

Sustainability of Italian seaports located near contaminated sites: results of an exploratory analysis

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Abstract

Introduction. Ports are strategic areas of economic importance, but they are also very critical contexts. Many Italian ports are included in contaminated sites of concern for remediation, with the presence of pressure factors that overload the burden capacity of local ecosystems and communities.

Aim. The aim of this study is to characterize Italian seaport areas through a general theoretical path on the theme of ports-sustainability-local communities, identifying the ports located in municipalities included in contaminated sites studied by the SENTIERI Project (Epidemiological Study of Residents in Italian Contaminated Sites). Many of the selected ports, are being part of complex industrial areas, where, in addition to the port area, there are other sources of environmental contamination potentially harmful to health.

Results. Excesses risk were observed for mesothelioma and for respiratory diseases, pathologies for which there is epidemiological evidence of an excess of risk associated with residence in port areas.

Discussion. The strong environmental pressures that characterize these areas make it necessary to adopt adequate environmental and health protection measures.

Key words

- seaports
- port areas
- maritime transport
- contaminated sites
- sustainability

INTRODUCTION

Italy's strategic position in the Mediterranean Sea has always favoured maritime transport and the construction of important ports distributed along its long coasts. Maritime transport is a strategic sector in international trade, and even in Italian ports it plays an extremely important role in both cargo and passenger transport.

At global level, ports are essential nodes of the maritime traffic network and of the links between maritime and land traffic. Each port differs according to dimension, activity and the type of goods handled, such as bulk goods transported directly into the ships holds, into containers, or RO-RO (Roll-on, Roll-off) ships that allow vehicles to enter and exit independently, without the use of cranes or elevators. Ports represent an important source of economic development and employment, but they are also highly anthropized geographical areas that exert considerable pressure on the environment, ecosystems, and local communities.

The different activities carried out in port areas, including maritime transport, may have negative impacts on human health and marine ecosystems, due to several

factors, such as: emissions of pollutants in the atmosphere [1-6], noise [7, 8], soil and water pollution [9-11], production of port and naval waste [12], dredging operations, exchange of ballast water and sediments identified as vectors for the transfer of harmful and pathogenic aquatic organisms between different marine ecosystems, handling of goods, internal vehicular traffic, storage of hazardous materials or accidental events such as spills of hazardous substances into the sea [13, 14].

The environmental impact of ports can be associated with three main aspects: i) problems caused by the port activity itself; ii) problems caused to the sea by ships calling into port; iii) emissions from intermodal transport networks serving the port hinterland [15]. The major ports developed in large urban contexts with a high population density and frequently incorporated into the full city context, can have a significant impact on the environmental hazardous exposures and health of local populations. The port-city relationship has changed a lot over time, and today the main ports are real nerve centres, complex logistics and shipbuilding chains with

large rear-port spaces, passenger terminals and other activities that are strongly interconnected with the surrounding areas.

In these areas, it is therefore important to pay increasing attention to combine the development of the transport system with the protection of the environment and health, implementing suitable policies to ensure sustainable development. At a national and international level, environmental policies have been launched aiming to transform maritime ports into *Green Ports* that are ports committed to a sustainable development, with a continuous improvement of environmental performances. A sustainable port is one in which the port authority, together with port users, proactively and responsibly adopt a green growth strategy and promote stakeholders' participation in mapping the long-term vision in a way that ensures that the port development meets the current needs of the region it serves, without compromising the ability of future generations to meet their own needs [16].

In Italy there are about three hundred and fifty main ports, more than fifty of which are of national importance from an administrative point of view. Many of them are in highly impacting areas on the territory, where other sources of industrial pollution are also present. Numerous Italian contaminated areas are in fact located along the coastal territory and coincide with important port areas. These areas which are currently or were in the past interested by anthropogenic activities that have produced chemical contamination of environmental media, with possible impact on human health. Some of these are contaminated sites of national interest for remediation, identifiable in relation to the characteristics of the site, as well as the quantity and the danger of the pollutants present, the impact on the surrounding environment in terms of health and ecological risk, and to the damage to cultural and environmental heritage [17].

The communities residing in districts close to port areas can suffer an overload of environmental, social and health stress compared to the communities residing in other districts, with the emergence of problems concerning Environmental Justice [18, 19], defined by the US Environmental Protection Agency as the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (<https://www.epa.gov/environmentaljustice/learn-about-environmental-justice>).

It is important to understand the measures that are being adopted in the sustainable management of ports, to improve the living and working conditions of local communities.

The objective of this study is to characterise Italian seaport areas through a general theoretical path on the theme of ports-sustainability-local communities, identifying and geo-referencing the national seaports located in the Italian municipalities included in contaminated sites studied by the SENTIERI Project (Epidemiological Study of Residents in Italian Contaminated Sites). SENTIERI is the epidemiological surveillance system

of the populations residing in the municipalities affected by the main Italian contaminated sites of interest for remediation [20]. The presence of port areas in Italy, combined with complex environmental conditions, make it important to further assess these areas in order to monitor and evaluate the environmental qualities necessary to guarantee the protection of public health through sustainable development. Indeed, environmental factors can negatively affect the health and well-being of populations, for this reason some of the main environmental health priorities of ports identified by EcoPorts, the main environmental initiative of the European Port Sector [21], will be examined factors such as the air quality, noise and the relationship with the local community.

