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Development of a pollution index for ports

Omotayo Abayomi Adegboye *

Faculty of Maritime Transportation, Ningbo University, Zhejiang Province, China.

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Abstract

The concept of a port pollution index is relatively new and as a result, there remains a need to introduce the concept to several audiences- particularly port users and operators- and to better understand its usage and benefits. It is in view of these that this study aimed to develop a port pollution index with Port Newcastle, Australia port as a case study. Amongst the different kinds of port pollution, water and air pollution were selected for consideration in this study because these two pollution types amount for the largest percentage of port pollution. Secondary data collection was the data collection method adopted for the study and the data were obtained from credible sources for the variables under consideration covering both summer and winter season. Collected data were analyzed using Microsoft Excel and Index parameters were formulated. The pollution index of the port (PPI) is found to be low with an index value of 26.73 during the winter period and 28.56 during the summer. P- Value of 0.03 at a correlation of 0.999 shows a strong significant correlation for the port pollution index between the summer and winter season. While the water pollution index (WPI) analysis of the case study unveiled that the lower DO levels and higher fecal coliforms markedly reduced the water quality of the port, air pollution index (AQI) analysis of the data set shows PM10 and PM2.5 as the major pollutants of the port under review with a minimum value of 71.2 μg/m3and 58.3 μg/m3 respectively. Emissions from ship engines is the major source of pollution which determines the ambient air pollution while shipping activities are major factors responsible for pollution of port water, the port quality index of port Newcastle is however found to be good for both winter and summer seasonal period with the PPI higher during the winter and lower during the summer time. The index formulated by this research can help port users determine the pollution level at a particular port. It can also help port managers determine and take control measure at all time.

Keywords: Pollution; Index; Emission; Port Pollution

1. Introduction

In recent time, environmental protection has become a widely discussed topic amongst different stakeholders in the maritime industry. Port management can be said to be somewhat inefficient if it doesn't take port pollution control and management into consideration. Several complex activities are being carried out in the port with each of these activities contributing its own quota to port pollution. Environmental pollution analysis from ports and Jetties are complicated due to the various types of pollution, sources and their different Characteristics. Pollution from port areas comes not only from ferries, ships and trade but also from industrial and shipyard activities as well as auxiliary services. Port pollution can produce negative effects both to the natural eco-system and to the urban population. When considering port pollution, several researchers have argued that the hinterland and even the port city should be considered as the effects of port pollution do not only stay in the ports but affect the port environment also.

* Corresponding author: Omotayo Abayomi Adegboye.

In this era of great economic growth and stimulation, the need for economic trade has greatly increased, thereby placing more pressure on the maritime industry (Olivier and Slack, 2006). The more the demand for international trade, the busier the ports. Also, there would be a significant increase in the demand for larger ports, larger warehouses, exploitation of resources, industry and offices in the hinterland and many other activities that would tell significantly on the port region and adjacent coastal area. The pursuit of environmental sustainability is an essential part of human well-being. However, environmental pollution from ports is an inevitable phenomenon so long as port operations exist.

A severe environmental issue in the maritime industry is the problem of air pollution from seafaring vessels while in ports, but this is a concern for just one part of the global maritime industry that is in dire need of reducing its use of bunker fuel. The dirtiest grade of diesel allowed under international law happens to be the bunker fuel and it contains about 45,000 ppm of sulfur. Ships using bunker fuel emit more sulfur dioxide than the entirety of the world's cars, trucks and buses combined and up to 21 percent of the greenhouse gases from all transportation sources. In the long term, depletion of oil resources and environmental pressure are likely to force the international marine shipping industry to switch to another fuel altogether. There is already some experience with natural gas use in ships (James, 2008).

As a result of the increasing concerns for health and environmental impacts of shipping, several regulatory measures have been put in place by different governments in order to control emissions and to encourage the use of low-sulfur fuel and clean technologies. For ocean shipping, the International Maritime Organization (IMO) under the United Nations has adopted SOx, PM, and NOx standards targeting oceangoing ships.

A switch to lower-sulfur marine fuel is still the most common approach to realizing the fuel sulfur standards. Feasibility testing of scrubbers for cleaning tailpipe SOx emissions is becoming a common practice amongst ship operators. Advanced NOx emissions control technologies, such as Selective Reduction Catalyst or Exhaust Gas Recirculation devices, have been deployed on ships because of incentives and the strict NOx emissions requirement to go into effect in North America.

Recurrent air pollution issues in recent years have prompted the Chinese government to adopt a new set of ambient air quality standards which has beyond reasonable doubts, contributed to a significant reduction of air pollution. Hong Kong was the first to strictly enforce the use of low-sulfur fuel (500 ppm, or 0.05% sulfur content) by local vessels and will soon be the first in China to require OGVs to use lower-sulfur marine fuel while docking. Shenzhen has followed Hong Kong, announcing a comprehensive list of measures for cleaning up ships, trucks, and port equipment. Other port cities and regions like Shanghai, Qingdao, Guangdong, Jiangsu, and Shandong provinces have also issued plans to promote shore power, electrification of port equipment, and the use of electric or natural gas–powered trucks. All in all, research into and adoption of measures to control air emissions from shipping and ports are still at an early stage in China. There is much room for enhancing the emissions control performance of vessels, trucks, and port equipment. Cleaning up ships, trucks, and port equipment therefore can contribute significantly to the important air quality improvement efforts undertaken in coastal regions (Freda et al. 2014).

1.1. Statement of the Problem

Despite the great advancement and accomplishments of the shipping industry, there are still some aspects that require further research and improvements. One of such areas is the evaluation of port pollution. The very complicated problem of establishing an index for port pollution remains crucial since the effects of port pollution travel beyond the jurisdiction of the port itself. Port users, Port operators, and governments need to make informed decisions on issues such as port choices and ports management. For instance, shippers would prefer to choose ports where their staff would be exposed to lesser health hazards and a port where they would incur lesser pollution management costs. There are no existing adequate tools to aid such efficient decision makings.

1.2. Aim and Objectives of the Study

The aim of this research is to develop a port pollution index for ports. Objectives of the study can be summarized as follows;

- To identify the effects of port pollution.
- To identify the different forms of port pollution.
- To identify the benefits of developing a pollution index for ports.
- To identify the different approaches to reducing port pollution.

1.3. Research Questions

- What is port pollution?
- What are the effects of port pollution?
- What are the different forms of port pollution?
- What is a port pollution index?
- What are the benefits of developing a pollution index for ports?

1.4. Research Hypothesis

H0: Seasonal variations have no effect on port pollution index H1: Seasonal variations have effect on port pollution index

1.5. Significance of Study

The purpose of this research is to create a pollution risk index to be used as a diagnostic tool for port pollution control purposes, i.e. to sort out which ports should be given special attention. The index would also be of great importance in terms of determining port competitiveness. It is evident that shippers and other port users would prefer to use a port where they can incur lesser cost on pollution management. Health concerns amongst port users also play a vital role in port choice.

1.6. Limitation of the Study

Some of the technical challenges that were encountered while carrying out this research include but not limited to data interpretation and analysis, mathematical computation and expression, restricted access to specific search engines and resourceful websites. Choosing an appropriate data analysis program was an issue as I tended not to have known which one had the greatest efficiency. A reasonable amount of time was also needed to learn the basic know-how and application of the program. In order to develop an index, one's mathematical and statistical knowledge needs to be well above average. This posed as a threat to me but my optimism and passion to contribute to this field of knowledge saw me through that.

Another limitation of this research is the acceptance of its proposed index as a tool to access pollution risks in ports but nonetheless, with the use of credible methods and existing related literature, a port pollution index was created and it will serve as a tool for port managers and authorities to determine to which ports attention should be given and in what magnitude.

2. Literature review

2.1. Conceptual and Theoretical Framework

The theoretical framework conjoins three research traditions or theories. The first tradition explores and projects the port as a multi-functional synergy that requires adequate conservation and sustainability. The first theory breaks port sustainability into three key dimensions which are; environmental, economic and social which are applied to many niches including that which is the aim of this research.

According to Asgari et al, 2015, the three focal points of port sustainability which are; environmental, social and economic are necessary to reduce costs and environmental impacts of shipping activities. The social factor has been gaining a lot of attention recently as many ports and port cities are being affected by ships' exhausts. SOx, NOx, and PMs and the other ship emissions from port-related activities are said to cause lung cancer and heart- related diseases. Cruise ships are more to blame for emitting the above gases than cargo ships because the former are normally berthed nearer city centers. Like all major port cities in Europe, people living in Asian port cities, among others, Hong Kong, Shanghai, and Singapore are more exposed to highly polluted air due to the fastest growing cruise industry in the world. NABU estimates the amount of pollution caused by cruise ships in large German ports and concludes that "heavy fuel oil can contain 3500 times more sulphur than diesel that is used for land traffic vehicles" (NABU, 2017). To properly analyze the three dimensions of sustainability, the externalities arising from gas emission needs to be considered.

Tzannatos (2010) tried analyzing gas emission alongside with its associated externalities. Despite the fact that the IMO has been implementing green shipping and port initiatives to reduce GHG from ships and port activities, it seems that sustainability in the maritime transport and logistics requires proactive measures referring to land transport and aviation sectors.

The second theory is that of Cullinane and Bergvist. It focused on the following issues

- The comparison of three options complying with ECA sulphur and NOX tier III regulation; benefits and costs analysis of sulphur reduction measures;
- Limitations of the financial assessment of technologies assisting compliance with the sulphur regulations of MARPOL Annex VI;
- The future low-sulphur fuel requirements in sulphur emission control areas (SECA).
- The estimation of emissions of noxious gases from vessel operations in potential ECAs.
- Case studies of SECA application to the North and Baltic Sea and the Mediterranean Sea.

