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Assessment of the tools to monitor air pollution in the Spanish ports system

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Abstract

In general, seaports are located in urban areas or in their environs, whereby their activity has a very direct effect on the population. Therefore, reducing environmental contamination and improving air quality are priority management goals for port authorities (PAs). In Spain, the state-owned seaport system consists of 28 PAs that manage 46 ports. Its regulation received a major impulse through the enactment of the Spanish Ports Law in 2010. The law establishes especially the obligation that, annually, the PA prepare a sustainability report with 111 sustainability indicators. This study is founded on a database that was created with information from the reports from 2011 to 2016. A statistical analysis studies the evolution of the implementation of 20 measures for the reduction of atmospheric contamination in Spanish ports and identify the strategic lines carried out by the PAs and the measures adopted depending on the size of the ports.

Keywords Port management · Environmental management · Indicators · Sustainability · Legislation

JEL classification Q01 · Q28 · Q56 · K32

Introduction

Seaports, both because of their location in urban areas or in their environs and also because of their activity, are a source of environmental contamination that mainly affects air quality, a fact that has consequences on human health. This fact, among others, has impelled the adoption of concrete measures to minimise this impact, demanding a proper and adequate management of the sources of air pollution in port systems to mitigate harmful effects on health (Bailey and Salomon 2004; Sorte et al. 2018).

Port systems have not remained on the sidelines of environmental awareness. This awareness began to acquire greater relevance in all areas as of the 1990s. The American Association of Ports Authorities (AAPA), the public ports alliance between the USA, Canada, the Caribbean and Latin America, were pioneers in the adoption of institutional measures, by proposing a series of recommendations regarding environmental issues for the groups of ports that belong to this association (AAPA 1998). In Europe, several initiatives have also originated, such as the European Sea Ports Organisation (ESPO) in 1994, which published a first version of the Environmental Code of Practices, which was later revised in 2001 and 2003 (ESPO 2012a). On the other hand, the ECOinformation Project (1997) set forth two very clear goals in matters of port environmental policy: identifying its main problems and subsequently categorising them to later develop a port classification. By using a survey-based methodology and repeating the same survey over several years, the most significant environmental impacts were classified in a number of lists. Air quality was underlined as the main and fundamental goal within port management, resulting from the surveys and proposed strategies (Darbra et al. 2004, 2005).

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In Spain, the most outstanding achievement in this regard is MESOSPORT (2007), led by the Port Authority of Valencia, and developed based on prior studies by Crespo Soler et al. (2007). It sets forth an approach to a methodology that served government port authorities to draft sustainability reports based on the three aspects of sustainable development (economic, social and environmental) following the guidelines of the Global Report Initiative (GRI 2009). The result was reflected in a document titled *Guidelines for the drafting of sustainability reports in the Spanish port system* (Puertos del Estado 2008). From then on, a number of Spanish ports voluntarily began to develop reports based on those principles.

The importance of controlling air quality in port systems

In order to abate the impact of air pollution on port activities, Gupta et al. (2005) emphasised the need to monitor and control these activities, an opinion that was later endorsed by Dinwoodie et al. (2011).

De Langen (2007) considers there is a common problem in all ports: port development leads to a conflict of interest with the protection of the environment, with the inhabitants that live near port areas and with the labour conditions of port workers. This is why the role of stakeholders is key in the environmental process. This is stated by Hall et al. (2013) who consider that mutual collaboration between these stakeholders and the port authority (PA) is essential for establishing and defining sustainable policies that respect the environment.

There is plenty of further literature that on the whole mainly favours the definition, identification and proposals for the selection of emission indicators in port matters. The ESPO, referring to the five indicators of the Port PeRformance Indicators: Selection and Measurement (PPRISM) project, introduces the category of environmental indicators for ports (ESPO 2012b). Puig et al. (2014) developed a method for identifying and selecting environmental indicators for ports, known as environmental performance indicators. Accioro et al. (2014) pointed out the importance of having environmental performance indicators in ports, concluding that their implementation and use significantly reduces the sources of greenhouse gases. On the other hand, after analysing the priorities of 79 ports members of the ESPO, Puig et al. (2015) concluded that during the period 1996–2013, air quality was a residual issue that later became one of high priority.

