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RESEARCH ARTICLE

Landscape assessment of the cities in the state of Maharashtra: first step towards air quality management (AQM) and strategic implementation of mitigation plans

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Abstract

Objective of the study This study aims to understand the need for landscape assessment of the 18 non-attainment cities in the state of Maharashtra, to understand and rank the cities according to the need and necessity for strategic implementation of air quality management. This air quality management is a National Clean Air Programme initiative to curb the air pollution level in all the highly polluted Indian cities by 20–30% till 2024.

Methodology The ranking and selection of the cities consisted of a two-phase approach including (a) desk research and (b) field interventions and stakeholders' consultations. The first phase included (a_i) review of 18 non-attainment cities in Maharashtra, (a_{ii}) identification of suitable indicators to inform prioritisation during the ranking process, (a_{iii}) data collection and analysis of the indicators and (a_{iv}) the ranking of the 18 non-attainment cities in Maharashtra. The second phase, i.e. field interventions included (b_i) Mapping of stakeholders and field visits, (b_{ii}) the consultations with the stakeholders, (b_{iii}) information and data collection and (b_{iv}) ranking and selection of cities. On analysing the score obtained from both the approaches a ranking of all the cities is done accordingly.

Results and discussion The screening of cities from the first phase gave a possible list of 8 cities—Aurangabad, Kolhapur, Mumbai, Nagpur, Nashik, Navi Mumbai, Pune, Solapur. Further, the second round of analysis involving field interventions and stakeholder consultations was done within the 8 cities to find out the most suitable list of two to 5 cities. The second research analysis gave Aurangabad, Kolhapur, Mumbai, Navi Mumbai and Pune. A more granular stakeholder consultation resulted in the selection of cities like Navi Mumbai and Pune as the cities where implementation of new strategies seemed feasible.

Intervention and activities New strategic interventions like (a) strengthen the clean air ecosystem/institutions, (b) air quality monitoring and health impact assessment, and (c) skill development to ensure the long-term sustainability of initiatives planned for the cities.

Keywords Air quality management · City action plan · Climate risk · Maharashtra · Mitigation strategies · National Clean Air Programme (NCAP) · Stakeholders

Background and introduction

The right to clean air is an undeniable and fundamental human right (Brajer et al. 2011; Brauer et al. 2019; Das et al. 2020). Ambient air quality is a critical indicator that determines the quality of life, well-being and the ability to prosper (Diener and Eunkook 1997; Darcin et al. 2017; WHO 2006). In recent years, the rising instances of acute air quality across the globe have brought urgent attention to tackling air pollution as a leading challenge for many countries (Sharma et al. 2022). Large-scale and unmitigated anthropogenic activities like transportation, manufacturing, mining, construction, burning of fossil fuels and poor waste

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management are some leading causes for the deterioration of ambient pollution (Central et al., 2017), HEI 2010). The growing concentration of toxic pollutants such as particulate matter (PM2.5 and PM10), sulphur oxides, nitrogen oxides and carbon monoxide expose over 90% of the global population to the harmful effects of inhaling poor-quality air, primarily in the low- and middle-income countries in south and east Asia, as per WHO estimates (WHO 2016). Over 4.2 million deaths occur annually due to ambient air pollution, along with the livelihoods and productivity of several million affected adversely (Guttikunda et al., 2019). By 2060, the global welfare losses are estimated to cross 18 trillion USD due to premature deaths caused by air pollution, with almost 30% taking place in South and Southeast Asia (OECD 2016). WHO recognises air pollution as a global public health emergency with unrestricted ripple effects? India's National Clean Air Programme India, a rapidly rising South Asian economy, is also among the worst affected countries due to poor air quality. It is home to more than half of the top 50 cities with the highest PM2.5 concentration globally (Chowdhury et al. 2019), and historically PM 2.5 is much more health hazards then compared to PM 10, because of its smaller size and capability to adhere more deeper to the lung chambers and acting as an toxic agent to enhance cell death (Das et al. 2020; Prakash et al. 2018). It is estimated that in 2016, India lost more than 8.5% of its gross domestic product in 2013 due to increased welfare costs and loss of labour caused by poor air quality (World Bank and IHME 2016). The future losses are expected to increase with worsening air quality and may even offset the economic growth that India gains in the coming years. A strong policy and regulatory push become imperative in driving actions and operationalising goals to mitigate air pollution in the country. The National Clean Air Programme (NCAP), launched by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India in January 2019, is a nation-wide effort to plan, prioritise and implement time-bound targets to measure, and control and reduce air pollution at a city level (Banerjee et al. 2017, Bhushan et al. 2020). Through developing and implementing city action plans for air quality management, NCAP aims to reduce PM2.5 concentrations in cities by 20–30% of the 2017 levels by 2024 (Gulia et al. 2018). To date, 124 non-attainment cities from 21 states and 2 union territories have been identified by the Central Pollution Control Board (CPCB) as those falling significantly short of the National Ambient Air Quality Standards (NAAQS) in the period from 2011 to 2015 (Guthikunda et al. 2019). Among the identified non-attainment cities, some states show a higher share of cities that are performing poorly on the Air Quality Index. Various factors contribute to the degradation of air quality such as the presence of industries, high population density, extensive construction activities, heavy vehicular usage and combustion activities. In particular, Maharashtra stands out as the state with the highest number of cities (18 non-attainment cities) in the state that have poor air quality and requires robust, well-planned efforts to mitigate this issue (Fig. 1). The possible reasons for this could be the highly industrialised and urbanised landscape of Maharashtra.