The third tradition which was reviewed by Lee et al. (2015) consisted of five papers of which the topics are

- A vessel speed reduction program introduced by the port of Los Angeles and Long Beach to reduce gas emission by fostering a co-operation between ports and shipping companies.
- Development of an evaluation tool based on a conceptual framework with institutional theory for the purpose of evaluating the impacts of internal green practices, institutional pressures and external green collaborations on green performance.
- Development of a resilience method to forbear unnecessary insufficient green operation in the situation of disruptions of truck placement inside a container terminal.
- An investigation of strategic responses of inland ports (dry ports) to institutional forces pressuring their adoption of sustainability practices, applying institutional theory.
- An estimation and analysis of ship exhaust emissions and their externalities, taking cases of two ports, Dubrovnik (Croatia) and Kotor (Montenegro) in the Adriatic Sea.

Cullinane and Bergqvist contributed to the increasing literature associated to ECA in participation with numerical evaluation and legal characteristics. Cheng et al. involved the maintainability problem in terms of shipping, port and supply chain. Lee et al focused on the downsizing and estimation of gas emission for achieving green shipping and ports. Having determined the confined view and number of sustainability issues in the three specialized problems in terms of maintainability in maritime transport and logistics, this research aims to enrich and increase the current literature in the topic.

2.2. Review of Related Literature

It is generally recognized that all businesses have a major role to play in preventing pollution and reducing releases of harmful emissions into the environment and this is particularly true of the shipping industry. The impact of pollution on fragile ecosystems is particularly severe in the marine environment, and to address this there is a substantial body of UK, European Union (EU) and wider international regulations related to environmental control, including comprehensive survey and certification requirements (Maritime and Coast Guard Agency, 2002).

2.2.1. Pollution in ports

Pollution can be said to be the introduction of contaminants into the natural environment thereby causing adverse change. Pollution can be in form of energy or chemical substances such as heat, light or noise. Some of the major forms of pollution include: Air pollution, light pollution, noise pollution, water pollution, plastic pollution.

Increasing global trade has made seaports key players of environmental pollution in coastal urban areas. This upsurge of global trade does not seem to be approaching its peak and it does not seem to reduce in the nearest future. In order to evaluate the pollution impacts of port activities, numerous sources that need to be considered include but not limited to locomotives, trucks, marine vessels, and off-road equipment used for cargo handling. The air quality impacts of ports are significant, with particularly large emissions of diesel exhaust, particulate matter, and nitrogen oxides which all have negative health impacts on the health of humans residing in the nearby local communities. These health hazards include but are not limited to lung cancer, cardiovascular disease, asthma, other respiratory disease and premature death. Several measures to mitigate these health impacts are being taken; examples of such measures include the use of low-sulfur diesel fuel, shore side power for docked ships, and alternative fuel (Diane and Gina, 2004).

The rate at which environmental sustainability has been receiving attention from all the port stakeholders has greatly increased within the last 30 years. In order to attain a reasonable level of port competitiveness, all the seaport stakeholders need to invest substantial resources to achieve high port competitiveness (Assunta and Luisa, 2018). Port pollution can be traced to many causative factors, some of which are pollution from ships and cargo handling operations, industrial activities in ports, port planning and hinterland extension initiatives.

According to the Aquarium of the pacific journal, pollution can be said to be the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.

Pollution can be traced as far back as humans have organized societies and carried out economic activities in them. Though the magnitude of pollution has varies from time to time in relation to certain determinant factors such as population (James Gustave, 1999). The more the population, the greater the need for increased economic activities such as transportation and shipping which thereby increases the amount of potential pollution. Amongst the world's largest cities are ports which contribute significantly to environmental pollution. The amount of sulfur contained in ship fuel oil is 3,500 times more than that which is contained in diesel, thereby, making shipping account for 2% of global carbon emissions and 13% of sulfur emissions. Sulfur dioxide can be a problem in busy waters and onshore breezes bring back sulfur oxides into coastal cities (Tony, 2019). Another major pollution causative factor in ports is the ships' auxiliary operation mode. Once ships are docked, they switch to auxiliary mode and hence run on diesel, thereby emitting nitrogen oxide.

Certain pollutants are of benefit to the environment and its inhabitants. A good example is Phosphate which is essential to aquatic life and may also cause some damage if not in the right proportion (James, 1999). Previous research have prove that carbon dioxide helps to keep the earth warm but its excessive build-up now poses as a threat by damaging the ozone layer and thereby altering the climate. Generally, health awareness has become a significant topic both in and outside the port. Pollutants such as dioxin and P.C.B.s have high toxicity that can increase one's chances of developing a life threatening condition such as cancer (Duhme et al, 1996).

Many port managers, governments and stakeholders in the maritime industry have adopted several measures targeted towards port pollution control and management. The European Sea Port Organisation's (ESPO) preparation of the "Environmental Code of Practice" is a typical example that creates an environmental framework guideline for ESPO members and other European ports to address pollution issues (ESPO, 2012). Many existing literatures and research have also taken port pollution risk management into consideration in recent years. A typical example is the cost of air pollution in Chinese port analysed by The State Environmental Protection Administration in conjunction with the World Bank (Nitonye and Uyi, 2018).

2.2.2. Air Pollution and Health Impacts from Port Operations

A synergy of the diesel engines powering ships, trucks, trains and cargo-handling equipment at ports create a large volume of air pollution thereby leaving port workers, port users and people residing near the port susceptible to various health risks (Dawson et al, 1998). Recent research has proven that the inhalation of air pollutants accounts of a great percentage of cancer causative factors (Bunekreef et al, 1997). Major air pollutants from diesel engines at ports that can affect human health include particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), and sulfur oxides (SOx) (Diane et al, 2004). A few amongst the health effects of ports pollution are cardiovascular disease, lung cancer, asthma, bronchitis and premature death (Ciccone et al, 1998). The larger contribution of port sources to air pollution can be attributed to the fact that pollution from cars, power plants, and refineries is somewhat controlled, whereas port pollution has continued to grow with almost no regulatory control. Figure 1 uses the Port of Los Angeles and the Port of New York and New Jersey as examples because they are the largest ports on the West Coast and East Coast of the United States of America, respectively. Figure 1 also highlights emissions of NOx and PM, because these pollutants are associated with very severe health impacts. Despite very conservative assumptions used to calculate port emissions, ports outpollute some of the largest sources of harmful emissions, raising the question, Should Ports be regulated like other large sources of pollution?

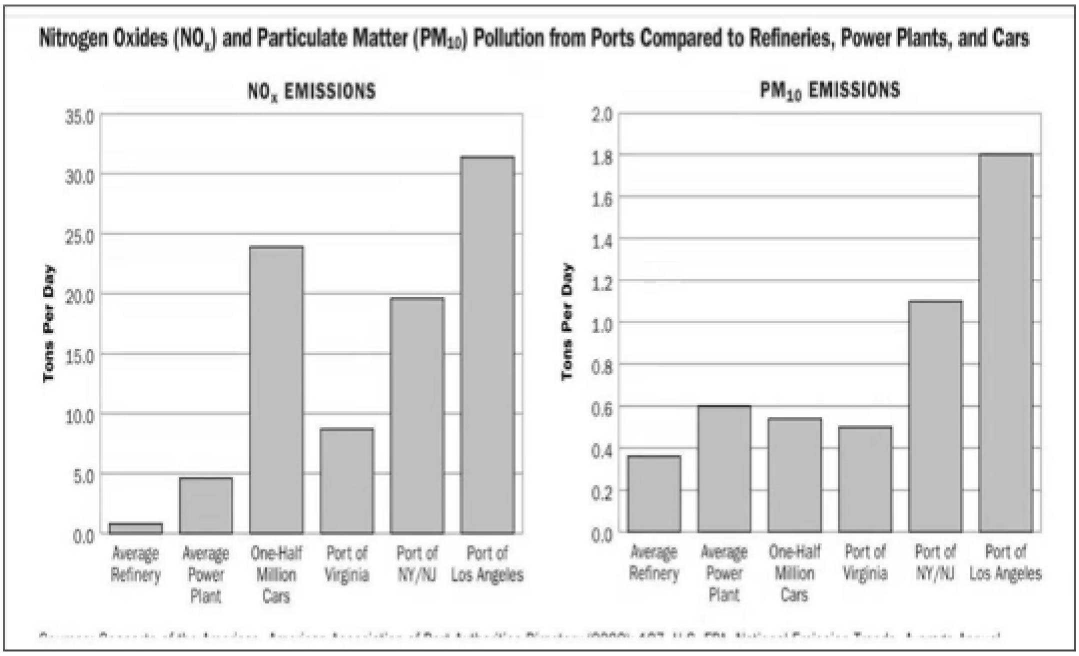

Figure 1 Air pollutant emission chart

Sources: Seaports of the Americas, American Association of Port Authorities Directory (2002): 127. U.S. EPA, National Emission Trends, Average Annual Emissions, All Criteria Pollutants, 1970–2001, August 13, 2003. Energy Information Administration, Petroleum Supply Annual 1982, Volume 1, DOE/EIA-0340(82)/1 (June 1983, Washington, DC), pp. 97-103 and Petroleum Supply Annual 2000, Volume 1, DOE/EIA-0340(2000)/1 (Washington, DC, June 2001),Table 40. Energy Information Administration, Form EIA-861, "Annual Electric Utility Report." As posted at www.eia.doe.gov/cneaf/electricity/public/t01p01.txt,U.S. Dept of Transportation, Federal Highway Administration, 2000 Highway Statistics, State Motor-Vehicle Registrations.

2.2.3. The Sources of Pollution at Ports

Many major ports, including the ports of Los Angeles and Long Beach, operate virtually next door to residential neighborhoods, schools, and playgrounds. These nearby communities face extraordinarily high pollution-related health risks resulting from their close proximity to the ports. In California, container ports account for roughly 6 percent of diesel particulate pollution (Daily Breeze,2012). This significant percentage is growing every year, in part because air emissions from port-related sources remain largely unregulated. Ships, container-handling equipment, and heavy trucks account for 95 percent of total NOx and 98 percent of total diesel PM emissions (AAPA, 2004).