Puente-Rodríguez et al. (2016) designed a fourfold proposal of port environmental indicators: water quality, energy use, noise and air quality; Antão et al. (2016) defined a proposal for a system of port performance indicators based on aspects involving occupational health and safety and the environment.

Recently, Puig et al. (2017a) developed a guide of environmental indicators applicable to all types of ports within the programme PPRISM and combined it with standards ISO-14001, EMAS and PERS. Similarly, Puig et al. (2017b), per initiative of the ESPO, carried out an analysis of a sample of ports that were evaluated using a self-diagnosis method (SDM). Their conclusion could not be more meaningful: all ports considered air quality to be their main priority in environmental matters. Lastly, evaluations on the impact of port activity on the air quality of the surrounding urban area have been carried out recently, both from a general perspective (Baldasano and Massagué 2017) as well as from the perspective of the port's specific activity (Sorte et al. 2019).

Introduction to the principles of sustainable development in the Spanish port regulations

The European Union's recommendations on port policies,[1] along with previous experiences adopted at their own initiative, is the basis for including the commitment to sustainability by Spanish PAs in the Law on State Ports and the Merchant Navy 33/2010.

This regulation, as it is worded in the revised text that appears in R.D. 2/2011 (Ley de Puertos del Estado y de la Marina Mercante 2011) explicitly indicates (in the Article 55) the planning instruments to be used by the PAs, which include the obligation of annually drafting a business plan containing the port's environmental sustainability objectives and indicators, and that it be accompanied by a sustainability report whose methodology is to be approved by Puertos del Estado. This methodological approach is based on the development of its own and specific indicators, introducing the institutional dimension as well as the three previous ones included in the initial experimental project (Puertos del Estado 2008).[2] Specifically, the selection of indicators in the environmental dimension was based on the analysis by (Fernández Francos et al. 2013):

– What the pressures or impacts of port activities on the environment are.
– Actions that can be taken by the PAs to limit the impact of the port community as a whole.

Based on these principles, indicators were introduced that were connected to:

- Environmental management and allocated economic resources
- Environmental quality

[1] See document COM 616 (2007).

[2] The new methodology is based on the development of 111 indicators found in the four dimensions of sustainability. In this regard, the proposal represents the inclusion of 60 indicators more than the previous one, based on the more corporate prescriptions of the GRI.

Table 1 Air polluting emissions: statement of measures introduced by the port authorities (indicator A7)

Administrative	Operational and technical	Specific technical
1 Mandatory regulations and disciplinary proceedings	1. Monitoring port operator regulatory authorisations and notifications regarding emissions	1. Installation of windbreaks
2 Good practices guidelines and voluntary environmental codes	2. Specific instructions from management for certain operations	2. Irrigation systems for bulk storage and roads
3. Systems to measure air quality parameters or regular campaigns	3. Direct supervision at wharfs by port authority technicians	3. Wheel wash systems
4. Characterisation studies of the effect of port activities on air quality	4. Reorganisation of port's plant activity to move sources of emissions away from sensitive areas	4. Warning and information systems involving wind speed
5. Incentives for lorries with lower contaminating emissions	5. Interior road improvement to reduce lorry traffic through urban areas	5. Operational shutdowns caused by adverse wind conditions
6. Include conditions on emissions in the specifications that regulate services	6. Environmental criteria in the organisation and allocation of berths	6. Incentives for lorries with automatic load covers or installation of points for load covering
7. Demand requirements on emissions in conditions for the granting of concessions		
8. Signing of good practices agreements		

Source: authors' own based on environmental indicator A7 (Puerto de Barcelona 2014)

- Ecoefficiency
- Introduction of management systems in the port community

Based on this philosophy and as of the passing of the law, each PA began the drafting of their sustainability reports as per the methodological principles developed by Puertos del Estado (Puerto de Barcelona 2014).

