on fuel oil consumption, as shown in Table 1. The guidelines do not provide any reference for VOC emissions from oil loading and ship bunkering operations, which also contribute to CO_2 emissions.

Table 1. Portion of the standardised data reporting as per SEEMP guidelines by IMO (MSC.282(70), 2016)

Method used to measure fuel oil consumption	Fuel Consumption (t)							Hours underway	Distance travelled	Power output (rated power) (kW)	
	Ethanol	Methanol	LNG	LPG	HFO	LFO	Diesel /Gas Oil	(h)	(nm)	Auxiliary Engine	Main Propulsion Power

The above analysis concludes that the current MARPOL regulations in 'Annex VI' focus mainly on

preventing air pollution due to exhaust gas emissions and monitoring energy efficiency through ship manoeuvring and fuel oil consumption. 'Regulation 15' of 'Annex VI' requires an amendment to restrict such VOC emissions and include all oil tankers, not only crude oil tankers. Also, there should be mandatory provisions to minimise or stop VOC emissions by ship operations, not on the oil terminal or ship operator's choice.

2.2 NATIONAL AND REGIONAL REGULATIONS

Only a few nations worldwide have adopted air quality laws in their respective countries based on their national pollution levels. Examples include 'Clean Air Act' in the USA in 1963, and 'LRTAP Convention' under 'UNECE' in 1979, and the reduction in VOC emission in Norway under 'The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone' (Hansen *et al.*, 2008; UNECE, 2015; EPA, 2020a).

The current review indicates that national regulations in the USA and Norway and regional regulations in Europe have been the main drivers for adopting measures to regulate VOC emissions from tankers.

2.2 (a) Regulations in the USA.

Federal laws in the USA are enforced through the 'Clean Air Act' (CAA), which has regulated air emissions from stationary and mobile sources since 1963 to control air pollution at the national level. 'Section 112' of the CAA addresses emissions of hazardous air pollutants (HAP), such as emissions from tanker terminals. The 1990 amendment of the act set new goals for achieving 'National Ambient Air Quality Standards' (NAAQS), established by the 'Environmental Pollution Agency' (EPA). The amendment requires the issuance of technology-based standards for 'Major Sources', defined as a stationary source or a group of stationary sources that emit or have the potential to emit 10 tons per year or more of a HAP or 25 tons per year or more of a combination of HAPs. HAPs are defined in federal regulations (EPA, 2020c).

'Title 40 Part 63' of 'Federal Regulations' provides regulations for 'National Emission Standards for Hazardous Air Pollutants for source categories (NESHAP)', which covers marine loading terminals. Oil terminals loading tankers and barges fall under the stationary source category. 'Subpart Y' of this section provides detailed requirements of vapour emission controls from marine loading terminals under the heading 'National Emission Standards for Marine Tank Vessel Loading Operations'. The details include the applicability of the rules, definitions, vapour emission control standards, compliance and performance testing, monitoring, recordkeeping, and implementation of standards for marine tank vessel loading operations (USA, 2020).

The standards define two methods to control vapour emission, 'Maximum Achievable Control Technology' (MACT) and 'Reasonably Available Control Technology' (RACT), for all products (including gasoline and crude oil) at marine loading terminals, except for products having vapour pressure less than 10 kilopascals (kPa) at 20°C and 760-mm Hg.

The regulation requires each marine terminal to have the following:

i. annual emission of 10 tons or more of each individual HAP (Hazardous Air Pollutants) or 25 tons of all HAP combined, following 'MACT' standard, or
ii. annual throughput of 10 million barrels of gasoline or 200 million barrels of crude oil loading operations follows the 'RACT' standard.

For the 'MACT' standard, the system should be designed to collect VOC vapours displaced from marine tank vessels during loading and prevent their venting into the atmosphere.

For 'RACT' standards, the terminal shall reduce captured VOC emissions from marine tank vessel loading operation by 98 weight-percent when using a combustion device or reduce captured VOC emissions by 95 weight-percent when utilising a recovery device (USA, 2020). Alternatively, the terminal can meet the requirement by reducing gasoline loading emissions to, at most, 1,000 ppm_v outlet VOC concentration. As per federal regulations, the terminals cannot operate if vapour collection or control devices are not fitted (USA, 2020).

The analysis of the above regulations in oil terminals in the USA concludes the following:

i. There are detailed specific federal regulations to limit VOC emission from tanker loading operations at tanker terminals,
ii. The rules specify various standards to follow to regulate VOC emissions from shore terminals, and
iii. The standards also broadly specify available technological solutions to regulate VOC emission.
iv. The federal rules in the USA may be used as guidelines by IMO member states to regulate VOC emissions.
v. Current standards in federal regulations do not cover ship bunkering operations.

2.2 (b) Regulations in EU.