2.2.4. Marine Vessels

For fossil fuel sources worldwide, marine vessels emit 14 percent of the nitrogen oxides, 5 percent of the sulfur oxides, and 2 percent of the carbon dioxide. In 2000, commercial marine vessels accounted for roughly 7 percent of NOx and 6 percent of PM emissions from all mobile sources in the United States. Because these vessels are poorly regulated, their share of polluting emissions is expected to double by 2020. In fact, commercial diesel ships are expected to account for one-fifth of all diesel particulate generated in 2020, making them the second largest source of this toxic soot.

2.2.5. Cargo-Handling Equipment

Every hour, thousands of large-size containers arrive by ship at the Chinese major ports, loaded with a wide range of imported products. Once on dry land, the containers are then transferred to rail and truck and transported to market. These containers, and the ships that carry them, require special cargo-handling equipment at ports. These equipment basically run on diesel fuel, the equipment is used to load and unload containers from ships, locomotives, and trucks, as well as to move those containers around container yards for storage. Cargo-handling equipment includes large gantry cranes used to load and unload ships, yard trucks that shuttle containers, and various others called top-picks, side-picks, straddle carriers, and forklifts. Regulation of off-road diesel equipment lags a few decades behind the regulation of on-road diesel trucks and buses. In fact, emission standards for heavy diesel equipment were not established until 1996 and are much weaker than on-road standards. Indeed, by 2007, new heavy diesel equipment will create 15 times more PM and NOx pollution than new highway trucks or buses. The Environmental Protection Agency's (EPA) recently adopted off-road diesel rule will significantly strengthen standards for off-road equipment. However, the rule will be phased in from 2008 to as late as 2015 and will cover only new equipment.

Container operations have considerably larger pollution effects than other types of cargo-handling operations at ports. At the Port of Houston, for example, only 42 percent of equipment is associated with container operations, but that equipment accounts for approximately 70 percent of NOx emissions from on-site port activities. The significant emissions from container-handling equipment are problematic at ports such as Los Angeles and Long Beach, where more than 90 percent of the roughly 2,000 pieces of equipment are associated with container operations.

2.2.6. Heavy Trucks Transporting Cargo to and from Ports

The majority of large trucks that service ports, dropping off and picking up containers, tend to be older and more polluting than long-haul trucks. Moreover, virtually all run on diesel fuel. Not only do the trucks add to existing traffic, but also they often form bottlenecks at terminal entrance gates, idling for long periods and contributing even more pollution. A single port complex can receive thousands of trucks entering and leaving on a typical business day.

2.2.7. Shipping Emissions in Ports

Shipping could somewhat be considered a relatively clean transport mode. This is particularly the case if one takes the angle of emissions per tonne-kilometer. Typical ranges of CO2 efficiencies of ships are between 0 and 60 grams per tonne-kilometer, this range is 20-120 for rail transport and 80-180 for road transport (IMO 2009). There is considerable variety between vessel types and CO2 efficiency generally increases with vessel size; e.g. CO2 emissions per tonne-km (in grams per year) for a container feeder ship (with capacity up to 500 TEU) were 31.6, three times higher than the emissions for Post Panamax container ships, with a capacity larger than 4,400 TEU. This difference is even larger for dry bulk ships, with a difference of more than a factor 10 between the smallest vessels (up to 5000 dwt) and capesize vessels (> 120,000 dwt) (Olaf, 2014).

In comparison with other transport modes, shipping emissions are also substantial. Whereas CO2 emissions of shipping might be approximately a fifth of those of road transport, NOx and PM emissions are almost on a par, and SOx emissions of shipping are substantially higher than those of road transport by a factor of 1.6 to 2.7. According to Eyring et al. (2003) international shipping produces about 9.2 more NOx emissions than aviation, approximately 80 times more SOx emissions and around 1200 times more particulate matter than aviation, due to the high sulphur content in ship fuel.

Table 1 Overview of studies on global shipping emissions

	Estimation (mlntonnes)	Year	Share of total emissions	Source
CO_2	949	2012	2.7%	IMO 2014
	1050	2007	3.3%	IMO 2009
	944	2007	-	Psaraftis&Kontovas 2009
	695	2006	-	Paxian et al. 2010
	813	2001	3%	Eyring et al. 2005
	912	2001	3%	Corbett & Koehler 2003
	501	2000	2%	Endresen et al. 2003
	419	1996	1.5%	IMO 2000
SOx	10	2012	-	IMO 2014
	15	2007	-	IMO 2009
	14	2005	10%	ICCT 2007
	12	2001	9%	Eyring et al. 2005
	13	2001	9%	Corbett & Koehler 2003
	6.8	2000	5%	Endresen et al. 2003
	16.5	2005	-	Cofala et al. 2007
	17	2012	-	IMO 2014

NOx	25	2007	-	IMO 2009
	22	2005	27%	ICCT 2007
	24.3		-	Cofala et al. 2007
	21.4	2001	29%	Eyring et al. 2005
	22.6	2001	31%	Corbett & Koehler 2003
	12	2000	17%	Endresen et al. 2003
PM10	1.3	2012	-	IMO 2014
	1.8	2007	-	IMO 2009
	1.9		-	Cofala et al. 2007
	1.7	2001	-	Eyring et al. 2005
	1.6	2001	-	Corbett & Koehler 2003
	0.9	2000	-	Endresen et al. 2003

Table 2 Emission inventories of ports

Port	Main indicators	Since
Los Angeles	Port-related GHG emissions (electric wharf cranes, building electricity, building natural gas, port employee vehicles, expanded GHG inventory) Diesel particulate matter (DPM), nitrogen oxides (NOx), SOx, CO2e emissions by source category: Ocean-going vessels (OGV), harbor craft (HC), cargo-handling equipment (CHE), heavy-duty vehicles (HDV), rail locomotives (RL). Containerized cargo volume trend Port DPM, NOx, SOx, CO2e emissions trend	2001
Long Beach	Port-related emissions (PM10, PM2.5, DPM, NOx, SOx, carbon monoxide (CO), HC) by category: OGV, HC, CHE, RL, HDV. Port-related GHG emissions (CO2E, CO2, N2O, CH4) by category: OGV, HC, CHE, RL, HDV.	2002
Seattle	Total air shed emissions (NOx, VOC, CO, SO2, PM10, PM2.5, DPM, CO2e) by source category: OGV, harbor vessels, RL, CHE, HDV, fleet vehicles	
New York - New Jersey	GHG emissions (CO2, CH4, N2O, HFCs, PFCs, SF6) by the category "Port Commerce" (commercial marine vessels, CHE, RL, HDV, buildings, landfill, fleet vehicles) Port commerce emission per TEU handled Total Criteria Air Pollutant (CAP) emission (NOx, NO2, PM)	2006
Oakland	Particulate Matter (PM, including diesel), NOx, SO2, Reactive Organic Gas (RO), and CO emissions by source category: ships, HC, CHE, RL, trucks.	2005
Vancouver	Common Air Contaminants (CACs): NOx, SOx, CO, VOCs, PM10, PM2.5, NH3, GHGs 2005 – CO2, CH4, N2O by source group (administration, CHE, on road, rail).	
Shanghai	Air pollutant emissions (NOx, SO2, PM, VOC, CO) of ships (ships of international 2006 shipping lines, ships registered at ports and managed by local maritime authorities, ships travelling along the coast, hotelling, internal rivers).	2006
Gothenburg	GHG emissions by: *Direct emissions: operational vessels, operational vehicles, heating buildings (by fuel 2010 usage), fire equipment *Energy indirect emissions: electricity usage, direct heating	

	*Other indirect emissions: business flights gallons per annum, business travel by car	

Source: Olaf Merk, 2014. Emissions at Sea. International Transport Forum, Paris, France

There is a limited related literature on shipping emissions which contain estimations on the in-port emissions, that is ship emissions in ports. The two examples of these studies are Entec (2002) and Dalsoren et al (2008). The Entec-study (2002) estimates emissions from ships associated with movements between ports in European countries; as they assign ship emissions to 50 km by 50 km grid squares the ship-related emissions in port areas are made visible. The paper of Dalsøren et al. (2008) uses an approximation of port time to calculate the in-port shipping emissions, but does not give details on individual ports, except for Singapore. Although these studies certainly have their merits with regards to calculation of ship emissions in ports, they both suffer from relatively inexact data or assumptions on the time that ships spent in a port. The Entec study uses port time data based on a questionnaire survey of ports; and although the Dalsøren et al. paper is more accurate in that it takes actual time in ports, it cannot be very precise because the dataset measures port time in days and not in hours, let alone minutes. Ports also increasingly measure emissions in port areas themselves via emission inventories (Table 2), but it is not always easy to separate the effects of shipping, port operations, hinterland transport and industrial development on the port site.

2.2.8. Oil Pollution

It is reasonable to say that oil pollution is synonymous to oil spillage. An oil spillage can be said to be a release of a liquid petroleum hydrocarbon into the environment due to human activity. Oil spills include releases of crude oil from tanker ships, directly from accidents and indirect from ship operations, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products, such as gasoline, diesel and their by-products and heavier fuels such as bunker fuel used by large ships, or the spill of any oily white substance refuse or waste oil (Hulsey &Ludivina, 2012).

Oil tanker vessel accidents are one of the most dangerous sources of oil pollution of the marine environment. A major disaster occurred on March 18, 1967; the Torrey Canyon was one of the first large supertankers, and it was also the source of one of the first larger oil spills. Although the ship was originally designed to carry 60,000 tons, it was enlarged to a 120,000-ton capacity, and that is the amount the ship was carrying when it hit a reef off the coast of Cornwall (UK). The spill formed an oil slick measuring 270 square miles, polluting 180 miles of coastland with many other catastrophic consequences (AL-Azab, 2005).