Research objectives

Practically all of the revised bibliography regarding emissions by ports points to the absolute priority of adopting measures that guarantee air quality. However, it is not easy to find clear references to the specific measures that should be adopted or any evidence as to the extent to which they are applied.

The sustainability reports by the 28 Spanish PAs (that manage 46 state-owned ports of general interest) provide highly valuable information which, when conveniently drawn up, makes it possible to formulate the following objectives for this study:

(a) Verify whether the implementation of the Ports Law has had a positive impact on promoting and setting up measures for controlling and reducing emissions at Spanish state-owned ports of general interest.
(b) Determine if the level of implementation of tools for the control of emissions has evolved progressively.
(c) Identify the specific measures adopted and under what category they have been included.
(d) Analyse if there are substantial differences in the actions adopted in order to mitigate air pollution depending on the size of the ports.
(e) Identify and typify the strategic lines carried out by the PAs and their correspondence with the measures adopted.

Methodology

In the mentioned document drafted by Puertos del Estado to produce the Sustainability Reports, of the 111 indicators it develops for ports, 35 fall within the environmental dimension (Puerto de Barcelona 2014). Of these, the one identified as A7 provides information on the measures set forth by the PAs to control air quality and emissions resulting from port activity. Specifically, a set of measures (with their descriptors) are included, which are classified under three categories:

Table 2 Classification of measures and strategies for the control of emissions according to type and characteristics

	Supervision and control	Infrastructures and equipment	Policies and regulations	Special facilities	Incentives
Operational and technical	3	3			
Administrative		1	5		2
Specific technical	1	1		3	1
Total	4	5	5	3	3

Source: authors' own

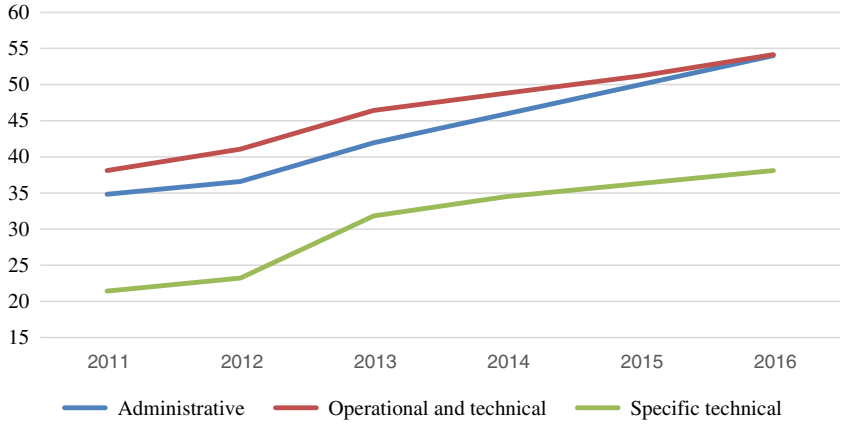

Fig. 1 Evolution of the percentage of PAs that have implemented measures for controlling and reducing emissions (2011–2016). Source: authors' own

(a) Administrative (eight items).
(b) Operational and technical (six items).
(c) Specific technical (six items).

Accordingly, all the PAs must respond to what degree they have implemented those 20 specific actions. The detailed classification of each measure for the above categories is shown in Table 1.

On the other hand, having indicated the aim of the mentioned actions for controlling and improving the quality of air in the seaport system, each category from the above table can be reclassified depending on the nature of each one, as shown in Table 2. We can see that the 20 proposed measures are based on strategic lines by the PAs through:

(a) Direct supervision and control actions
(b) Adoption of measures for the management of infrastructures and facilities
(c) Regulation of operational and specific policies
(d) Installation of special facilities.
(e) Providing incentives to third parties for the use of systems that reduce the level of emissions

Now that the Ports Law has become operative, verified results are already available for a sequence of seven consecutive years (2010–2016). The sources of information used are for 2010 from the sustainability report for the system of ports of general interest (Puertos del Estado 2012) and for the remaining years the information is provided directly by Puertos del Estado.