The 'Long-range Trans Boundary Pollution' (LRTAP) convention guides air pollution control in the European Union (EU). Under the European Parliament, various directives are issued to advise the EU members on their implementation of obligations under the LRTAP Convention. The EU community was instructed to work closely for revisions in the MARPOL Convention 1996 (EU, 1994). EU Directive 94/63/EC on the control of VOC emission resulting from the storage of petrol and its distribution from terminals to service stations declares that the VOC emission during the loading of ships must be drawn at IMO level for vapour control and recovery systems to apply to both loading installations and ships, on the grounds of international standardisation and of safety during the loading of ships. The Directive applies to vehicles such as road and rail tankers and inland waterway vessels transferring petrol from one terminal to another. It explicitly excludes the loading of the ships (tanker loading operation). There is no mention of air pollution due to ship bunkering operations.

Article 9, 'Monitoring and Reporting' of the Directive, invited the European Commission to look at extending the scope to include vapour control and recovery systems for loading installations and ships. A study was conducted in 2001 to support this obligation. The study aimed to identify and assess the cost and effectiveness of measures to reduce VOC emissions from loading and unloading ships' tanks in the EU (AEAT, 2001). The report analysed the VOC emission from crude oil tankers in Europe. It concluded that the impact on ozone in ambient air be assessed first before proceeding with measures for their abatement, as most loading operations occur in the North Sea. The study conducted in 2001 remains current as per the EEA report published in 2019 (EEA, 2019). As per this report, the local air quality issues in Gothenburg oil harbour have resulted in using vapour emission control systems in ship loading operations. It was concluded that the emissions resulting from the ship-loading of gasoline and crude oil in the EU represent 0.07% and 0.8%, respectively, of all VOCs emitted annually in the EU, and it would not be cost-effective for the relative gains obtained.

The following conclusions are drawn from the above analysis:

i. The current deciding factor for regulating VOC emission in the EU is still based on the study conducted in 2001.
ii. VOC emission from tanker loading operations is a tiny percentage of total VOC emission in the EU, leading to cost ineffectiveness.
iii. Major tanker loading operations emissions are in the North Sea, away from any populated area.
iv. Gothenburg oil harbour has regulated VOC emission as a local rule to protect the surrounding population from the toxic effect of VOCs.

2.2 (c) Norwegian regulations

'Norwegian Environment Agency' (NEA), a government agency under the 'Ministry of Climate and Environment,' implements and advises on developing climate and environmental policy and exercises regulatory authority (NEA, 2020). In 2002, the 'Norwegian Climate and Pollution Agency' (KLIM) imposed regulations on oil companies to reduce the overall emissions from offshore loading by 30% in 2003, increasing to 70% in 2006 (Hansen *et al.*, 2008).

The primary sources of NMVOC emissions in Norway are the storage and loading of crude oil in offshore areas. Emissions from the petroleum sector are directly regulated through requirements on using the 'Best Available Techniques' (BAT) and specific emission limits in permits under the 'Pollution Control Act' (Petroleum, 2020). Since the early 2000s, NMVOC emissions from the petroleum sector have been substantially reduced, mainly because of investment in NMVOC recovery equipment. Under the Gothenburg Protocol of the LRTAP Convention, Norway has undertaken to reduce its overall NMVOC emissions by 40% by 2020, when compared with the 2005 VOC emission level. In 2018 the total NMVOC emissions were 40,500 tonnes.

Numerous shuttle tankers operating in Norwegian offshore waters were fitted with 'VOC Recovery Systems' or 'VOC Emission Control' technologies to meet these national targets between 2000 to 2010. The technologies were used in FSO, FPSO and shuttle tankers (Martens *et al.*, 2001; IPIECA, 2013). The techniques recommended by various IMO circulars were used in these projects, and a substantial reduction in VOC emission was achieved.

Thus, the following conclusions are drawn:

i. Norwegian rules explicitly declared the reduction targets for regulating VOC emission from tanker loading operations since 2003,
ii. The tanker operators designed and fitted various technologies onboard tankers to meet the targeted VOC emission reduction from loading operations, and
iii. The national rules in Norway have significantly reduced VOC emissions from tanker loading operations.

2.2 (d) Industry guidelines

Tanker owners and operators follow recommendations from 'Oil Companies International Marine Forum' (OCIMF) and 'Independent Tanker Owners Federation' (Intertanko) to ensure the commercial acceptability of tankers for continued commercial employment. The most crucial influence is vetting inspection under the 'Ship Inspection Report Programme' (SIRE) and following tanker best practices as per the 'International Safety Guide for Oil Tankers and Terminal Operators' (ISGOTT) safety guide.

Major oil companies commercially employ tankers for global oil shipment. Due to the potential pollution liabilities of operating oil tankers, the oil companies manage their fleet on various charter parties instead of owning the ships. To assist in finding the best-managed tankers worldwide, a tanker vetting database under SIRE is used. The tanker owners offer their fleet to be inspected by accredited vetting inspectors or vetting companies. The ship inspection programme lists an elaborate requirement to fulfil various criteria ranging from ship certification, manning levels, tanker safety features for cargo, ballast, and pollution controls to machinery operations. Some of this inspection's requirements exceed safety standards under SOLAS and MARPOL conventions.