Ship operations are one of the main sources of oil pollution of the marine environment, especially operating giant oil tanker vessels to transport oil from production regions to consumers. It is not only the risks for catastrophic oil spills when ships ground or collide. All ships also carry fuel oil which may be as bad to the environment. There are many reasons for potential risks of environmental pollution, not only from accidents but also from the operation in the field of maritime navigation. For example, the dirty water contaminated with even small amounts of oil in the engine room space, causes pollution of the marine environment when pumping out this water into the sea further, the oil leaking from fuel oil bunkering into the sea in highly sensitive areas has the high impacts on the marine environment (National Research Council, 2002).

Table 3 Major oil spills since 1977 (quantities have been rounded to nearest thousand)

Position	Ship name	Year	Location	Spill size (tonnes)
1	Atlantic Empress	1979	Off Tobago, West Indies	287,000
2	Abt Summer	1991	700 nautical miles off Angola	260,000
3	Castillo de Bellver	1983	Off Saldanha Bay, South Africa	252,000
4	Amoco Cadiz	1978	Off Brittany, France	223,000
5	Haven	1991	Genoa, Italy	144,000
6	Odyssey	1988	700 nautical miles off Nova Scotia, Canada	132,000
7	Torrey Canyon	1967	Scilly Isles, UK	119,000
8	Sea Star	1972	Gulf of Oman	115,000
9	Irenes Serenade	1980	Navarino Bay, Greece	100,000
10	Urquiola	1976	La Coruna, Spain	100,000

11	Hawaiian Patriot	1977	300 nautical miles off Honolulu	95,000
12	Independenta	1979	Bosphorus, Turkey	95,000
13	Jakob Maersk	1975	Oporto, Portugal Oporto, Portugal	88,000
14	Braer	1993	Shetland Islands, UK	85,000
15	Khark 5	1989	120 nautical miles off Atlantic coast of Morocco	80,000
16	Aegean Sea	1992	La Coruna, Spain	74,000
17	Sea Empress	1996	Milford Haven, UK	72,000
18	Nova	1985	Off Kharg Island, Gulf of Iran	70,000
19	Katina P	1992	Off Maputo, Mozambique	66,700
20	Prestige	2002	Off Galicia, Spain	63,000

Source: ITOPF Handbook, 2013, p. 2

Occasional oil pollution is an inevitable event in an active oil terminal and the port authority must live with this fact. Hence, the port authority needs to put some antipollution measures into place (Andrzej, 1995).

Oil pollution emergency plans for ports should be developed in accordance with the following principles:

- Every pollution incident must be reduced to a reasonable minimum.
- When pollution occurs, antipollution measures must be taken immediately; acceptance of responsibility and acceptance for payment should be considered in second order only.
- The steps taken must be designed to keep at an absolute minimum the possibility of any oil getting ashore.
- Removal of oil from sea surface is always to be preferred over chemical dispersion, but in certain cases, particularly with crude oil, dispersants may be the most effective measure.
- The equipment must be kept constantly in full preparedness and must be continuously modernized.
- Human error is, and always will be, the single most important cause of oil pollution. It should be emphasized that human error is not a synonym for sheer carelessness, and may be the result of tiredness, language problems, or even plain ignorance.
- The main contamination of port and sea waters comes not from tanker operations but from industrial effluents, sewage, urban and river runoff, natural seepage, offshore oil production, and ships other than tankers.
- Big ports must be equipped to receive ballast water and tank washing water. Oil terminals must be equipped with technical means sufficient to deal with average spills. Larger spills have to be dealt with by using other antipollution services and will require national response.

2.2.9. Water pollution

Port operations can cause significant damage to water quality and subsequently to marine life and ecosystems, as well as human health. These effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish. Major water quality concerns at ports include waste water and leaking of toxic substances from ships, storm water runoff, and dredging (The ocean conservancy, 2002).

Oily bilge water is one major pollutant from ships. Water collected at the bottom of the hull of a ship, known as the bilge, is often contaminated by leaking oil from machinery. This bilge water must be emptied periodically to maintain ship stability and to prevent the accumulation of hazardous vapors. This oily wastewater, combined with other ship wastes, including sewage and wastewater from other on-board uses, is a serious threat to marine life (Ibid).

Other pollutants from ships are the antifouling additives used in the paint on ships to prevent the growth of barnacles and other marine organisms on ship surfaces. Some of these additives contain tributyltin (TBT), a toxic chemical that can leach into water (Caltrans, 2003). Once in the water, TBT is absorbed by marine life. In fact, TBT bioaccumulates, meaning that it is not simply released by marine life but rather builds up in the body and is taken in by predators. Not surprisingly, researchers have found TBT in bottleneck dolphins and bluefin tuna. TBT can cause masculinization of female snails through disruption of endocrine systems (J peeples, 2003). In shipyard workers, TBT has been linked to skin irritation, stomach aches, colds, influenza, and such neurological symptoms as headaches, fatigue, and dizziness.

2.2.10. Pollution Index

This research aims to fill the gap that has been left by existing research in the field of port sustainability. Despite the brilliant conclusion and ideas that have been proposed and drawn by various researchers, it appears that a pollution index has not been created.

According to Merriam-Webster, an index is a number (such as ratio) derived from a series of observations and used as an indicator or measure. In many countries, an air quality index (AQI) is used by government agencies (The original, 2015) to communicate to the public how polluted the air is or how polluted it is forecast to become.

Risk indicators are added to scorecards that are used in the formula to calculate the indexes. The following risk indices are available for calculating risk:

The risk index is the overall result of a risk assessment. All indicators and indexes can be used in the calculation for the risk index. It is a composite of the likelihood and impact index.

- Likelihood: The likelihood index shows the probability of a risk event occurring. This is measured in percentage. All indicators of a risk assessment can be used to calculate this index.
- Impact: The impact index shows the impact a risk event has on the company. This is measured by an abstract value range. All indicators of a risk assessment can be used to calculate this index.

I would define a pollution index as a diagnosis tool that can aid the decision making of Port managers, users and other stakeholders. A pollution index can help to determine amount of pollution present in each port. It can also be a pointer, showing the Port managers the different kinds of port activities and their environmental impacts.

3. Research methodology

3.1. Study Area

This study was carried out on Port Newcastle located in New South Wales, Australia. The Port of Newcastle is a major seaport in the city of Newcastle, New South Wales Australia. It is made up of facilities in the Hunter River estuary. The port was the first commercial export port in Australia and is the world's busiest coal export port that also deals with raw materials for steelworks, fertilizer and aluminium industries, grain, steel products, mineral sands and woodchips [Newcastle port corporation, 2018].

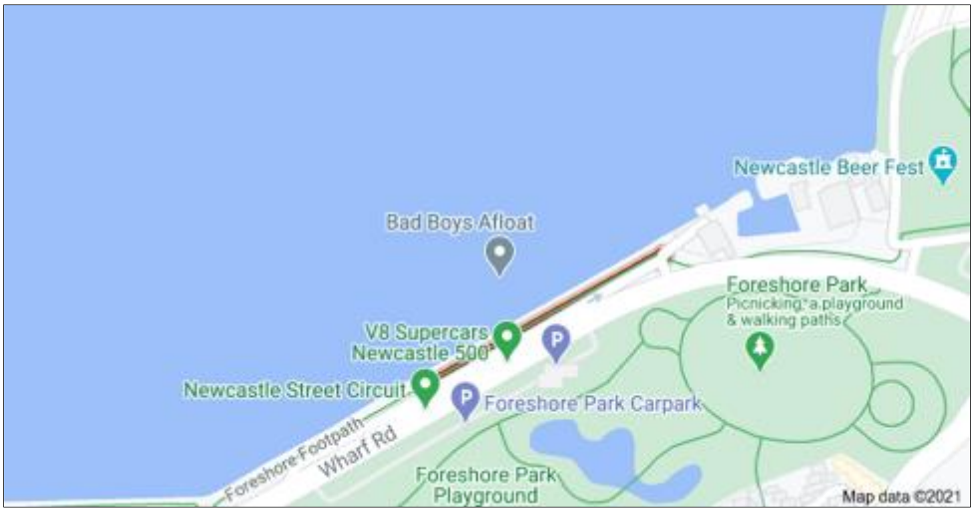

Figure 2 Map data (Port Newcastle)

3.2. Data Collection

Data for this research were collected through secondary data means which are collected following the procedures as detailed below. The data used for water quality under quality index are the one obtained by (Vladimir, 2017) in his study of Water quality assessment of Australian ports while Air variables were obtained from the work of (Buchholz et al., 2017) in their study of Source and meteorological influences on air quality at a Southern Hemisphere urban site.

The port water sampling was carried out between the periods of December 2016 to March 2017. Five water samples were collected from different points among which one was background sample collected from outside of the port area. The sampling positions were recorded by a GPS. Composite water sample was prepared from each point by mixing water from different depths, which was collected using Niskin water sampler. The Niskin water sampler was previously cleaned with deionised water and conditioned for at least 15 minutes at each depth of water collection. These samples were collected with sterile 75 cm screwed top plastic bottles; they were stored in a temperature of 4oC. In order to avoid staleness of samples, On-site measurement of pH, dissolved oxygen (DO) and temperature were performed using EUTECH EcoScan pH6, EUTECH CyberScan DO 300 meters. The turbidity and conductivity were measured using HANNA HI 98703 turbidimeter and EUTECH CyberScan CON 400 conductivity meters. All instruments were calibrated prior to each sampling day (Vladimir, 2017)

However, twenty-five (25) air samples were collected from each location for a period of 8 hours duration and the various parameters like wind speed, direction, relative humidity and temperature were also noted.