NCAP mandates the key urban local body in the non-attainment cities to submit city action plans to CPCB that address the challenge of air pollution. These action plans outline mitigative, preventive and monitoring measures and interventions that cover various areas like transportation, industry, waste management, construction and urban development, along with outlining the monetary allocation required to achieve their targets. Despite these plans receiving approval from the CPCB, there remain several gaps in implementing these measures and generating meaningful impact. While distinct responsibilities are designated to different urban agencies, factors like complex interdependencies, lack of integrated planning, poor coordination and limited fiscal autonomy of the urban local bodies (ULBs) act as barriers to effective action to manage air quality (Ahluwalia et al. 2019; AIGGPS 2015). Additionally, without a strong data-driven foundation, the city action plans do not show a distinct prioritisation of some action points over others (Ganguly et al. 2020). The impact of these factors becomes particularly exacerbated in cases where a state has a higher share of non-attainment cities, like the case of Maharashtra. Moreover, with the pan-regional nature of air pollution, which leads to the delineation of airshed regions, it is important to define the institutional and administrative arrangements that are necessary to resolve the regional influences of the air pollutants. This was also a common aspect missing in the different city action plans submitted from Maharashtra. With 18 non-attainment cities, the state of Maharashtra stands out with a large potential to plan targeted efforts that can have wide-ranging impacts across cities.

With the primary goal of improving the air quality and public health of Indian cities through lasting reductions in air pollution emissions, with a focus on the urban-industrial nexus. Maharashtra has been selected as the larger geography of this project due to its top rank with the highest number of cities polluted beyond the standard limits. It is also the third-most urbanised and highly industrialised state in the country. A study by Balakrishnan et al. (2019) and Indian Council for Medical Research in 2017 found that Maharashtra was the second most impacted state in terms of the number of lives lost due to air pollution. Moreover, CPCB found that 21 out of 25 air pollution rule violation cases were from Maharashtra (NCRB 2019). As a result, Maharashtra faces a particularly high risk from the negative effects of air pollution, unlike any other state in India. Targeted and effective interventions to improve the quality of ambient air in the state will require a clear definition of the geographic boundaries of the project. The demonstration of successful measures in these geographies from the project's efforts can then be replicated in other geographies.