A specific example related to the current study is the mandatory carriage and use of 'Personal Protective Equipment' (PPE) during oil loading operations. The ship's crew must carry and use 'Personal Gas Monitors' while working on deck during oil loading operations to safeguard their health against toxic gas exposures from cargo tank vapour vents. There is no requirement in SOLAS for mandatory carriage of such instruments during oil loading operations. The other examples include the detailed requirement for 'Enclosed Space Entry Procedure', carriage of mandatory 'Emergency Life Support Apparatus' (ELSA) during tank entry, carriage of multiple 'Personal Gas Analysers', Personal Gas Monitors' and carriage of sufficient spare parts and calibration requirements have been tanker industry-standard much earlier than that were added in SOLAS.

It can be concluded that the SIRE programme under OCIMF has been able to address the exposure risks of shipboard staff from toxic VOC emissions, which are currently not resolved by any regulations in the SOLAS and MARPOL conventions.

ISGOTT safety guide, jointly prepared by 'The International Chamber of Shipping (ICS), OCIMF, and 'The International Association of Ports and Harbour (IAPH)' has been the tanker industry standard for standard operating practices for oil tanker operations. The guide provides recommendations for tanker and terminal personnel on the safe carriage and handling of crude oil and petroleum products on tankers and terminals.

The guide does not recommend the design and construction of the tankers. There is detailed guidance in ISGOTT on the various standard operating procedures for operating different gas measuring instruments, their use to check toxic exposure levels, venting systems and vapour emission control systems. The guide assists in filling up some gaps that have not been made to any reference in SOLAS and MARPOL conventions. Detailed guidance is available to marine personnel to safeguard against exposure risks.

Based on the above details for the international and national regulations, as well as industry guidelines, it can be concluded that:

i. The toxicity hazard of OVE needs to be included in the SOLAS convention to minimise or stop toxic VOC exposure for seafarers and marine personnel,
ii. MARPOL convention Annex VI Regulation 15 and Regulation 22 be amended to minimise or stop VOC emission during loading operations in oil tankers and bunkering operations on all ships.
iii. Local rules in the USA, EU states, and Norway related to controlling VOC emissions from tankers should be studied in detail for their efficacy. That approach may be used to amend international conventions and national regulations.
iv. Guidelines in ISGOTT may provide reference to control inhalation exposure risk of seafarers.

3. DISCUSSION AND PROPOSED AMENDMENTS

Up to date, no regulation in SOLAS and MARPOL conventions references the toxic exposure due to VOC emission from oil vapour venting during oil tanker loading and ship bunkering operations. The toxic effect of VOC emission from venting operations during oil tanker loading and ship bunkering operations has been neither analysed nor mentioned in any of these conventions. The literature review in Section 2 concludes that there are no regulations in SOLAS and MARPOL convention, which require:

i. to provide any specific fixed or portable equipment to monitor exposure risks due to VOC emission,
ii. to install any equipment in ship design to limit or stop VOC emission,
iii. to have a minimum safe distance between air vents and sounding pipes for oil tanks, based on the VOC vapour cloud propagation for exposure risk assessment,

iv. ships to monitor VOC emission for exposure risks during tanker loading and ship bunkering operations,
v. tankers to have any target for the reduction of VOC emission during loading operations,
vi. tankers transporting clean petroleum products such as gasoline and naphtha to have any VOC Management Plan, and
vii. ships/tankers to include VOC emissions during loading and bunkering operations to calculate direct CO_2 emission from ship operations under SEEMP or 'Carbon Intensity Indicator' (CII) rules.

The local and regional regulations are stricter than SOLAS and MARPOL under local air quality laws, such as in the USA, EU, and Norway. The local laws in the EU, USA, and Norway declare clear VOC reduction goals and specify standards and technological solutions to regulate the VOC emission from tanker loading operations.

SIRE programme under OCIMF and standard operating guidelines from ISGOTT guide provide details on the operational procedures to manage the oil vapour exposure risks for the ship staff onboard.

VOC Toxicity from tanker loading and ship bunkering operations is not addressed in any international convention. As per the report prepared for the EU Commission, for every tonne of crude oil loaded in a tanker, there is a 1 kg VOC emission if no control measures are adopted (AEAT, 2001). One thousand eight hundred eighty-six million tonnes of crude oil was loaded in 2018, implying 1886 thousand tonnes of VOC emission from tanker loading operations globally (UNCTAD, 2020). The concentrated VOC emission from the oil-exporting ports at a local level is a significant cause of concern. Bunkering ports such as Rotterdam, Singapore, Houston, and Fujairah handle a few thousand ship bunkering operations annually, contributing to toxic VOC emissions in the local area. The importance of regulating this VOC emission is evidenced by a few oil tanker terminals in various countries where local air quality rules have enforced no VOC emission during tanker loading operations, as shown in Table 2 below.