Suspended particulate matter (SPM) of size above 10 µ present in ambient air was measured by using a respirable dust sampler with a cyclone attachment for a period of one day by sucking a known quantity of air through glass filters (Horaginamani &Ravichandran 2010). The mass concentration of SPM was calculated by measuring the weight of collected matter in known volume of air sampled. The final results are expressed in terms of µg/m3. Sulphur dioxide: The determination of SO2 was done by modified West and Gaeke method (Kavuri& Paul 2013).

In this method, SO2 is absorbed from a known quantity of air in a solution of sodium tetra chloromercurate to form stable dichlorosulphito- mercurate mixture. Formaldehyde is then used for reaction and the color intensity is estimated photometrically.

Nitrogen dioxide: Jacob Hochheiser method was used to estimate concentration of NO2 in the air (Mamta&Bassin 2010). Nitrogen oxides are collected from sodium hydroxide solution to form stable sodium nitrite. The ion of nitrite produced is measured photometrically.

3.3. Assessment

Upon collection of data through secondary data source, quality indices were calculated as outlined below.

3.3.1. Water Pollution (WPI) calculation

Water Pollution Index (WPI) expresses the overall water quality of a particular source at a certain time using a 'single value' based on selected water quality variables of the study area. The WPI for the purpose of this research incorporates four parameters including dissolved oxygen, pH, biological oxygen demand (BOD) and fecal coliform. The index is calculated from P value and weight factor W, where P indicates the level of water pollution relative to any single parameter and the weight factor represents the relative importance of the single parameter to the overall water quality.

Assigning weight to parameters-

$$\mathrm{Wi} = \frac{\mathrm{wi}}{\mathrm{i} = 1}$$

$$\sum\nolimits_{\mathrm{n}} = \mathrm{wi}$$

Where Wi = relative weight

n= number of parameters

$$\frac{P_i}{S_i} = 100 - C_i \times 100$$

Where Pi = is the pollution rating

Ci = is the concentration of each chemical parameter in each water sample Si = is the standard for each chemical parameter

WPI = $\sum WiPi$ = WDOPDO + WPHPPH + WBODPBOD + WFecalCaliformPFecalCaliform

3.3.2. Calculating Air Pollution Index

An Air Pollution Index (API) for the purpose of this study is an environmental index which describes the overall atmospheric air status. It is the measure of ratio of the concentration of pollutants to the condition of atmospheric air in the area.

The following computation was used to arrive at the API values of the Port Newcastle under study. High API value refers higher status of air pollution and greater effect on the health.

In this study PM10, PM2.5, SO2, NO2 and are the pollutants under consideration.

Pi = (Ci * Si)/100… (1)

Where Pi is the air pollution index for the pollutant "i", Ci is the corresponding concentration of the pollutant "i" in the air (calculated from the dataset) and Si is the air quality standard for the pollutant as prescribed by the

Australian National Environment Protection Council (NEPC)

Secondly, using (2) the aggregation of pollution index is computed using weighted additive form.

$$\mathrm{Wi} = \frac{\sum_n \mathrm{w}}{\mathrm{W}_i = 1}$$

Finally, the API is estimated as follows:

API = ∑ (Wi * Pi) (3)

API = WPM10PPM10 + WPM2.5PPM2.5 + WSO2PSO2 + WNO2 PNO2

Where; IPM10, IPM2.5, ISO2, INO2 are the individual values of PM10, PM2.5, SO2 and NO2 respectively obtained during sampling. SPM10, SPM2.5, SSO2, SNO2 are the atmospheric air quality standards prescribed by Australian National Environment Protection Council (NEPC)

3.3.3. Port Pollution Index (PPI)

This is an index that describes the overall condition of a port area. In this study, we take into consideration Air and Water pollution variable. The following computation were used in other to arrive at the PPI for port New Castle under Review.

Assigning weight to parameters- Wi ……………(1)

$$\mathrm{Wi} = \frac{\sum_n \mathrm{w}}{\mathrm{W}_i = 1} \quad \dots\dots\dots.. \quad (2)$$

PPI = Wwpi*WPI + Wapi*API …………(3)

Wwpi= Relative Weight of Water Pollution Index Wapi= Relative Weight of Air Pollution Index

3.4. Quality Ranking

The overall quality ranking criteria falls under five categories for all the index factors considered for the purpose of this study.

3.4.1. Water Pollution Index ranking

The overall water quality ranking criteria falls under five categories which are very good when WPI is < 25, good when WPI is 26–50, moderately polluted when WPI is 51–70, highly polluted WPI is 71–90 and extremely polluted when in the range of 91–100.

3.4.2. Air Pollution Index Ranking

The overall Air quality ranking criteria used for the purpose of this studyfalls under five categories which are Good (with minimal impact) when API is < 25, Moderate when the API is 26–50, umhealthy when API is 51– 75, highly unhealthy when the API is 76–90 and hazardous when the API value is above 91.

Table 4 Air pollution index ranking

Air Quality Index	Levels of Health Concern	Colour Code
0 to 25	Good (Minimal Impact)	
26 to 50	Moderate (Minor Breathing Discomfort to sensitive people)	
51 to 75	Unhealthy (Breathing Discomfort to the People with Lungs and heart Diseases	
76 to 90	Unhealthy (Respiratory Illness)	
91 and above	Hazardous (Affects healthy people and seriously impacts	

3.4.3. Port Pollution Index Ranking

The overall port pollution ranking criteria falls under five categories which are very good when PPI is < 25, good when PPI is 26–50, moderately polluted when PPI is 51–70, highly polluted PPI is 71–90 and extremely polluted when in the range of 91 and above.

4. Results and Discussion

4.1. Water Pollution Index

The descriptive statistics of the three physicochemical and one biological parameters of water pollution with their observed standard deviations for each site for the summer were calculated and are as presented in table

while table 6 however present the result for that of the winter. Table 7 however present the water pollution index per location of the port under study. The original data of the measurements are presented on the appendix page. The pH values in port Newcastle ranged from 7.46 to 7.92 during the summer while it however ranges from 7.88 to 7.93 during the winter period which are all within the standard values.

Table 5 Water Pollution Index Parameters (Summer)

Summer	pH	DO (Saturation)	BOD (mg/l)	Fecal Coliform (/ 100ml)	WPI	Remark
1	7.88	89.50	0.90	1,002.50	28.57	Good
2	7.46	80.30	0.90	472.50	30.21	Good
3	7.94	80.10	0.90	1,003.00	29.41	Good
4	7.92	78.40	0.90	210.00	22.71	V. Good
	7.8±0.23	82.08±5.02	0.9±0.00	672±396.67	27.73±3.41	Good

Source: Author’s calculations and elaborations, based on data sourced

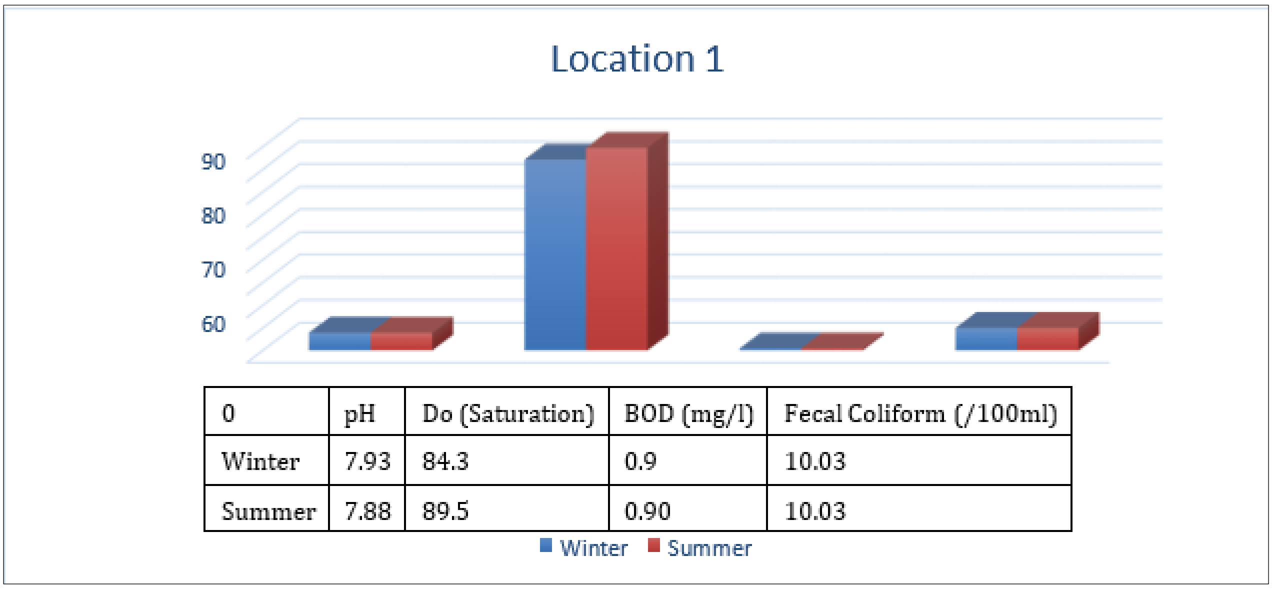

Figure 3 Variation of water pollutant in Location 1(Note: Scale for Fecal Coliform (/100ml) x0.01)

The mean DO (%) values, however are higher during the winter time compared to during the summer period. The DO is higher in location 1 and 2 during the summer compared to during the winter time. While the DO value remain the same for location 3 during this winter and summer time. It is however considerably higher during the winter time compared to summer time for the four locations.

Table 6 Water Pollution Index Parameters (Winter)

Winter	pH	Do (Saturation)	BOD (mg/l)	Fecal Coliform/ 100ml	WPI	
1	7.93	84.30	0.90	1,003.00	24.48	Good
2	7.88	78.20	0.90	1,003.00	22.91	V. Good
3	7.90	80.10	0.90	1,003.00	29.61	Good
4	7.89	91.20	0.90	1,003.00	28.57	Good
	7.9±0.02	*83.45±5.76*	*0.9±0.00*	*1003±0.00*	*27.39±3.03*	*Good*

Source: Author's calculations and elaborations, based on data sourced

Port Newcastle can be said to have a standard BOD level during both summer and winter period as the BOD is uniform for all the ports and is are as well within the standard.