However, during the first year of operation (2010), the fulfilment of the items under indicator A7 was voluntary for the PAs; it did not become mandatory until 2011. Therefore, it was possible to create a homogenous and consolidated database for the 6-year period of 2011–2016.

The operation for the calculation of these 5 years consisted of building a 20 × 28 matrix of values for each year, processing 3360 responses or data for the entire period which was then used to analyse, among other aspects, the frequency of the measures adopted and their hierarchies.

Findings

Global

Figure 1 shows the cumulative totals and their evolution during the period referred to. Several matters need to be highlighted: first of all, the Spanish PAs have given priority to the adoption of operational and technical measures to control emissions. Secondly, they support administrative actions (that in 2016 reached the level of the first ones) and finally, they favour the application of specific techniques.

Moreover, the upward trend in the measures introduced as the time frame progresses; that is, as the precepts of the Ports Law[3] are gradually applied, especially from 2012 to 2014, is a significant fact. This upward trend also reveals a feature worth highlighting: it happens almost simultaneously for each of the three categories considered.[4] In short, Spanish PAs choose to develop environmental management policies that are increasingly more comprehensive as the studied period progresses.

Results according to measures adopted

The use of the database makes it possible to determine the importance of the measures introduced by each PA to mitigate emissions within each category and, at the same time, by using

[3] This Act introduces quite novel aspects in environmental management, as is the case of the demand for means to prevent and reduce marine, atmospheric and land contamination in all manner of facilities that are located in ports (Art. 62.2), a strict sanctioning system (Art. 306.1.a) and the rescue of the concession in the event of environmentally harmful actions (Art 99).

[4] By processing the basic data used to create Fig. 1, we get a Pearson correlation coefficient of 0.988 (p = 0.000) for the evolution of operational or technical and administrative measures, of 0.986 (p = 0.000) for operational or technical and specific technical measures and of 0.965 (p = 0.003) for administrative and specific technical measures. All of the significance levels (p) are lower than 0.05.

an analysis of frequencies, to prioritise or establish the operational levels for each one. In this way, the findings are shown (for each strategy) classified from greater to lesser priority based on the higher frequency (level 1) of adoption of each measure. Likewise, they are analysed based on the order of priorities as stated by the ports.

Technical and operational measures

The findings for the first group are shown in Table 3. The table shows that the six technical and operational measures have grown considerably during the period studied. It is important to highlight that the three measures of higher operational level result from direct PA actions on port operations through its technical staff (supervision of wharfs, operator control and specific instructions). The next three in rank refer to the use and management of port infrastructures (berth environmental criteria, reorganisation of plant activity and road improvement to reduce lorry traffic in urban areas).

Administrative measures

As was the case for the ones analysed in the previous section, with the exception of offering incentives for lorries with lower emissions (of limited presence), all these measures reveal an upward trend during the time span for the period studied (Table 4). The first four operational levels stand out, particularly the introduction of systems to measure air quality parameters and the organisation of regular campaigns. In 2016, four out of every six PAs had already implemented them. Equally, they had laid down good practice guidelines, carried out studies on the effect of port activities on air quality, and established mandatory regulations and disciplinary proceedings. A quite similar behaviour is seen in the introduction and promotion of good practices agreements with the operators; an activity that has increased considerably by 240% since 2011.

Specific technical measures

The behaviour of the PAs during this period for this type of measures is similar: as of 2011, the level of implementation grows, especially with regard to equipment for irrigation systems in bulk storage areas and roads. In general, these consist of special equipment to prevent environmental contamination, and they are closely linked to the idiosyncrasies of each port and their degree of specialisation (Table 5).

Results based on port size

In its comparative analysis for ports environmental performance, Puig et al. (2017b) classified a sample of 91 European ports according to the volume of tonnes moved. They identified four subgroups:

- Small ports that move up to 5 million tonnes/year.
- Medium ports, between 5 and 15 million tonnes/year.
- Large, that move between 15 and 50 million tonnes/year.
- Very large, over 50 million tonnes/year.