Various guidelines issued by IMO and the related developments in the maritime industry to minimise or stop VOC emission are proposed to be included as new or amended regulations in SOLAS and MARPOL conventions, as listed below:

i. Provision of 'Vapour Return Line' at all oil exporting terminals to operate VECS systems onboard tankers, and provision of VECS system on all oil tankers (MSC/Circ.585, 1992)
ii. The increased setting of P-V Valves onboard oil tankers to at least 120 kPa (MEPC.1/Circ.680, 2009).
iii. Provision of VOCON valve for oil tanker loading operations (MEPC.1/Circ.680, 2009).
iv. Provision of KVOC system onboard oil tankers (MEPC.1/Circ.680, 2009).
v. Provision of CVOC system onboard oil tankers (MEPC.1/Circ.719, 2010).
vi. Provision of Vapour Recovery Systems onboard oil tankers (MEPC.1/Circ.680, 2009).
vii. Use recovered VOCs, from Vapour Recovery Systems, as fuel onboard oil tankers (DNV, 2010; AET, 2020).
viii. Inclusion of activities related to oil tanker loading and ship bunkering operations in the enhancement of efficiency of operations as per SEEMP Regulation 26 in Annex VI of MARPOL convention (MARPOL, 2023)
ix. Including activities related to oil tanker loading and ship bunkering operations as a potential carbon emission activity, calculate operational carbon intensity under CII rules, as per Regulation 28 in Annex VI of the MARPOL convention(MARPOL, 2023).
x. Review Regulation 15 Annex VI of the MARPOL convention to include product tankers to have a mandatory 'VOC Management Plan', to minimise or stop VOC emission during loading operations (MARPOL, 2023).

Table 2. List of ports regulating VOC emission during tanker loading operations

S.No	Port	Description	Remarks
	As per Regulation 15(b): A party regulating tankers for VOC emission shall submit a notification to the Organization.(MARPOL, 2023).		
1	Netherlands	VOC emission is regulated and reported to IMO under Regulation 15 Annex VI of the MARPOL convention (GISIS, 2020).	Reported to IMO as below: In 2011, for the port of Amsterdam, Vlissingen, Terneuzen, and Moerdijk, In 2012, for the port of Groningen, and In 2014: for the port of Rotterdam.
2	South Korea	VOC emission is regulated and reported to IMO under Regulation 15 Annex VI of the MARPOL convention (GISIS, 2020)	Reported to IMO as per below: In 2009, for the port of Busan, Incheon, Pyongtaek, Ulsan, Yeosu, and Kwangyang, In 2015, for the port of Taesan.
	As per local rules		

3	Gothenburg, Sweden	Local air quality rule to regulate VOC emission from tanker loading operations under Gothenburg Energy Port Regulations (EEA, 2019; Gothenburg, 2020)	It is enforced as a local initiative to control air quality in the port.
4	USA	Under 'The Clean Air Act' rule, oil exporting terminals must adopt MACT or RACT options to regulate VOC emission based on the quantum of oil handled, as required under 40 CFR Part 63 of EPA regulations. (EPA, 2020d)	National initiative to control air pollution from tanker loading terminals.
5	Norway	Vapour Recovery Unit is fitted at the oil exporting terminals to receive full OVE back to the oil terminal (Martens *et al.*, 2001; Energy, 2008)	A local initiative to control emissions in the port areas. It started in 1996 in the port of Sture, and 2008, in the port of Mongstad.

The following section provides specific details on the proposed amendments.

3.1 PROPOSED AMENDMENTS FOR SHIP DESIGN IN THE SOLAS CONVENTION

Current information from oil and gas industry practices and local air quality rules in various countries justifies amendments to existing SOLAS and MARPOL regulations to regulate VOC emission at the local level.

The basis of the proposed amendments in the SOLAS convention is to carry out a detailed risk assessment for VOC toxicity in any shipboard operations involving OVE, such as oil tanker loading and ship bunkering operations. The following mandatory task is proposed to be included in the SOLAS convention for all ships:

i. To conduct 'VOC Toxicity Hazard Assessment' (VOCTHA) for the location of venting points and manual sounding ports for cargo oil and bunker tanks (for cargo tanks as shown in Figure 1 and for bunker tanks as shown in Figure 2). It is proposed to be included in the SOLAS convention.

ii. To conduct VOCTHA also for the tanker loading ports, where multiple loading operations are performed, and for the bunkering ports, to make a regional basis of strict compliance to stop VOC emission, as shown in Figure 3. This is proposed to be included in the MARPOL convention.