METHODS

Selection of seaports

The seaports selected for this study are located in one of the Italian municipalities included in the Fifth Report of the SENTIERI Project. SENTIERI currently covers 46 sites (39 classified as sites of national interest and 7 of regional interest, covering a total of 316 Italian municipalities) [20]. The SENTIERI Project describes the health profiles of the populations residing in these sites, in relation to their sources of environmental contamination which include chemical plants, petrochemical plants and refineries, steel plants, power plants, steel mills, mines or quarries, production and asbestos mining, landfills, incinerators and port areas.

From the 45 sites analysed by the project, a "coastal site" criterion was adopted identifying all coastal sites with contamination extending both on land and in the sea. For many of them the "harbour area" is specifically indicated as one of the sources of contamination, but for the selection made in this work, the "coastal site" criterion was preferred because there are ports that do not fall within the boundaries of the site, but which may contribute to additional impact factors in the surrounding area.

Characteristics of the seaports selected for the study

Information on the SENTIERI contaminated sites of interest for remediation, whose municipalities include seaports selected for the study, were collected and summarised concerning i) the Italian establishing law, ii) the municipalities included in the site, iii) the land/sea extent of the contaminated areas, and iv) the current Italian Ministerial Decree defining the boundary, as retrieved from the Ministry of Ecological Transition (Ministero dell'Ambiente e della Sicurezza Energetica) website (<https://bonifichesiticontaminati.mite.gov.it>).

Information on the seaports included in this study, in relation to the coordination of ports of national importance in Port System Authorities (PSAs), was retrieved and analysed in order to characterise the activities carried out in the main Italian seaports [22]. The seaports studied were then divided into their respective PSA, by assigning them two main attributes. The first one is the univocal UN / LOCODE (United Nations Code for Trade and Transport Locations), the geographical coding scheme developed and maintained by the United

Nations Economic Commission for Europe (<https://un-ecce.org/trade/uncefact/unlocode>). The second attribute is the exact geographical location, retrieved with the geographical coordinates from Marine Traffic (<https://www.marinetraffic.com>), the provider of ship tracking and maritime intelligence. The inclusion of the port in the Trans-European Transport Network (TEN-T) was also verified [23].

Evaluations were also made to verify the presence or absence of the selected seaports on the EcoPorts website (<https://www.ecoport.com>), the main environmental initiative of the European port sector to raise awareness on environmental protection through cooperation and sharing of knowledge among ports and to improve environmental management. Ecoports is fully integrated into the European Sea Ports Organization (ESPO) (<https://www.espo.be>), the community-level representative of seaports.

Health profile of seaports populations

This study summarises the main aspect of the health profile of the populations residing in the municipalities of the selected seaports included in the SENTIERI Project. As each site includes one or more municipalities within its boundaries, a geospatial analysis was carried through the Geographical Information System (GIS) software, to identify the national seaports located in one of the SENTIERI municipalities. Main results for each Site including ports documented in the VI SENTIERI Report [20] will be summarized, focusing on the diseases classified in SENTIERI as associable with ports as a source of contamination based on the evidence from the epidemiological scientific literature [24].

Finally, some of the main environmental health priorities related to ports are described, also reported by the ESPO Environmental Report 2022 [21].

RESULTS

Based on the SENTIERI Project, 17 contaminated sites were selected for this investigation. These sites met the criteria outlined in the methods section. 18 seaports located in one of the municipalities included in these sites were identified (Figure 1). The ports are more numerous than the sites because the site of Priolo includes two ports (Syracuse and Augusta). The Italian regions with the greatest presence of ports located near contaminated sites are Sicily and Apulia: 4, Tuscany: 3, Sardinia: 2, while Calabria, Friuli Venezia Giulia, Veneto, Marche and Liguria have one seaport. Information on the Italian contaminated sites of interest for remediation establishing law, the municipalities of the site, the land/sea extent of the contamination, and the current Italian Ministerial Decree defining the boundary, are reported in Table 1.

In terms of sources of contamination, most of these sites are characterised by the presence of complex industrial settings, 82% (14 out of 17) including chemical plants, 65% (11/17) with petrochemical and/or refinery industry, and 53% (9/17) including both chemical plants and petrochemical/refinery industry. Moreover, 30% of sites have a steel factory together with chemical or petrochemical/refinery plant. 10 sites (59%) already



Figure 1

18 Italian seaports located in one of the municipalities of 17 contaminated sites included in the SENTIERI Project (Epidemiological Study of Residents in Italian Contaminated Sites). The Priolo Site includes two seaports: Syracuse and Augusta.

included, by Ministerial Decree, an harbour area in the site boundaries.

During the economic development of the 1960s these areas were chosen for the construction of major industrial centres precisely because of the presence of infrastructure such as ports, airports or railways, as the case of Gela (Sicily), Porto Torres (Sardinia) and other localities which later became contaminated sites.