As they had already done for the total number of ports, they verified the specific environmental priorities for each category and concluded that in 2016, air quality always ranked first place.

Taking into account that 2016 was the last year of analysis carried out in this investigation and that the measures implemented are progressive, the 28 Spanish PAs can be classified by size according to the volume of tonnes moved in 2016, according to the same intervals. The data for traffic were those obtained from Puertos del Estado (2016). Accordingly, there are subgroups of PAs: small (13), medium (6), large and very large (9). Based on this classification, each category can be analysed to determine if there is a differentiated behaviour in

Table 3 Hierarchy of technical and operational measures adopted by the PAs to reduce emissions and percentage of PAs that have introduced them (evolution of frequencies 2011–2016)

Level	Technical and operational measures	2011	2012	2013	2014	2015	2016
1	Direct supervision of wharfs by port authority technicians	53.57	53.57	67.86	67.86	71.43	71.43
2	Monitoring port operator regulatory authorisations and notifications regarding emissions	42.86	42.86	50.00	57.14	60.71	64.29
3	Specific management instructions for certain operations	32.14	35.71	35.71	42.86	46.43	53.57
4	Environmental criteria for berth management and allocation.	32.14	42.86	42.86	42.86	42.86	46.43
5	Reorganisation of port's plant activity to move sources of emissions away from sensitive areas	32.14	32.14	42.86	42.86	46.43	46.43
6	Improvement of interior roads or accesses in order to reduce lorry traffic through urban areas	35.71	39.29	39.29	39.29	39.29	46.43

Source: authors' own

Table 4 Hierarchy of the administrative measures adopted by the PAs to reduce contaminating emissions and percentage of PAs that have introduced them (evolution of frequencies 2011–2016)

Level	Administrative measures	2011	2012	2013	2014	2015	2016
1	Systems to measure air quality parameters or regular campaigns	53.57	60.71	60.71	64.29	64.29	64.29
2	Good practices guidelines and voluntary environmental codes	42.86	46.43	57.14	57.14	64.29	64.29
3	Characterisation studies of the effect of port activities on air quality	39.29	42.86	53.57	64.29	64.29	64.29
4	Mandatory regulations and disciplinary proceedings	42.86	42.86	46.43	57.14	64.29	64.29
5	Demand requirements on emissions in conditions for the granting of concessions	25.00	25.00	42.86	46.43	60.71	60.71
6	Signing of good practices agreements	39.29	39.29	39.29	42.86	42.86	60.71
7	Include conditions on emissions in the specifications that regulate services	32.14	32.14	32.14	32.14	35.71	50.00
8	Incentives for lorries with low levels of emissions	3.57	3.57	3.57	3.57	3.57	3.57

Source: authors' own

the adoption of control measures for air quality and the reduction of environmental contamination (Fig. 2).

The results for the whole port system reveal that in 2016, 54% of the PAs had adopted both administrative and specific technical measures for controlling emissions. The figure for operational and technical measures was of 38%. There follows an analysis of the distribution of these measures according to port size.

Small ports

The 13 Spanish ports that moved less than 5 million tonnes in 2016 have specialised in the adoption of operational and technical measures. The only exception is direct supervision at wharfs by port authority technicians (which nevertheless have been adopted by 77% of the smaller PAs); in all the others, they stand out above larger ports. From the administrative measures, it is worth highlighting those involving good practice guidelines and voluntary environmental codes, characterisation studies of the effect of port activities on air quality and mandatory regulations and disciplinary proceedings, adopted by 69% of small ports. Finally, from the specific technical measures, the one with the greatest impact has been that of operational shutdowns caused by adverse wind conditions, followed in order of importance by irrigation systems for bulk storage and roads. The urban or semi-urban situation of these small ports is, undoubtedly, a conditioning factor of this specialisation.