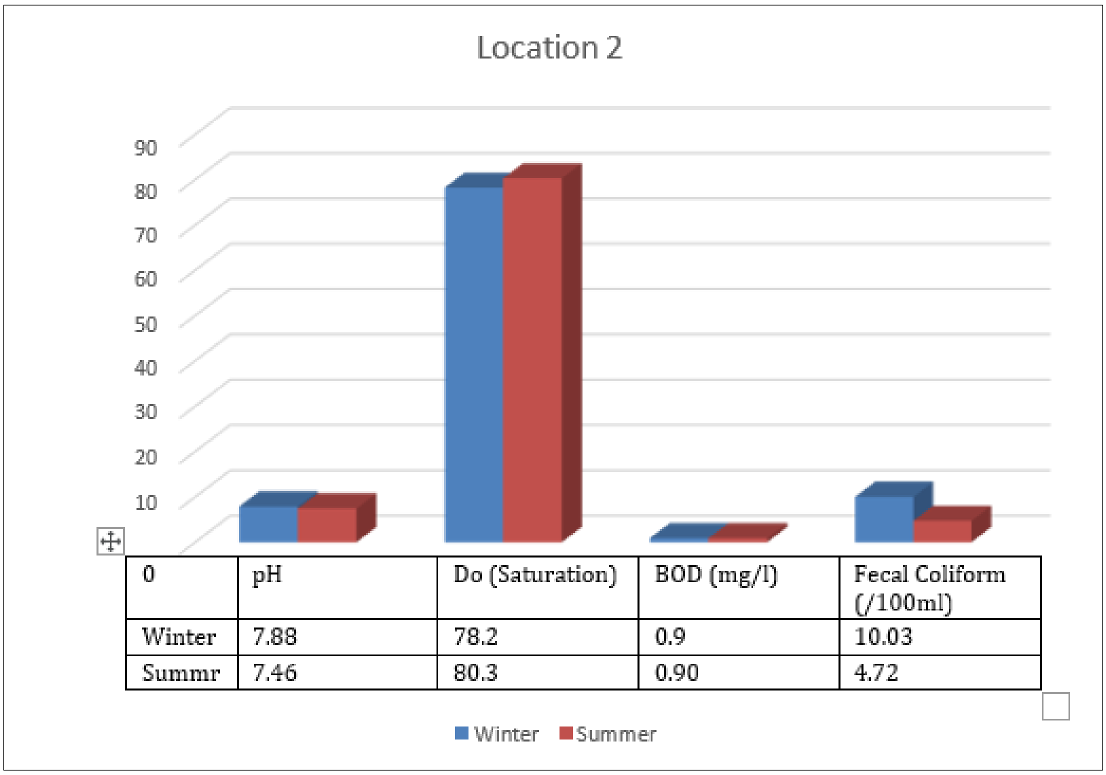

Figure 4 Variation of water pollutant in Location 2(Note: Scale for Fecal Coliform (/100ml)

Presence of fecal coliform is detected at the port during both winter and summer period. While the presence is so high with a mean value of 1003 (/100ml) during the winter, there is however a low value of fecal coliform during the summer with a mean value of 672 (/100ml).

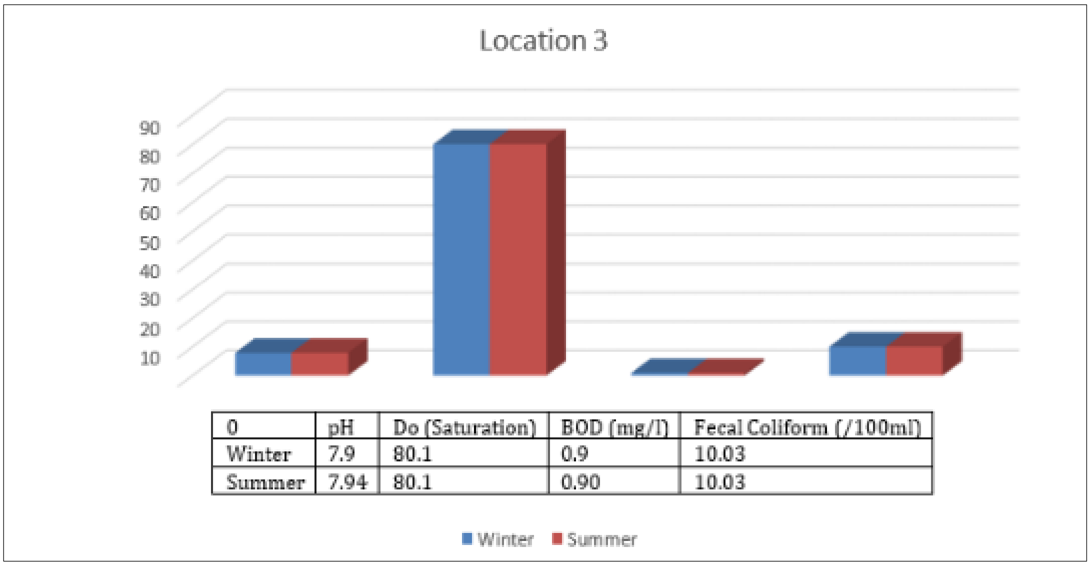

Figure 5 Variation of water pollutant in Location 3(Note: Scale for Fecal Coliform (/100ml)

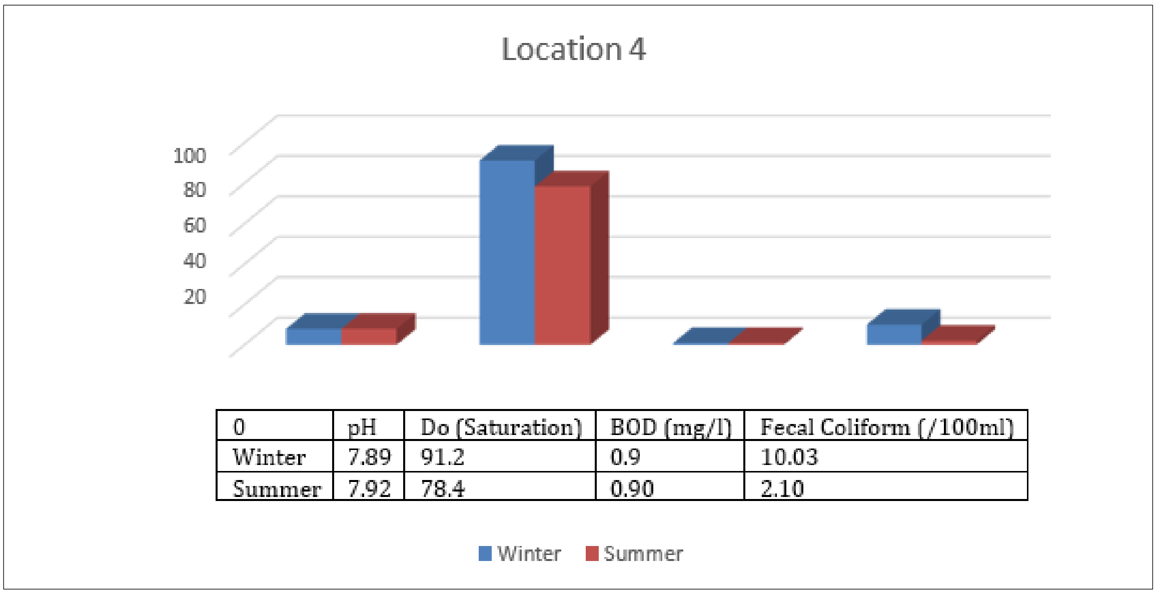

Figure 6 Variation of water pollutant in Location 4 (Note: Scale for Fecal Coliform (/100ml)

As presented in table 6 below, the water pollution index for the four locations within port Ne castle are within 25 – 50-mark range and as a result have good water quality. While the index level are precisely 27.73 and 27.39 for winter and summer time respectively. It shows that the water quality of the port is good. Out of the four parameters considered for water pollution index computation for this study, DO (%) and fecal coliforms were the two deciding parameters exhibiting the maximum influence in WQI calculations.

Table 7 Water Pollution Index by Location

Location	**WPI**	**Remark**
1	28.53±0.06	Good
2	26.56±5.16	Good
3	29.51±0.14	Good
4	25.64±4.14	Good

Source: Author's calculations and elaborations, based on data sourced

Table 8 Correlation analysis of water pollution parameters between summer and winter period

		Summer	**Winter**
Summer	Pearson Correlation	1	.852**
	Sig. (2-tailed)		.000
	N	16	16
Winter	Pearson Correlation	.852**	1
	Sig. (2-tailed)	.000	
	N	16	16

**. Correlation is significant at the 0.05 level (2-tailed). Source: Author's calculations and elaborations, using SPSS

Table 9 T-Test analysis of water pollution parameters between summer and winter

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Summer	2.250	15	.040	190.69375	10.0535	371.3340
Winter	2.511	15	.024	273.81250	41.4343	506.1907

Source: Author's calculations and elaborations, using SPSS

Table 10 Correlation between water parameters

		PM10	PM2.5	SO2	NO2
PM10	Pearson Correlation	1	0.837**	0.872**	0.512
Sig. (2-tailed)			0.010	0.005	0.194
N		8	8	8	8
PM2.5	Pearson Correlation	0.837**	1	0.866**	0.327
	Sig. (2-tailed)	0.010		0.005	0.430
N		**8**	**8**	**8**	**8**
SO2	Pearson Correlation	0.872**	0.866**	1	0.461
	Sig. (2-tailed)	0.005	0.005		0.250
	N	8	8	8	8
NO2	Pearson Correlation	0.512	0.327	0.461	1
	Sig. (2-tailed)	0.194	0.430	0.250	
	N	8	8	8	8

**. Correlation is significant at the 0.05 level (2-tailed).

The impact of periods on the water pollution index was tested with the statistical t-test, where $P > 0.05$ advocates no significant difference of the seasonal variations, as shown in Table 4.1.4 and table 4.1.5. Although the t-test results presented shows that there is a significant relationship between the water parameters during the winter and summer period at 0.852 correlation value which shows a strong inference.