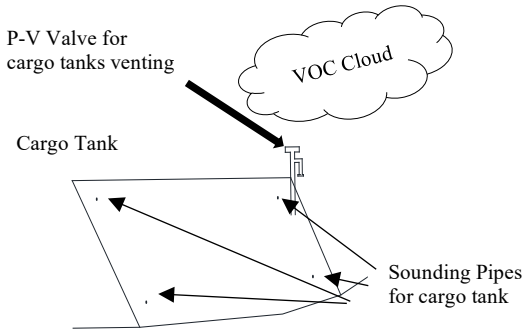

Figure 2: P-V Valve arrangement and location of sounding points for a cargo tank, showing the probabilistic extent of VOC cloud for venting during the loading operation

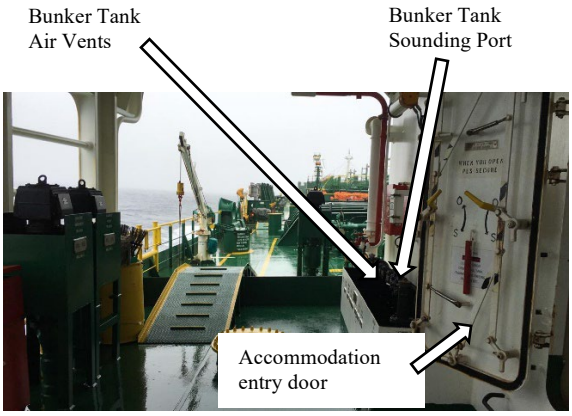

Figure 3: Proximity of the bunker tank air vent and the sounding ports to the accommodation entrance

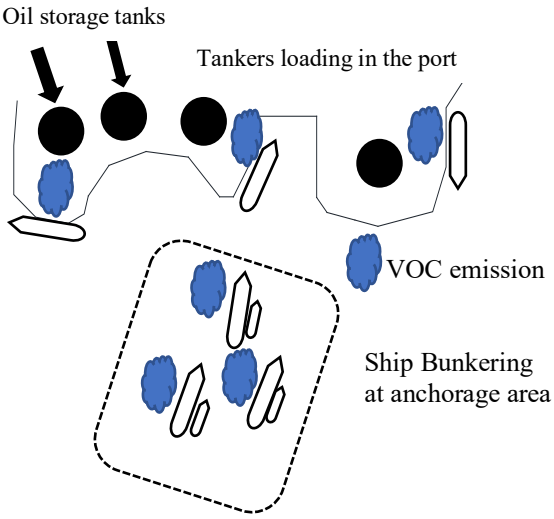

Figure 4: Overview of VOC emission from a tanker loading port and ship bunkering operations at the anchorage

3.1.1 Introduction of a new Chapter XI-3 titled 'Special measures to enhance maritime health'

i. No explicit and clear-cut acknowledgement and management of toxicity of VOC emission from oil vapour venting, affecting human health, exist in any IMO convention. It is proposed to include VOC Toxicity issues in the SOLAS convention under a new Chapter XI-3 titled 'Special measures to enhance maritime health', on similar lines as per the existing Chapter XI-1' Special measures to enhance maritime safety' and Chapter XI-2, 'Special measures to enhance maritime security'.

ii. This chapter should provide guidance to include VOCTHA as part of the current 'Risk Assessment' under Chapter IX' ISM'. This code should provide detailed guidance for conducting exposure risk assessment due to VOC emissions from various oil tank vents, such as cargo oil tanks onboard tankers and fuel tanks onboard all ships. The code should guide the recommended spacing between air vents and sounding pipes, the height of the vent pipe and the safe distance of bunker tank air vents from the accommodation area and entrances for safe exposure to toxic VOCs in OVE. The code should provide the methodology for assessing VOC exposure risk with simulation tools such as CFD software within the ship's vicinity and software such as MARPLOT for dispersion analysis within a port.

iii. The proposed new Chapter XI-3 should regulate the shipboard crew's mandatory 'Personal VOC Monitors' carriage during oil vapour venting during tanker loading and ship bunkering operations. The safe alarm limits should be specified to assist the crew in timely evacuation to a safe area. Alternatively, the ship may also be required to have a fixed 'VOC Emission Monitoring System' on deck to provide centralised information in the control room to guide the crew for safe evacuation.

iv. It is proposed to issue a new Code, under the SOLAS convention, titled VOCTHA Code, on similar lines to the 'Fire Safety and Systems' (FSS) Code, to support the proposed new Chapter XI-3, as per above.

v. The position of vapour vents for all oil tanks should be finalised based on exposure risk assessment, as per the VOCTHA code, to ensure minimum exposure to VOCs for seafarers working on deck. The requirement for the safe height of the vapour vent should also apply to bunker tanks.

3.1.2 Amendments to SOLAS Chapter VI Regulation 3 'Oxygen Analysis and Gas Detection Equipment'

SOLAS Chapter VI Regulation 3 'Oxygen Analysis and Gas Detection Equipment' should be amended to include its compliance for tankers transporting oil and all ships using oil as fuel—the mandated equipment to have a personal 'VOC Monitor' for ship staff working on deck.