Some of the analysed port areas in this study are internal or close to the borders of the sites and in some cases involve both land and sea areas. Many of them have developed in conjunction with important industrial plants, close to urban environment and, at times, with industrial piers that occupy much of the space available in the port. The marine-coastal areas included in these contaminated sites are generally made up of port areas, lagoons, coastal stretches, and river mouths, where there is often the concomitance of various high-impact industrial activities, uncontrolled landfills, military arsenals, shipyards, port areas with high maritime traffic, etc. Thus, the natural conditions of these places have been altered by an input of contaminants into the aquatic environment or as a result of physical changes, such as the modification of the shoreline due to the construction of anthropogenic activities [25].

In Italy in 2016, the port reorganization for the coordination of ports of national importance led to establish sixteen new PSAs, defined as special non-economic public bodies entrusted with the management of some of the 57 main national ports [22]. Table 2 shows the 18 selected seaports divided into their respective PSA.

Eight of the selected seaports (La Spezia, Livorno, Augusta, Bari, Taranto, Ancona, Venezia-Marghera

Table 1

Description of the 17 main Italian contaminated sites selected in this study of interest for remediation and of the 18 seaports located in one of the municipalities including in the sites

Region	Site name and establishing law	Municipality/ municipalities	Sources of emissions [§]	Extension (ha)		Current perimeter Italian Decree	Seaport located in one of the municipalities of site
				Land	Sea		
LIGURIA	Pitelli L. 246/98	La Spezia, Lerici	A, AP, C, D, E	4 km ² *	1,564*	Decree of the Minister of the Environment and Land and Sea Protection of 11 January 2013	Port of La Spezia
TUSCANY	Massa e Carrara L. 426/1998	Carrara e Massa	A, AP, C, D, I, P&R, S	116		Decree of the Minister of the Environment and Land and Sea Protection of 29 October 2013	Port of Carrara
	Piombino L. 426/1998	Piombino	AP, C, D, E, S	931	2,117	Decree of the Minister of the Environment January 10, 2000	Port of Piombino
	Livorno L. 468/2001	Livorno	AP, P&R	206		Decree of the Minister of Ecological Transition November 17, 2021	Port of Livorno
SARDINIA	Aree industriali di Porto Torres L. 179/2002	Porto Torres e Sassari	AP, C, D, E, P&R	1,874	2,748	Decree of the Minister of the Environment and the Protection of the Territory and the Sea of 21 July 2016	Port of Porto Torres
	Sulcis - Iglesiente - Guspinese D.M. 18/09/2001, n. 468	Portoscuso + 38 other municipalities	C, D, M	19,751	32,416	Decree of the Minister of the Environment and Land and Sea Protection of 28 October 2016	Port of Portovesme (Portoscuso)
CALABRIA	Crotone - Cassano - Cerchiara D.M. 18/09/2001, n. 468	Cassano allo Ionio, Cerchiara di Calabria, Crotone	C, D	874	1,448	Decree of the Minister of the Environment and Land and Sea Protection of 9 November 2017	Port of Crotone
SICILY	Milazzo L. 23 dicembre 2005, n. 266	Milazzo, San Filippo del Mela, Pace del Mela, San Pier Niceto e Monforte San Giorgio	A, D, E, P&R, S	549	2,198	Decree of the Minister of the Environment and Land Protection of 11 August 2006	Port of Milazzo
	Gela L. 426/1998	Gela	C, D, P&R	795	4,583	Decree of the Minister of the Environment January 10, 2000	Port of Gela
	Priolo L. 426/1998	Augusta, Priolo, Melilli and Siracusa	A, AP, C, D, P&R	5,814	10,129	Decree of the Minister of the Environment and Land Protection of 10 March 2006	Port of Siracusa and Port of Augusta
APULIA	Bari - Fibronit D.M. 18/09/2001, n. 468	Bari	A	15		Decree of the Minister of the Environment and Land Protection of 8 July 2002	Port of Bari
	Brindisi L. 426/1998	Brindisi	AP, C, D, E, P&R	5,851	5,597	Decree of the Minister of the Environment January 10, 2000	Port of Brindisi
	Taranto L. 426/1998	Taranto	AP, D, P&R, S	4,383	7,006	Decree of the Minister of the Environment January 10, 2000	Port of Taranto
	Manfredonia L. 426/1998	Manfredonia	C, D	216	855	Decree of the Minister of the Environment January 10, 2000	Port of Manfredonia
MARCHE	Falconara Marittima L. 31 luglio 2002, n. 179	Falconara Marittima	C, E, P&R,	108	1,165	Decree of the Minister of the Environment and Land Protection of 26 February 2003	Port of Falconara/ Port of Ancona
VENETO	Venice (Porto Marghera) L. 9 dicembre 1998, n. 426	Venice	AP, C, D, P&R	1,618		Decree of the Minister of the Environment and the Protection of the Territory and the Sea of 22 December 2016	Port of Venice (Marghera)
FRIULI VENEZIA GIULIA	Trieste D.M. 18/09/2001, n. 468	Trieste	AP, C, P&R, S	435	1,196	Decree of the Minister of Ecological Transition March 16, 2021, n. 95	Port of Trieste

*For sites within the competence of the regions, as the case of Pitelli site, the information was recovered from the official documents of the Region (http://www.comune.laspezia.it/export/sites/SPEZIAnet/Aree_tematiche/Ambiente/Focus/bonifiche/doc/Microsoft-Word-descrizione-pitelli.pdf).