Medium-sized ports

The medium-sized ports adopt administrative measures as a priority. Particularly noteworthy are the mandatory regulations and disciplinary proceedings, demand requirements on emissions in conditions for the granting of concessions and signing of good practices agreements. These three measures have been implemented by 83% of medium-sized ports. On the other hand, within the two remaining categories (specific technical and operational and technical), all the ports have implemented irrigation systems for bulk storage and roads,

Table 5 Hierarchy of technical and operational measures adopted by the PAs to reduce emissions and percentage of PAs that have introduced them (evolution of frequencies 2011–2016)

Level	Specific technical measures	2011	2012	2013	2014	2015	2016
1	Irrigation systems at bulk storage areas and roads	35.71	35.71	53.57	53.57	60.71	64.29
2	Operational shutdowns caused by adverse wind conditions	35.71	42.86	42.86	42.86	42.86	42.86
3	Wheel wash system	17.90	17.90	37.51	39.30	42.86	42.86
4	Warning and information systems involving wind speed	21.43	21.43	32.14	35.71	35.71	39.29
5	Installation of windbreaks	14.30	17.90	21.43	32.14	32.14	32.14
6	Incentives for lorries with automatic load covers or installation of points for load covering	3.57	3.57	3.57	3.57	3.57	7.14

Source: authors' own

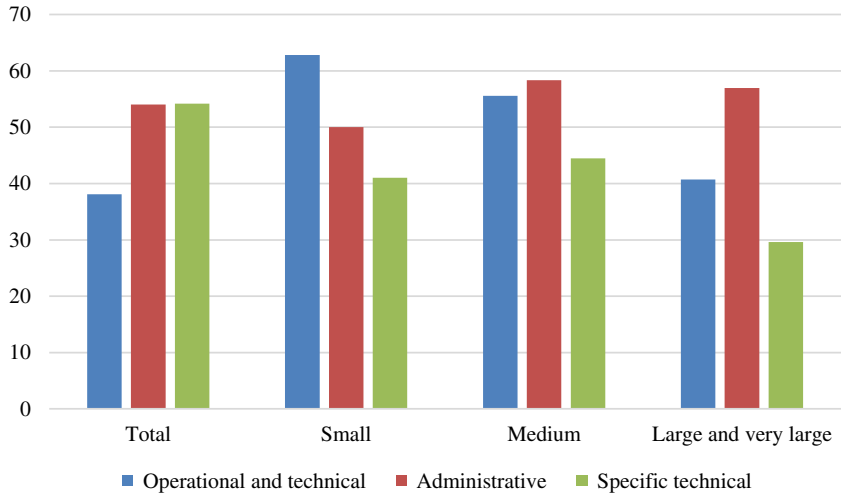

Fig. 2 Percentage of PAs that have implemented measures for controlling and reducing emissions according to type of measure and port size (2016). Source: authors' own

within the first type of measure, and direct supervision at wharfs by port authority technicians within the second (83%).

Large and very large ports

The nine PAs that in 2016 moved over 15 million tonnes reveal a behaviour that is very similar to that of medium-sized ports with regard to the percentage that adopts administrative measures, but under different categories; in this case, in systems to measure air quality parameters or regular campaigns, good practice guidelines, and voluntary environmental codes and characterisation studies of the effect of port activities on air quality. This group of ports is not especially relevant in the adoption of specific technical measures, a group where irrigation systems for bulk storage and roads and wheel wash systems slightly stand out and with a very low presence of the remaining measures in this category. Finally, a similar behaviour can be seen for operational and technical measures, where only a low number of measures with a certain degree of importance can be cited (direct supervision at wharfs by port authority technicians and monitoring port operator regulatory authorisations and notifications regarding emissions).

Results as per strategies

Table 2 showed the classification of strategies for the control and reduction of emissions as per the three categories that group together the measures to be adopted by ports. Once the data has been used, the real degree of implementation of these strategies (Fig. 3) can be calculated (for 2016 and for the entire Spanish ports system).

We can see that two types prevail: first of all, actions involving policies and regulations and supervision and control measures (implemented by 63% of ports) and, secondly, supervision and control measures (58%). Those that represent the provision of facilities and infrastructures do not reach even half of all Spanish ports; that is to say, only 45% of the PAs have contributed to infrastructures and equipment, and to the installation of special facilities. Finally, policy incentives to reduce air pollution were only adopted by one out of every five ports.