3.1.3 Amendment to SOLAS Chapter VI Regulation 5-1 'Material Safety Data Sheets'

SOLAS Chapter VI Regulation 5-1 'Material Safety Data Sheets' should be expanded to declare the toxicity of VOC emission from oil vapour venting, like Regulation 3, in the same chapter, which explicitly states the reasons for precautions for solid bulk cargo liable to emit toxic or flammable gas.

3.1.4 Introduction of a new Part D, 'Special Provisions for Carriage of Oil' in SOLAS Chapter VI

It is proposed to introduce a new part, Part D, 'Special Provisions for Carriage of oil' in SOLAS Chapter VI, like the existing 'Part B' and 'Part C', which address particular issues related to the carriage of Solid Bulk Cargo and Grain respectively. This chapter should include the possible options to regulate VOC emission based on the available technological or design options, such as 'VOC Recovery Systems' and using captured VOCs as fuel. Other mandated ship equipment includes remote oil gauging and in-line oil sampling systems. It should be mandatory to have such equipment to maintain air quality and protect the health of seafarers due to toxic VOC emissions from oil tanks.

3.1.5 Proposed amendment to regulations related to oil tanker design and safety of operations under the SOLAS convention

It is proposed to apply a tiered design requirement based on the cargo-carrying capacity of an oil tanker to minimise or stop VOC emissions. This is proposed to be achieved by the available equipment and technologies as per various IMO guidelines, as suggested below, according to the ship's deadweight, as per Table 3.

Table 3. Proposed amendments in SOLAS convention for oil tankers

Oil Tanker Size	Design Requirement	Safety requirement
DWT < 100,000 tonnes	Oil vapour vents, ullage port and sampling port location, are to be designed as per VOCTHA code; remote gauging and in-line sampling system are mandatory. Use P-V Valves with a pressure setting of 2100 mm WG, Vapour Recovery Unit, and any of the following options to be installed: VOCON valve, KVOC system, or CVOC system.	Provide Personal VOC Monitor Or Fixed VOC Emission Monitoring System covering potential emission areas onboard.
DWT between 100,000 tonnes to 150,000 tonnes	Oil vapour vents, ullage port and sampling port location, are to be designed as per VOCTHA code; remote gauging and in-line sampling system are mandatory. Use P-V Valves with a pressure setting of 2100 mm WG, Vapour Recovery Unit, a VOCON valve, and either KVOC or CVOC to be installed.	Provide Personal VOC Monitor And Fixed VOC Emission Monitoring System covering potential emission areas onboard.
DWT 150,000 tonnes and above	Oil vapour vents, ullage port and sampling port location, are to be designed as per VOCTHA code; remote gauging and in-line sampling system are mandatory. Use P-V Valves setting to 2100 mm WG, Vapour Recovery Unit, VOCON valve, KVOC, and CVOC systems to be installed.	Provide Personal VOC Monitor And Fixed VOC Emission Monitoring System covering potential emission areas onboard.

3.1.6 Proposed amendments to regulations under the SOLAS convention for all ships related to bunkering

For ship bunkering operations, a tiered design requirement based on the ship's deadweight is proposed to minimise or stop VOC emission, as shown in Table 4.

Table 4. Proposed summary of amendments in SOLAS convention for all ships related to bunkering

Ships DWT	Design Requirement for regulating VOC emission during ship bunkering operations	Safety requirement for assessment of VOC Toxicity Hazard under SOLAS regulations
DWT < 100,000 tonnes	The bunker tank vapour vent height and spacing between the vapour vent and sounding pipe will be designed per the VOCTHA code. Remote gauging and in-line sampling systems are mandatory.	Provide Personal VOC Monitor Or Fixed VOC Emission Monitoring System covering potential emission areas
DWT 100,000 tonnes and above	The bunker tank vapour vent height and spacing between the vapour vent and sounding pipe will be designed per the VOCTHA code. Remote gauging and in-line sampling systems are mandatory.	Provide Personal VOC Monitors And Fixed VOC Emission Monitoring System covering potential emission areas

3.2 PROPOSED AMENDMENTS FOR SHIP OPERATIONS IN THE MARPOL CONVENTION

The current MARPOL regulations in Annex VI focus mainly on preventing air pollution from exhaust gas emissions and monitoring energy efficiency through ship manoeuvring and fuel oil consumption.

Only Regulation 15, Annex VI, in the MARPOL convention, mentions VOC emission from tankers. In this regulation, the decision to regulate VOC emission depends on the oil terminal, thus limiting its effectiveness. The requirement for tankers to have a 'VOC Management Plan' applies only to crude oil

tankers. For tankers handling clean petroleum products, there is no mandatory requirement to control VOC emissions. There is no reference to monitoring the surrounding atmosphere from oil vapour vents for toxic VOCs in OVE, whether from oil loading or ship bunkering operations.