§Legend of acronyms of environmental sources of contaminations (20): A: asbestos/other mineral fibres; AP: harbour area; C: production of chemical substance/s; D: landfill; E: electric power plant; I: incinerator; M: mine/quarry; P&R: petrochemical plant and/or refinery; S: steel industry.

Table 2

Geographical characteristics and other information of the seaports located in the municipalities of the contaminated sites of the SENTIERI Project (Epidemiological Study of Residents in Italian Contaminated Sites)

Port located in one of the municipalities of the contaminated site	The Italian Port System Authorities (PSAs)	UN/LOCODE	Latitude/Longitude	Trans-European Transport Network (TEN-T)	EcoPorts*
Port of La Spezia	PSA of the Eastern Ligurian Sea	ITSPE	N 44° 06' 16.98" E 009° 50' 15.01"	Core network	
Port of Carrara	PSA of the Eastern Ligurian Sea	ITMDC	N 44° 01' 55.63" E 010° 02' 26.21"	Comprehensive network	
Port of Piombino	PSA of the North Tyrrhenian Sea	ITLIV	N 43° 33' 46.12" E 010° 18' 22.18"		Ecoports network: ISO14001 Certified EMAS Certified
Port of Livorno	PSA of the North Tyrrhenian Sea	ITPIO	N 42° 55' 57.50" E 010° 32' 56.25"	Core network	Ecoports network: ISO14001 Certified EMAS Certified
Port of Porto Torres	PSA of the Sardinian Sea	ITPTO	N 40° 50' 31.62" E 008° 23' 57.17"	Comprehensive network	
Port of Portovesme	PSA of the Sardinian Sea	ITPVE	N 39° 11' 42.12" E 008° 23' 42.93"	Comprehensive network	
Port of Crotona	Southern Tyrrhenian and Ionian Sea	ITCRV	N 39° 04' 48.33" E 017° 08' 14.00"		
Port of Milazzo	PSA of the Strait	ITMLZ	N 38° 13' 04.83" E 015° 15' 33.46"	Comprehensive network	
Port of Gela		ITGEA	N 37° 02' 53.24" E 014° 14' 56.36"	Comprehensive network	
Port of Augusta	PSA of the Eastern Sicily Sea	ITAUG	N 37° 11' 57.10" E 015° 12' 51.02"	Core network	
Port of Siracusa		ITSIR	N 37° 03' 41.91" E 015° 17' 04.94"	Comprehensive network	
Port of Bari	PSA of the Southern Adriatic Sea	ITBRI	N 41° 08' 11.63" E 016° 51' 29.19"	Core network	Ecoports network
Port of Brindisi	PSA of the Southern Adriatic Sea	ITBDS	N 40° 38' 53.22" E 017° 57' 34.30"	Comprehensive network	Ecoports network
Port of Taranto	PSA of the Ionian Sea	ITTAR	N 40° 29' 20.00" E 017° 11' 16.33"	Core network	
Port of Manfredonia	PSA of the Southern Adriatic Sea	ITMFR	N 41° 37' 31.13" E 015° 55' 07.89"		Ecoports network
Port of Falconara/ Port of Ancona	PSA of the Central Adriatic Sea	ITFAL ITAOI	N 43° 38' 24.84" E 013° 23' 08.91" N 43° 37' 10.33" E 013° 30' 08.69"	Core network	
Port of Venice/ Marghera	PSA of the Northern Adriatic Sea	ITVCE	N 45° 26' 11.31" E 012° 17' 19.17"	Core network	
Port of Trieste	PSA of the Eastern Adriatic Sea	ITTRS	N 45° 38' 16.37" E 013° 45' 50.74"	Core network	

*For some ports, ISO14001 and EMAS (Eco-Management and Audit Scheme) Environmental Management Standards are indicated.

and Trieste) are part of the Core network of the TEN-T based on a "corridor approach". The remaining seven ports (Carrara, Porto Torres, Portovesme, Milazzo, Gela, Siracusa and Brindisi) are part of the comprehensive network, a global network that ensure full coverage of the EU territory and accessibility to all regions. The TEN-T is divided into these two levels for the development of the international network. The most handled goods in Italy are energy products (coal, coke, crude oil, refined petroleum products, natural gas) [26].

As for the Ecoports European port sector environmental initiative, the network currently includes 108 member ports. The Italian ports included are the Port of Genoa, North Tyrrhenian Ports Sea, and Southern Adriatic Sea Port Authority. An environmental certification recognized at a European level, is issued to ports that comply with stringent eco-sustainability parameters. Among the ports included in the contaminated sites that are part of the Ecoports network, Livorno and Piombino are certified with the Environmental Management System (EMS) ISO14001 and Eco-Management

ment and Audit Scheme (EMAS). The port of Brindisi, while part of the network, is currently working to obtain environmental certifications (<https://www.adspmam.it/i-porti/network-ecoports>).