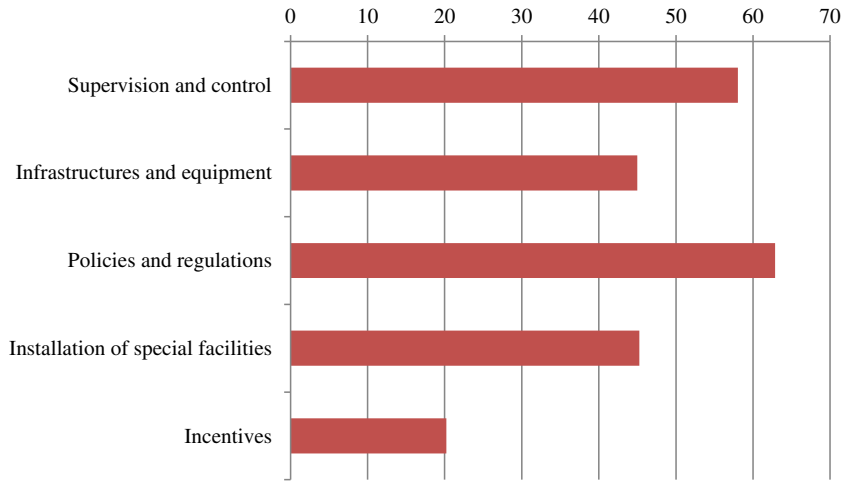

Fig. 3 Strategies developed to reduce emissions and percentage of PAs that have implemented them (2016). Source: Authors' own

Conclusions

This study has analysed the level of introduction of the specific measures that have been carried out by Spanish government ports of general interest to control and mitigate emissions within their facilities and improve air quality. The results obtained are in line with the research targets initially set forth. We have been able to determine that throughout the time period studied, which is the object of our study, PAs have based their strategy on the progressive introduction of operational and technical, administrative and specific measures. During the period in question, practically all of these measures have progressively increased.

Undeniable proof of the incidence of this behaviour since the enactment of the ports law and the introduction of the measures included therein can be seen in two aspects: firstly, the availability of strict information elements through the sustainability reports that each PA must submit annually, and secondly, the elements included in the new regulation to encourage and correct behaviours. The fact that the introduction of these measures at Spanish ports has evolved positively throughout the period studied for practically all of them adds even greater strength, if possible, to the importance of the development of the law and to its commitment to sustainability. It would be of great interest in the future for Puertos del Estado to develop comprehensive information regarding the A06 indicator which provides information on complaints about air quality made by stakeholders relating to the PAs. This view would serve to contrast the coincidence of the strategies and measures adopted from such a perspective with the complaints made and their effectiveness.

On the other hand, the measures proposed by the methodology developed by Puertos del Estado are varied and have been classified under a number of categories. The adoption of administrative and specific technical measures is noteworthy of the entire port system. Segmentation by groups of ports based on traffic volume (measured per tonnes moved), has made it possible to distinguish between the different ways ports tackle the problem of air pollution, revealing different action patterns. It has been established that the operations show considerable differences depending on the volume of port traffic: administrative actions are often consolidated for the entire Spanish port system, because it is the large and very large PAs that declare they implement measures of this type. On the other hand, the implementation of operative and technical measures is more developed in small ports. In larger ports, hardly any specific techniques against air pollution have been implemented.

Finally, the analysis carried out according to the grouping together of the measures and actions taking into account the five strategic categories is quite significant: the regulatory and supervision and control actions (of scarce economic relevance) have primacy; on the other hand, those strategies that represent a commitment with the endowment of adequate infrastructures are implemented to a lesser extent, as are those that encourage third parties to use less contaminating elements. The results indicate the need for some ports to refocus their investment strategy in infrastructures, equipment and installation of special facilities, with the purpose of improving the quality of air in their premises: according to the Puertos del Estado's statistical information (indicator I37), Spanish ports as a whole invested 0.07% of the total investments for the period analysed (2011–2016) in environmental matters.

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