Monitoring of operational environmental efficiency is required as per IMO guidelines related to Regulation 26, Annex VI of the MARPOL convention, under Ship Energy Efficiency Management Plan (SEEMP). Current activities in enhancing operational environmental efficiency in SEEMP do not include VOC emission from oil tanker loading and ship bunkering operations (MSC.282(70), 2016).

As per Regulation 28, operational carbon intensity reporting was introduced in 2022. However, the amendments in Annex VI of the MARPOL convention also do not include VOC emission from oil tanker loading and ship bunkering operations (MEPC.304(72), 2018; MEPC.328(76), 2023).

For tanker loading operations and ship bunkering operations, there are no regulations in the MARPOL convention which require:

i. ships to monitor VOC emission for exposure risks during tanker loading and ship bunkering operations,
ii. tankers to have any target for the reduction of VOC emission during loading operations,
iii. clean petroleum tankers transporting clean petroleum products such as gasoline and naphtha to have any VOC Management Plan,
iv. ships/tankers to include VOC emission during loading and bunkering operations to calculate direct CO_2 emission from ship operations under SEEMP Regulation 26 and CII Regulation 28, Annex VI of the MARPOL convention.

The following amendments are proposed in Annex VI of the MARPOL convention:

3.2.1 Amendments to the existing Regulation 15 MARPOL Annex VI, Volatile organic compounds

i. It should be mandatory for all tanker loading terminals to regulate VOC emission by providing a 'Vapour Return Line' to facilitate closed loading operations to preserve air quality in the port areas. To assist the tanker terminals in monitoring VOC emission in the port area, the MARPOL convention should issue simplified guidance on calculating VOC emission by adopting 'Emission Factors' issued by EPA or EU regulations. Ports loading 100 million barrels of crude oil, or 10 million barrels of gasoline (same basis as per the current USA regulations) must enforce the installation of' VOC Recovery Equipment' in their oil terminals to preserve local air quality. The amendment should include this as an operating requirement. Appropriate records related to the vapour return line, VOCs recovered by the recovery equipment, CVOC and KVOC systems, as applicable, should be maintained.
ii. Currently, Regulation 15 requires only crude oil tankers to have VOCMP. It is proposed that the scope of VOCMP should also be extended to include product tankers
iii. As oil loading operations will cause VOC emission, the current regulation should also be expanded to include monitoring of VOC emission from ship bunkering operations, especially when new fuels such as 'Hydrotreated Vegetable Oil' (HVO), 'Fatty Acid Methyl Ester' (FAME), 'Low Sulphur Fuel Oil' (LSFO), and blends are being adopted to be used as new fuels. Appropriate guidance should be made available for different fuel types to record VOC emissions in VOC Management Plan (VOCMP) for bunkering. Reference should be made to VOCMP guidance provided for oil tanker loading operations.
iv. Oil level monitoring and sampling in cargo and bunker tanks must be done by remote gauging systems and an in-line sampling system fitted as per amended SOLAS Ch XI-3.
v. It should also set specific reduction targets for VOC emission, i.e., by using VOC Recovery Systems from oil tanker loading and ship bunkering operations, similar to those defined for NOx emission Regulation 13 in Annex VI. Detailed guidance should be included for each ship's standardised calculations by amending Regulation 15, Annex VI of the MARPOL convention.
vi. Fixed VOC emission monitoring systems or personal VOC monitor (PGM) shall be used during oil tanker loading and ship bunkering operations to safeguard the health of seafarers. The requirement to provide VOC Emission Monitoring System and personal VOC monitor (PGM) is proposed in Sub-section 7.1.1 and 7.1.2, under amendments to the SOLAS convention.

3.2.2 Amendment to monitor operational environmental performance by 'Carbon Intensity Indicator' and SEEMP

VOC emission from oil tanker loading and ship bunkering operations should be included in reporting under the 'Annual Operational Carbon Intensity Indicator', as per Regulation 28, Annex VI, in the

MARPOL convention. Similarly, reusing recovered VOCs as fuel to enhance fuel consumption efficiency should be included in SEEMP records (MEPC.328(76), 2023).

3.2.3 Amendments to IMO Strategic Directions

The current IMO Strategic Direction Roadmap does not include any VOC emissions to be monitored from oil tanker loading and ship bunkering operations. It is proposed that Strategic Direction 2 (SD2), 'Integrate new and advancing technologies' in the regulatory framework and Strategic Direction 3 (SD3), 'Respond to climate change', to be reviewed and amended to include this critical VOC emission (IMO, 2019).

3.2.4 Summary of amendments in MARPOL convention

The summary of amendments proposed for regulations in the MARPOL convention is shown in Table 5.