Italian Port System Authorities have dedicated a section of their websites to Environmental Policy and Protection and a series of initiatives and publications, which will be considered in the discussion section, aimed at developing a green port policy with particular special attention to the port-city relationship.

Health profile of the Italian seaports included in SENTIERI Project

SENTIERI identified the following diseases with "Limited Evidence" of health risk for the populations living in the neighbourhood of port areas as sources of contamination: pleural mesothelioma/pleural malignant tumors, respiratory system diseases and asthma [24]. Table 3 shows results of the VI SENTIERI report for mortality and hospitalization for such diseases.

Almost all sites (10 out of 12, 83%) with the inclusion of ports as sources of contamination show an excess of risk for mesothelioma in men for both the mortality and hospitalization outcomes. In the same sites, many excesses of risk of mesothelioma are present in women,

albeit based on a lower number of cases. The picture is different for the group of respiratory diseases for which higher than expected risk in both outcomes and genders concern 4 sites: Pitelli, Trieste, Porto Torres, and Bari; in other sites, this pattern is not consistent across genders and/or outcomes, while in the sites of Livorno and Piombino, the risk is prevalently lower than expected. Results for asthma are not shown in the Table 3 since they are often below the privacy threshold of three observed cases.

As to the five SENTIERI coastal sites with ports (Table 3), an excess mortality risk for mesothelioma in the Manfredonia site, and an excess risk of hospitalization in the Gela site were observed among males, while no excess of risk was observed in women. An excess of risk related to respiratory diseases in both health outcomes and genders was observed in the site of Sulcis Iglesiente Guspinese. In the other four sites mesothelioma and respiratory diseases were in excess for both mortality and hospitalization but only in males.

Sustainability and environmental health priorities for ports

The increasing attention to the issue of sustainable development in the port area has led the recent reform of port legislation to introduce significant innovations in

Table 3

Summary table of results of SENTIERI Project (Epidemiological Study of Residents in Italian Contaminated Sites) for mortality (2013-2017) and hospitalization (2014-2018) for mesothelioma and respiratory system diseases

A - PLEURAL MESOTHELIOMA / PLEURAL MALIGNANT TUMORS⁵

Site	Mortality males*		Hospitalization males**		Mortality females*		Hospitalization females**	
	OSS	SMR (CI 90%)	OSS	SHR (CI 90%)	OSS	SMR (CI 90%)	OSS	SHR (CI 90%)
SENTIERI - Sites with port area as source of contamination								
Pitelli ⁺	74	263 (217-318)	72	219 (180-266)	11	148 (91-243)	16	160 (106-241)
Venice - Porto Marghera ⁺	42	189 (147-244)	66	197 (161-241)	11	133 (81-217)	19	137 (94-199)
Trieste ⁺	45	133 (104-169)	99	349 (296-411)	7	121 (66-223)	17	145 (97-215)
Massa e Carrara ⁺	18	225 (153-331)	30	251 (186-338)	7	386 (209-712)	7	138 (75-254)
Livorno ⁺	45	411 (322-525)	50	306 (242-386)	14	580 (375-897)	14	206 (133-318)
Piombino	6	240 (124-464)	9	244 (142-419)	<3		3	201 (80-503)
Bari ⁺	34	195 (148-259)	51	187 (148-235)	13	299 (190-471)	18	176 (120-259)
Brindisi ⁺	9	204 (118-350)	19	271 (186-395)	<3		<3	
Taranto ⁺	40	366 (282-474)	50	286 (227-361)	10	359 (214-600)	25	377 (271-523)
Aree industriali di Porto Torres ⁺	8	119 (67-211)	14	98 (63-152)	<3		11	270 (165-441)
Milazzo ⁺	<3		<3		<3		<3	
Priolo ⁺	20	208 (144-300)	35	218 (165-287)	8	386 (218-685)	11	235 (144-384)
SENTIERI - Coastal sites with ports								
Falconara Marittima ⁺	5	352 (171-723)	4	137 (62-306)	<3		<3	
Sulcis Iglesiente - Guspinese	13	103 (66-162)	30	113 (84-152)	<3		5	71 (35-146)
Manfredonia	<3		5	89 (43-184)	<3		<3	
Crotone ⁺	3	146 (58-365)	4	84 (38-187)	<3		3	195 (78-488)
Gela	6	170 (88-329)	10	170 (101-284)	<3		<3	