4.2. Air Pollution Index

In the present study, the concentrations of PM10, PM2.5, SO2 and NO2 were measured in selected four locations in Port Newcastle. Table 7 shows the climate wise air quality status for various parameters.

The variation of pollutants in location 1 (NC1), which represents the activity shown in Figure. 4.2.1 PM10 exceeds the recommended limits in all the climate conditions and other parameters are within the standard limits.

Figure 7 shows the variation of pollutants in location 2. The results revealed that all parameters are within the standard limit, except PM10 which is slightly above the standard level.

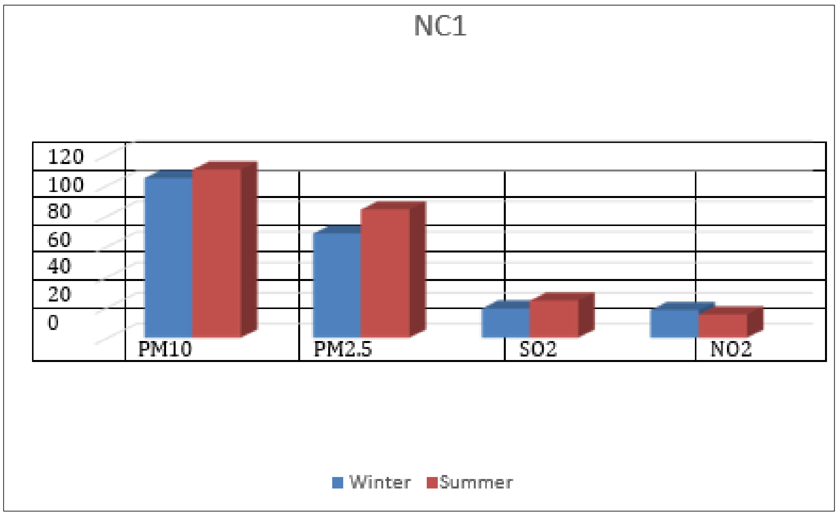

Figure 7 Variation of pollutants in Location 1

Table 11 Average ambient air quality data for different parameters

	Location Code	PM10	PM2.5	SO2	NO2
Summer	NC1	110.2	84.1	24.3	15.4
	NC2	93.2	75.3	21.2	14.1
	NC3	85.6	65.2	19.1	11.9
	NC4	77.3	64.6	11.8	10.9
Winter	NC1	104.6	68.2	19.1	18.1
	NC2	91.3	68.6	19.4	18.3
	NC3	84.2	61.2	15.3	10.2
	NC4	71.2	58.3	13.2	15.1
		Air Quality Index		Air Quality	
Average AQI per Location	NC1	32.755±0.01		Moderate	
	NC2	31.335±0.02		Moderate	
	NC3	24.265±0.05		Good	
	NC4	23.17±0.02		Good	

Source: Author's calculations and elaborations, based on data sourced

Table 12 Air quality categories based on air pollution index

Air Quality Index	Levels of Health Concern	Colour Code
0 to 25	Good (Minimal Impact)	
26 to 50	Moderate (Minor Breathing Discomfort to sensitive people)	
51 to 75	Unhealthy (Breathing Discomfort to the People with Lungs and heart Diseases	
75 to 100	Unhealthy (Respiratory Illness)	
100 and above	Hazardous (Affects healthy people and seriously impacts	

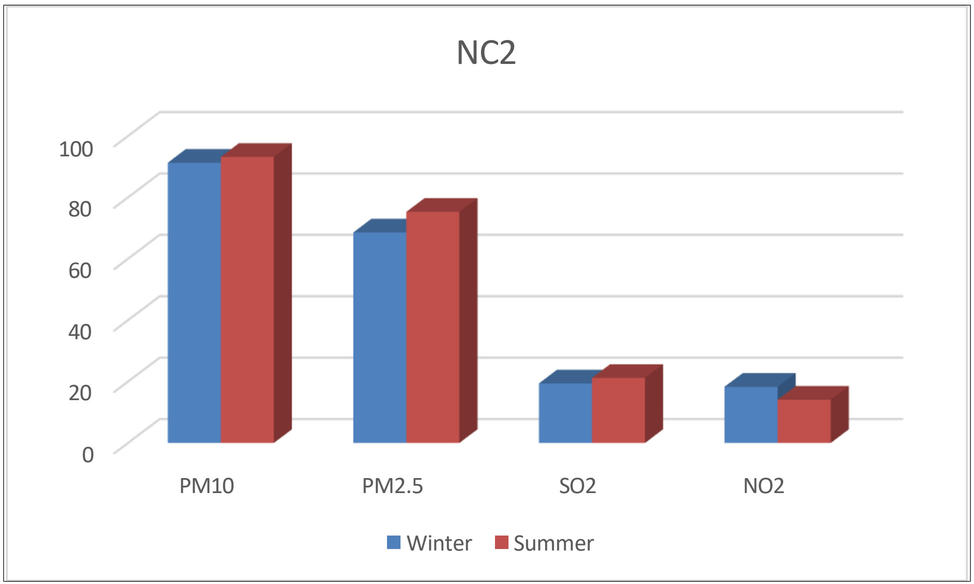

Figure 8 Variation of pollutants in Location 2

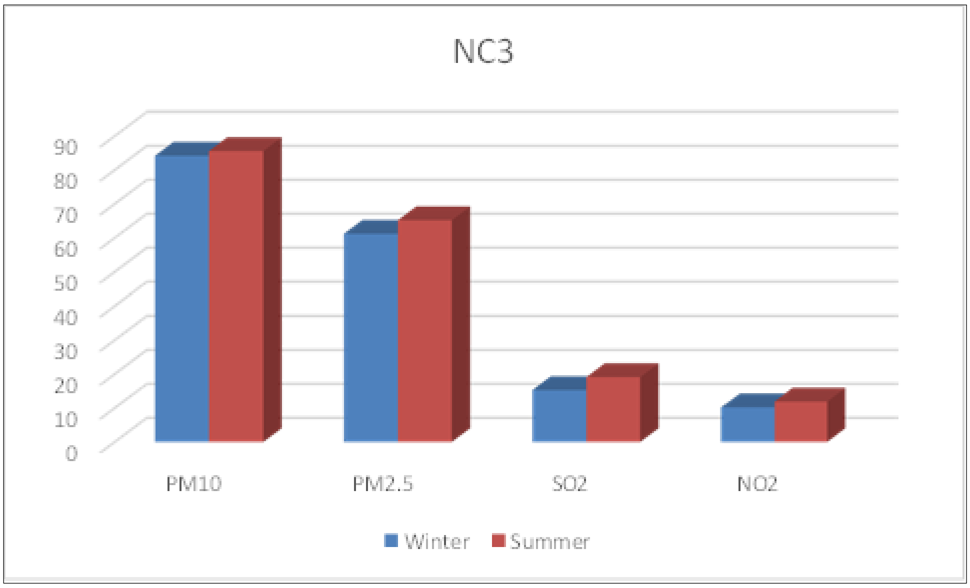

Figure 9 Variation of pollutants in Location 3

Figures 9 and 4.2.4 show the variation of air pollutants location 3 and 4 respectively and they revealed that all the parameters are well within the range of standard levels. It was revealed that pollutant concentrations vary widely for various zones.

Table 7 gives the average values of AQI comprising of various climatic conditions. It reports that location three and location for which are area at the entrance of the port and area 500m away from the port are in low air pollution status with good air quality. Location 1 and location two however has moderate air quality value.

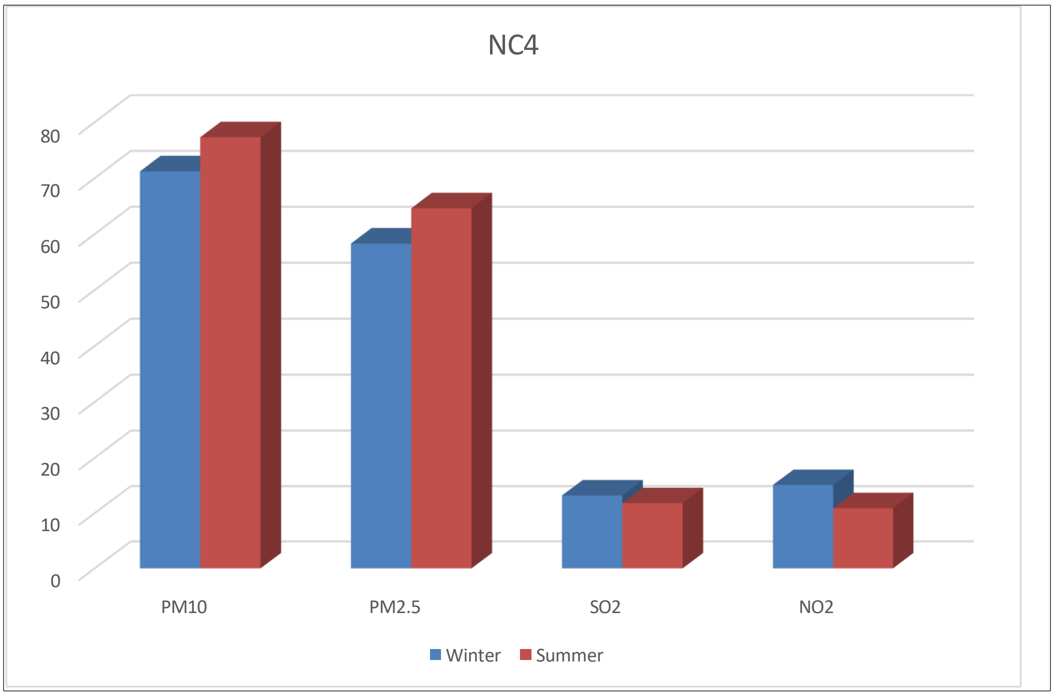

Figure 10 Variation of pollutants in Location 4

Table 13 Correlation analysis of Air pollution parameters between summer and winter period