Table 5. Proposed summary of amendments in MARPOL convention for all ships

Ship Type	Design requirement for regulating VOC emission for air quality	Operational requirement for monitoring VOC emission
Oil Tankers, during loading operations	Vapour Return Line to be mandated on all oil exporting terminals. (Regulation 15)	Oil tankers must use close loading operations (Vapour return line) or VOC recovery equipment, as applicable. (Regulation 15)
	The efficiency of VOC Recovery Systems should be indicated (Regulation 15).	VOC emissions from tanker loading operations at oil terminals must be recorded. (Regulation 15)
	Include VOC emission in SEEMP. (Regulation 26)	Must use personal VOC detectors or/and a fixed VOC Emission Monitoring System, as applicable. (Regulation 15)
	Include VOC emission in Annual operational Carbon Intensity Indicator reporting. (Regulation 28)	Oil level monitoring and oil sampling must be executed by using remote gauging systems and in-line sampling systems. (Regulation 15)
		Monitor and report VOC emissions during loading for product tankers by referring to VOCMP. (Regulation 15)
		Monitor and report VOC emissions in SEEMP and Annual CII reporting. (Regulation 26 and 28)
All Ships, during bunkering operations	Include VOC emission in SEEMP (Regulation 26)	Use personal VOC detectors and a fixed VOC Emission Monitoring System. (Regulation 15)
	Include VOC emission in the Annual Operational Carbon Intensity Indicator report. (Regulation 28)	Oil level monitoring and oil sampling must be executed by using remote gauging systems and in-line sampling systems. (Regulation 15)
		Ship staff to record VOC emission as per VOCMP for bunkering operation. (Regulation 15)
		Monitor and report VOC emissions in SEEMP and Annual CII reporting. (Regulation 26 and 28)

3.3 PROPOSED AMENDMENTS IN THE LOCAL REGULATIONS

Monitoring toxic VOCs in OVE from oil tanker loading and ship bunkering operations largely depends on local and regional initiatives. It is seen that few nations and regional blocks are active in regulating such emissions, as described in sub-section2.2 (a), 2.2 (b) and 2.2 (c), such as EPA USA, EEA EU, and NEA Norway (UNECE, 2015; EEA, 2019; EPA, 2020b; NEA, 2020). Industry-led initiatives such as the SIRE programme under OCIMF and standard operating guidelines from ISGOTT guide to managing the exposure risks of shipboard staff. These are also described in sub-section 2.2 (d) (ICS, 2020).

Examples of the 'Clean Air Act' in the USA, the 'LRTAP Convention' under 'UNECE', and the reduction in VOC emission in Norway under 'The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone' may be adopted by other nations and regional blocks as a reference to actively regulate such toxic emissions from oil tanker loading and ship bunkering operations (Hansen *et al*., 2008; EPA, 2020a; UNECE, 2020).

4. CONCLUSION

The regulations in SOLAS and MARPOL conventions have not included any 'VO
C Toxicity Exposure Assessment' for oil tanker loading and ship bunkering operations. Due to siting tank vents and the sounding pipe's proximity, the current oil tanker and ship design can expose seafarers to toxic VOCs during oil tanker loading and ship bunkering operations. Due to toxic VOCs in OVE, current ship design rules do not account for exposure risk assessment. The regulations in SOLAS and MARPOL convention are proposed to be amended to include appropriate equipment and operational measures to minimise or stop VOC emission from oil tanker loading and bunkering operations.

Amendments in SOLAS regulations include an additional chapter, 'Chapter XI-3', to address 'Special measure to enhance maritime health', including a new code-named 'VOC Toxicity Hazard Assessment'. The code will provide a methodology to conduct toxic hazard assessment from VOC emission within the ship's perimeter and the port, as well as provide guidance on the minimum safe distance between air vents and sounding pipes, air vents and the nearest accommodation doors and the height of air vents for bunker and cargo tanks to address the toxicity hazards. Additional equipment to monitor exposure risk includes the 'VOC Emission Monitoring System', mandatory carriage of a personal VOC monitor (PGM), remote oil level monitoring devices and in-line oil sampling systems. Various technological solutions, such as KVOC, CVOC, Vapour Recovery Units, P-V valves with higher pressure settings, and VOCON valves, to minimise VOC emission, are also proposed to be included in a new 'Part D' in SOLAS Chapter VI.

Amendments and additions proposed in Annex VI of the MARPOL convention relate mainly to Regulation 15. It is proposed that Regulation 15 in Annex VI be made mandatory for clean petroleum tankers also, in addition to crude oil tankers as per the current arrangement. It is also proposed to include all oil-exporting terminals in this regulation and to make it mandatory to provide a vapour return line to stop VOC emission for effective regulation of VOCs globally. Alternatively, all oil tankers are proposed to be fitted with VOC recovery equipment. The scope of this regulation is proposed to apply to all ships, which carry oil as cargo, or oil as fuel on
similar lines as per the 'Shipboard Oil Pollution Emergency Plan' (SOPEP) regulation in Annex I of the MARPOL convention. It is also proposed that MARPOL regulations declare VOC emission reduction targets on the same lines as done for the current NO_x emission regulation in Annex VI.

Regional rules in the EU and national rules in USA and Norway may be used to minimise or stop VOC emissions from oil tanker loading operations.

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