Continues

Table 3
Continued

Site	Mortality males*		Hospitalization males**		Mortality females*		Hospitalization females**	
	OSS	SMR (CI 90%)	OSS	SHR (CI 90%)	OSS	SMR (CI 90%)	OSS	SHR (CI 90%)
SENTIERI - Sites with port area as source of contamination								
Pitelli+	318	109 (99-120)	2,994	123 (119-127)	287	105 (95-115)	2,794	124 (120-127)
Venice - Porto Marghera+	531	87 (81-94)	5,990	99 (97-101)	638	102 (95-108)	5,632	103 (101-105)
Trieste+	641	118 (111-126)	5,867	116 (113-118)	687	111 (104-118)	5,716	122 (119-125)
Massa e Carrara+	338	124 (114-136)	3,008	103 (100-106)	285	101 (92-112)	2,710	99 (96-102)
Livorno+	337	82 (75-90)	3,415	84 (82-86)	343	90 (82-99)	3,068	83 (81-86)
Piombino	97	101 (86-120)	742	87 (82-92)	62	74 (60-91)	606	79 (74-85)
Bari+	34	195 (148-259)	51	187 (148-235)	13	299 (190-471)	18	176 (120-259)
Brindisi+	158	97 (85-111)	1,763	99 (95-103)	152	117 (103-134)	1,635	116 (112-121)
Taranto+	422	103 (95-112)	4,690	107 (104-110)	338	104 (95-113)	3,766	107 (104-110)
Aree industriali di Porto Torres+	273	121 (109-133)	3,469	112 (109-115)	261	142 (128-157)	3,092	121 (117-125)
Milazzo+	88	91 (76-108)	920	99 (93-104)	65	101 (82-124)	679	94 (88-100)
Priolo+	297	86 (78-94)	4,570	122 (119-125)	215	95 (85-106)	3,514	123 (120-127)
SENTIERI - Coastal sites with ports								
Falconara Marittima+	50	74 (59-93)	601	97 (90-103)	37	67 (51-88)	520	100 (93-108)
Sulcis Inglesiente - Guspinese	652	147 (138-157)	6,228	111 (108-113)	420	123 (114-134)	4,840	109 (107-112)
Manfredonia	111	75 (64-87)	1,689	113 (109-118)	81	75 (63-90)	1,307	118 (113-123)
Crotone+	79	94 (78-113)	1,191	110 (104-115)	55	99 (79-123)	883	108 (102-114)
Gela	125	102 (88-118)	1,679	113 (109-118)	72	106 (87-128)	1,382	(120-131)

*Number of observed cases (OSS), standardized mortality ratio (SMR), 90% confidence intervals (CI 90%) (ratio * 100).

**Number of observed cases (OSS), standardized hospitalization ratio (SHR), 90% confidence intervals (CI 90%) (ratio * 100).

+Presence of asbestos or presence of shipbuilding activities in which the presence of asbestos is recognized.

§Estimates are not reported for privacy reasons under <3 cases.

terms of sustainability. The Legislative Decree 169/2016 provides that the Port System Authorities promote an Energy and Environmental Planning Document of the Port System to define the strategic guidelines for an environmental energy planning with the aim of improving the environmental quality of the port area, to safeguard health and the well-being of local communities and workers and increase the competitiveness of port systems. Art. 5 introduces article 4-bis to law No. 84/1994 ("Reorganization of port legislation": https://www.assoporti.it/media/11132/testo-legge-84_94-vigente-versione-2022.pdf) for promote the drafting of the energy and environmental planning document of the Port System with the aim of pursuing adequate objectives, with reference to the reduction of CO₂ emissions (<https://www.assoporti.it/it/autoritasistemaportuale/atti-adsp-italiane/documento-di-pianificazione-energetico-ambientale-del-sistema-portuale-dpeasp>). Below is a description of the main environmental priorities of the ports among the 10 reported by the European Port Sector [21].

Climate change

Climate change has become the top environmental concern for the port sector in 2022, overtaking air quality. Attention to climate change in recent years has in

fact grown a lot, becoming a fundamental objective for the port industry. Ship traffic emissions contribute to global climate impacts and degrade local air quality. More stringent environmental regulations are adopted by the authorities to limit emissions of pollutants and greenhouse gases (GHG) resulting from energy consumption.

Air quality

Air quality move down on the second place of environmental concern of the port sector. Maritime transport is a significant source of emissions of sulfur dioxide (SO₂), nitrogen oxide (NO_x), particulate matter (PM) and volatile organic compounds (VOCs), and reduction policies have been introduced for these emissions, starting with the MARPOL Convention (MARine POLLution) 73/78 [27]. Air pollution in port areas can come from vessels navigating in the port or at berth, port operations, and relating land traffic in the area. Most of these ports are near urban areas and then air quality is very important to safeguard the health of the local community and the port but also the port workers. Furthermore, the ports selected for this study are close to sites of industrial activity often polluting the air, and for this reason the ports could add further

emission contributions to an already critical environmental situation.

Noise

There are many potential sources of noise in the port area, which can be ambient and/or, underwater. It is also very important in the port-city relationship because, like air pollution, exposure to noise can also have serious health effects. Noise can come from machinery and cranes used for loading and unloading goods, but also from the use of ship's auxiliary engines in ports. Noise can disturb people living near ports, harbour wildlife and surrounding habitats. In addition, the industrial activities often present in ports (oil, shipbuilding, etc.) contribute to the already complex port situation, by adding additional sources of noise.