Winter	**Pearson Correlation**	**1**	**.993****
	Sig. (2-tailed)		0.000
	N	16	16
Summer	Pearson Correlation	0.993**	1
	Sig. (2-tailed)	0.000	
	N	16	16

**. Correlation is significant at the 0.05 level (2-tailed). Source: Author's calculations and elaborations, using SPSS
Source: Author's calculations and elaborations, using SPSS

Table 14 T-Testanalysis of water pollution parameters between summer and winter

Test Value = 0						
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Winter	5.493	15	0.000	49.01250	29.9956	68.0294
Summer	5.602	15	0.000	46.01875	28.5082	63.5293

Source: Author's calculations and elaborations, using SPSS

4.3. Port Pollution Index

As reflected in table 4.3.1 below which presents the port pollution index for port Newcastle during both the summer and winter period. It shows that the port pollution index for the port under review is good for both the summer and the winter time with an index value of 26.73 and 28.56 respectively.

Table 15 Port Pollution Index

	Summer	Winter
WPI	27.73±3.41	27.39±3.03
API	23.72±0.77	32.05±1.00
PPI Port Quality	26.73 Good	28.56 Good

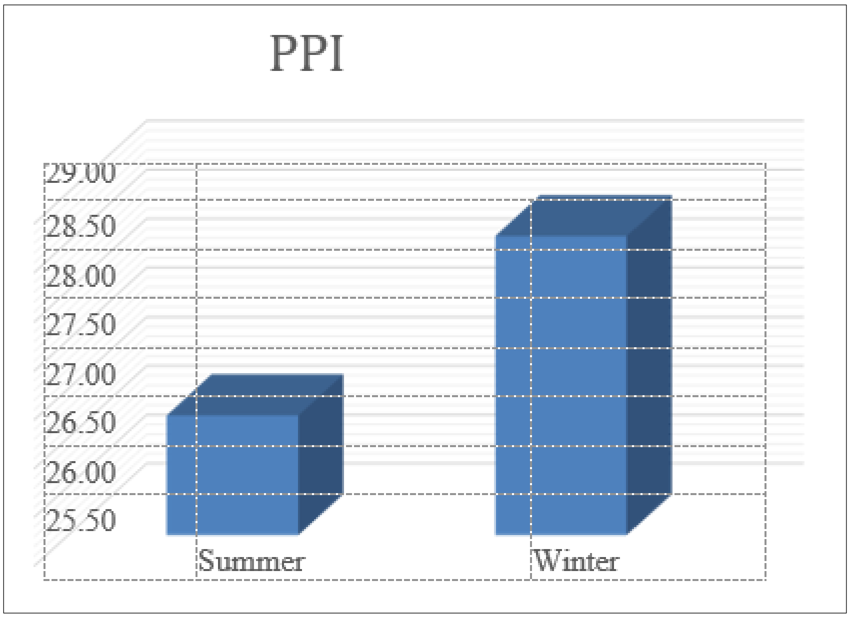

Figure 11 Port pollution index for summer and winter period

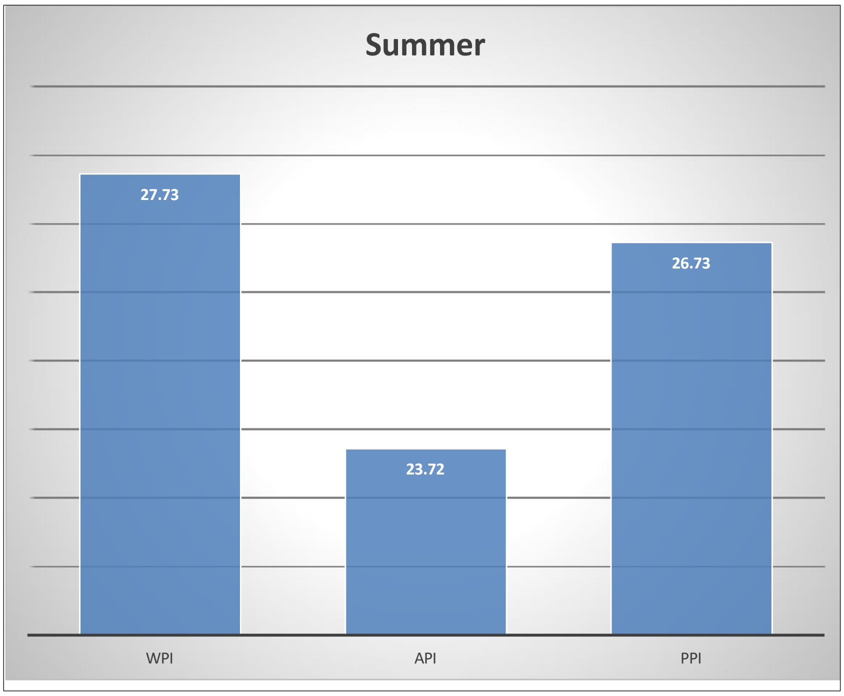

Figure 12 Pollution index for summer period

Table 16 Correlation analysis of Port pollution parameters between summer and winter period

		Summer_PPI	Winter_PPI
Summer_PPI	Pearson Correlation	1	-0.999*
	Sig. (2-tailed)		0.030
	N	3	3
Winter_PPI	Pearson Correlation	-0.999*	1
	Sig. (2-tailed)	0.030	
	N	3	3

Source: Author's calculations and elaborations, using SPSS

Table 17 T-Testanalysis of port pollution parameters between summer and winter

Test Value = 0						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Summer_PPI	17.847	2	0.003	26.67000	20.2404	33.0996
Winter_PPI	17.156	2	0.003	28.72333	21.5198	35.9269

Source: Author's calculations and elaborations, using SPSS

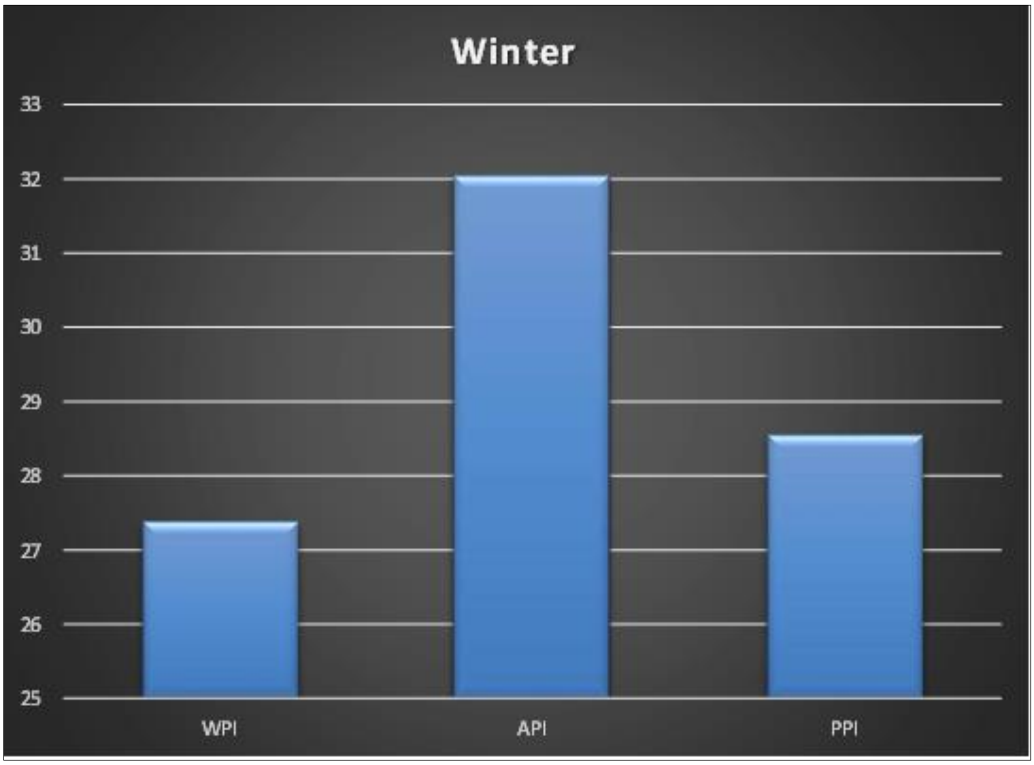

Figure 13 Pollution index for winter period

5. Conclusion

This study develops pollution index for ports with water and air parameters being considered among the various pollution types affecting ports. The water pollution index (WPI) analysis of the port area unveiled that the lower DO levels and higher fecal coliforms markedly increase the water pollution of the port which invariable increases the port pollution index as well . By analyzing data from readings taken for air quality variables namely (NO_2, SO_2, $PM_{2.5}$, PM_{10}) for the port, air pollution index (API) of four different locations with two within and two outside the port. Emissions from the ship engines are the major sources of pollution which determine the ambient air pollution condition of the zone. It is observed that the API is higher during the winter and lower during the summer which invariably means that air quality is better during the summer time compared to the winter period. This research work points out that on an average the port quality is good with a low pollution index and seasonal variation do have impact on the port quality. This invariably shows that port pollution index is an effective tool in evaluating port pollution and therefore recommends regular monitoring and management of port activities accounting for both biological and chemical toxicological profiles of the discharging activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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