Relationship with the local community

The relationship with the local community is the sixth environmental priority. It is extremely important from both the health point of view and the quality of life of the populations living or working near these areas. Many great Italian ports are incorporated into the urban context and many neighbourhoods border the port area which often causes problems and concerns to the local community, as atmospheric pollution, noise, road traffic.

The need to identify and mitigate environmental inequalities in ports has been addressed by the Environmental Protection Agency which has developed a guidance document "Environmental Justice Primer for Ports. The Good Neighbour Guide to Building Partnerships and Social Equity with Communities" [28] with the aim of helping port authorities and decision makers to identify and respond to the needs of resident communities, and to build trusted relationships with the local context during planning activities. In Europe the ESPO Award for social integration has been established instead, and a Code of good practices has also been published to strengthen the relationship between port and city.

Other environmental priorities of the ports are energy efficiency, water quality, ship waste, port waste, port development (land related) and dredging operations.

DISCUSSION

This paper presents, for the first time to our knowledge, an overall picture of the Italian seaports located in complex areas characterised by the presence of multiple environmental pressures. The attention has been focused on ports located in the municipalities included in the contaminated sites of concern for remediation, given that these areas are more critical than others due to the additional impact of the surrounding industrial activities, which may further increase the health risks for the local communities and workers, as well as for the ecosystems. Industrial activities have left a legacy of thousands of areas contaminated by toxic chemicals that represent a current or future potential threat to the health [29]. In the Italian marine-coastal and transitional areas included in National Priority Contaminated Sites (NPCSS), the extent of the contamination

is directly related not only to type of activity and the amount of the released contaminants but also to the geomorphological, bathymetric, and sedimentological characteristics of the area [25].

The results of the SENTIERI Project report excess risk for pathologies for which there is *a priori* epidemiological evidence of a causal association with ports as sources of contamination, in most of the sites for mesothelioma, and in some sites for the group of respiratory diseases [20].

It is probable that the criticalities observed in the health profile of population living in seaports are related to the complex environmental contamination, and in particular are linked to air pollution, deriving from the presence of multiple anthropic and industrial activities in most of the sites that include harbours. Furthermore, an excess risk of malignant tumors of the pleura/mesotheliomas was also observed in these sites, highlighting the presence of asbestos, classified as a human carcinogen by IARC [30]. The results highlighted that 13 sites examined show an excess risk of pleural mesothelioma (hospitalization and mortality), for example in sites where asbestos is present such as in Pitelli, Massa Carrara, Milazzo, Priolo, etc. In the site of Pitelli for example, considering data on asbestos exposure [31] methods show that in 84% of cases asbestos exposure occurred in the workplace, including in the shipbuilding sectors. Though asbestos as environmental exposure is explicitly mentioned in the Decrees for only some of these sites, all areas include port or shipyards, where the presence of asbestos is well recognized. In the excesses for asbestos-related pathologies, an important role of exposure to asbestos in the workplace can be conceivable. The presence of asbestos or shipbuilding activities (where the use of asbestos is recognised) is documented in 11 of the sites examined. In addition to industrial sites, the impact on health from exposure to asbestos affects a wide range of activities and work and living environments characterized by the "in place" presence of this material [32].

Excesses of risks in both genders, particularly for mesothelioma, would lead to hypothesize a non-negligible role of environmental exposures, as occupational activities involving asbestos use were mainly carried out by men.

However, regarding the respiratory diseases, a possible synergistic effect between the various factors analysed, such as the lifestyle of the population, the environmental emission sources and occupational factors should also be considered.

The ports always affect, as a source of contamination, only a sub-area of the sites' territory, and usually a municipality, while the health results in SENTIERI concerns a set of municipalities. In a few cases a site corresponds to a single municipality, and those examined include Piombino, Falconara Marittima, Bari, Brindisi, Gela and Venice. Furthermore, even within the same municipality, some neighbourhoods may be, or may have been, potentially exposed to pollutants, as some areas are closer to port activities. In addition, port areas can be located inside or outside the contaminated site area and the boundaries can vary over time with

increases or decreases in the affected surfaces. A port area, even if formally not internal to the site, can still potentially represent an additional source of impact for the territory and the local community.

This limitation of SENTIERI underlines the need to have an accurate monitoring of the impact of port emissions, especially in the areas adjacent to the ports and the need for analytical epidemiological studies to verify if the presumed causal factor(s) is/are associated to the pathology under study.

There are different sources of emissions in these areas, and it is not easy to identify the precise apportionment of the sources in order to evaluate the contribution of each one. Moreover, factors related to the conformation of the territory and the influences of local meteorology must also be examined: meteorology, ship positioning and engine type influence the port role on nearby cities air quality [33]. Geographically, many seaports on the peninsula have coastal hills that limit the widespread dispersion of emissions and therefore regularly increase the level of local pollutants [34]. It would be important, especially for these areas, to create targeted studies on sources apportionment to obtain a complete chemical characterization. Several studies have highlighted the difficulty of identifying the impact of ship emissions in situations where there is the joint presence of industrial, port and urban emissions, while also considering the weather conditions and the territorial morphology; all factors that can also affect the exposure of the population [2, 35]. For example, Gobbi *et al.* [33] distinguishes emissions originated in the port area from the ones pertaining to the city of Civitavecchia, the mayor port of Rome. This is a critical area due to the simultaneous presence of many industrial agglomerations. The study identified main points of emission and their contribution to the measured loads of regulated pollutants as NO_2 , PM_{10} , and SO_2 , representing a reasonable estimate of the ports area contribution to the air pollution at the port-city border and a good quantification of sources of unregulated pollutants.

As described by Merico *et al.* [36], port logistics also play an important role in determining the total impact of maritime transport on the air quality of nearby coastal areas, since the dimensional distributions of maritime contributions are different for the manoeuvring and helling phases.

Just as difficult is the accurate field measurements of port noise, given the complexity of the port area. Port noise prevention and management are also rendered difficult by the quite limited knowledge of specific sources in scientific literature, as reported in the study carried out by Fredianelli *et al.* [37], which reports field measurements as difficult to perform and interpret when multiple types of sound emitters are mixed and confused with each other.

Each port examined is characterized by its own peculiarities due to its geographical morphology or its type of productivity, which makes the comparison among different realities it is very difficult. Brewer's study [34] notes that, although there are a variety of sources regarding data on ship activity and emissions in Italian

ports, there are notable differences in the lists of indicators, and for this reason it is not currently possible to carry out a complete comparison of port indicators but only a summary of the overall systems and data concerning each port.

However, the ESPO report finds that ports are demonstrably improving their environmental management [21] and major Italian ports, including those examined in this study, have undertaken major environmental initiatives to become green ports. Some of them are part of the Ecoports network and have achieved specific environmental certifications, while others are still working on it. Fifteen ports examined are part of the TEN-T, and this allows for a better use of infrastructures, a reduction of the environmental impact of transport, greater energy efficiency and greater safety.

Many of the port authorities consulted have already published, or are about to do so, sustainability reports to measure their contribution to achieving sustainable development. For example, in the sustainability report of La Spezia and Carrara ports, the concrete contribution to achieve 12 of the 17 Sustainable Development Goals (SDGs) of the UN 2030 Agency was assessed, which concern energy efficiency, air quality monitoring, and sustainable cities and communities, the fight against noise pollution and the protection of life underwater, with particular attention to marine protected areas [38]. Many of them, as described on their websites, have undertaken actions of urban regeneration and improvement of the quality of the city communities, with urban and environmental enhancement projects of the port waterfronts (the urban strip overlooking the sea), buffer zones located on the border between the port and the city, and sound absorbing barriers.

CONCLUSIONS

Seaports are strategic areas of economic importance but the strong environmental pressures that characterize them make it necessary to have adequate environmental and health protection measures. The environmental performance of ports represents an element of competitiveness in the panorama of international traffic, and for this reason it is necessary to harmonize the relationship between port and city, promoting knowledge on environmental issues and involving all interested parties in decision-making processes, to encourage concrete actions for the benefit of the entire local community and to ensure sustainable development for all activities to be implemented.

It is crucial to encourage the use of standardized and homogeneous methods and approaches in the European Community for monitoring pollutants generated by port activities and to make the data comparable and shareable. It would be also advisable to launch specific epidemiological surveillance plans in port areas to investigate criticalities in the health profile of the populations residing in these complex areas.

The environmental health issues in complex seaports areas are therefore best addressed with a strong sustainability perspective, considering both the human and ecosystem health, and the social context. These aspects require an intersectoral approach leading to a social ne-

gotiation, where the legitimate needs and aspirations of residents, workers, and investors, are considered in a balanced cost-benefit analysis process.

In Italy a focus on Environmental Justice has been launched for contaminated sites, since usually the communities living in or close to contaminated areas have socioeconomic fragilities, in addition to being affected by the exposure to pollutants [39, 40]. Seaports are indeed frequently represented in Italian contaminated sites assessed by the SENTIERI Project (about 40% based on our study). It is therefore important to extend attention on Environmental Justice also to the communities living in the neighbourhoods close to the ports, even more so when it comes to critical areas such as those of contaminated sites. It is also important to carry out adequate analytical epidemiological studies on the communities living in Italian seaport, trying to address also the mobility of local populations and to account for residential and occupational exposure to key contaminants. To this aim, a polycentric cohort mortality study performed in five Italian harbours, including active and retired workers (longshoremen) employed between 1960 and 1981, found an excess of lung cancer in four out of five harbours [41].

Studies on the impacts that directly affect the daily lives of these local populations, who often bear a disproportionate burden of port activities, are also desirable. Residents' concern can be reduced by improving

direct access to technical and scientific information in lay language and by developing specific risk reduction strategies to improve the conditions and quality of life in the neighbourhood, thus enhancing the cultural and identity heritage of the Italian port cities.

A comprehensive analysis of different environmental health scenarios can support the identification of policies for climate change mitigation and adaptation, at global and local levels. Public health actions in some areas, like those represented by seaports in industrially contaminated sites, can help to achieve multiple health benefits while reducing emissions.

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Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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