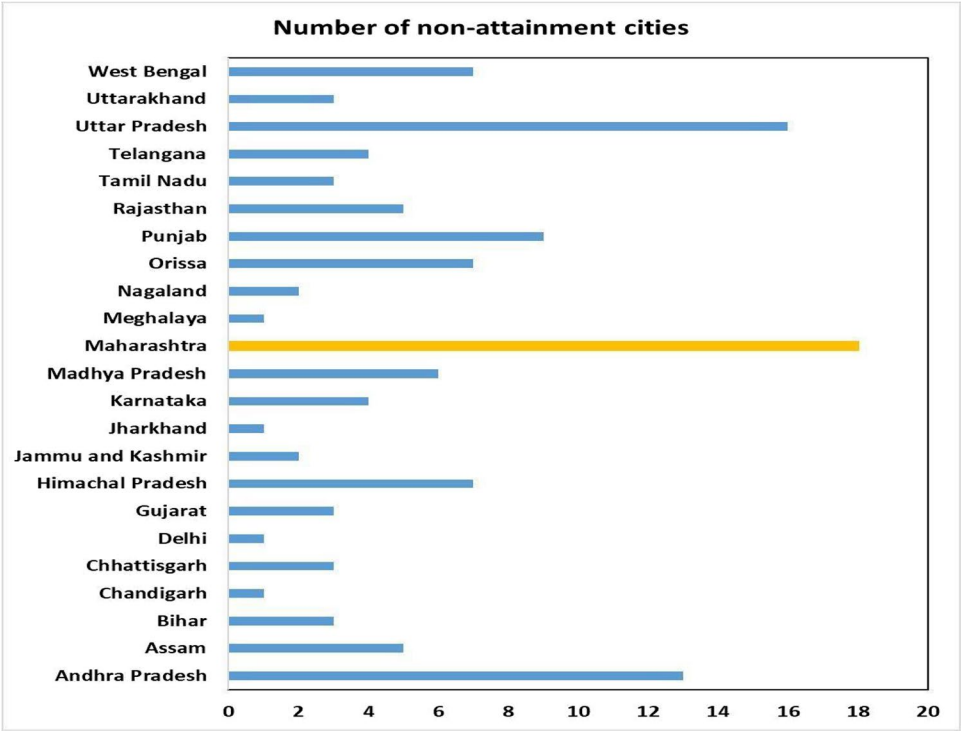

Fig. 1 State-wise distribution of the non-attainment cities

The climatic details of these 18 cities are shown in supplementary table 1. There is a correlation required of landscape with the air pollution. The correlation analysis and history of landscape have been already provided in the City Action Plans initiated by NCAP (supplementary table 2 in the supplementary sheet).

Consequently, it is important to develop a robust framework to rank the 18 cities and select those with the highest potential for impact through this project. The next section delves in the framework developed by the researchers for the ranking, shortlisting and selection of the 18 non-attainment cities in Maharashtra and its findings, along with the outcomes.

Methodology

Selection framework

The selection framework consisted of a two-phase approach comprising desk research followed by field interventions. Supplementary table 3 shows the selection criteria and their importance for ranking of cities for mitigation activities. The first phase, i.e. desk research included the following four steps: (1) the review of the 18 non-attainment cities in Maharashtra, (2) the identification of suitable indicators to inform prioritisation during the ranking process (Han et al. 2006), (3) data collection and analysis of the indicators and (Garghava et al. 2016), (4) the ranking of the 18 non-attainment cities in Maharashtra. The first phase of the selection framework was designed to shortlist 8 cities for phase 2.

The second phase, i.e. field intervention consisted of the following four steps: (1) Mapping of stakeholders and field visits, (2) the consultations with the stakeholders, (3) information and data collection and, (4) ranking and selection of cities. Thus, 2 cities could be finalised based on the two-phase approach (Schwarz et al. 2010).

Data collection

The desk research consisted of data collection on the following criteria (Schwarz et al. 2010; Sharma et al. 2015); (1) PM10, (2) the AQI with respect to PM2.5 and PM10 (for 24 h), (3) presence and review of city action plans, (4) industry-related interventions in the city action plans, (5) presence of industry clusters, (6) the number of industries present, (7) type of industrial clusters, (8) population in the cities and (9) emission inventories for the 18 non-attainment cities in Maharashtra (viz. Akola, Amravati, Aurangabad, Badlapur, Chandrapur, Jalgaon, Jalna, Kolhapur, Latur, Mumbai, Nagpur, Nashik, Navi Mumbai, Pune, Sangli, Solapur, Thane and Ulhasnagar). The air action plan of Thane was not prepared by the Thane municipal corporation and as such could not be reviewed.

Analysis of the 18 non-attainment cities

The above-discussed criteria were critically analysed to find gaps and potential interventions in the 18 non-attainment cities (Roychowdhury et al. 2020).

Shortlisting of cities—why?

In the aim of starting the work in cities the technique of selection of cities on priority basis was done, this included selection in phases detailed out in the subsequent sections of the study. PM10 and AQI with respect to PM2.5 and PM10 (for 24 h) had the highest priority on the list of indicators in the selection framework. Data from the CAAQMS and NAMP stations was gathered and analysed on AQI with respect to PM2.5 and PM10 (for 24 h) for the 18 non-attainment cities in Maharashtra to determine which cities should be prioritised. All 18 cities in the State of Maharashtra does not have a particular source of CAAQMS and NAQMS data. However, the general source is CPCB site (weblink- https://cpcb.nic.in/about-namp/) for major data collection. There are a total of 131 cities which are under NCAP tracker and is declared to have poor air quality conditions throughout (these standards are compared to NAAQS and WHO prescribed thresholds (weblink Source: https://prana.cpcb.gov.in/#/NCAPTracker). Also, the decision on declaration of the non-attainment cities in India is done by CPCB (Central Pollution Control Board). There are a total of 131 cities which are under NCAP tracker and is declared to have poor air quality conditions throughout (these standards are compared to NAAQS and WHO prescribed thresholds). Figure 3a below shows the 18 non-attainment cities in Maharashtra and their respective AQI levels (Cocchia 2014).

City action plans for each of the cities were reviewed to see similarities and unique air pollution interventions to ascertain the priority areas for the municipal corporations. City action plans which had a dedicated section on industrial air pollution abatement strategy were prioritised over other intervention areas as measurable impact can be achieved in this domain as it is a point source for air pollution and thus relatively easy to arrest.

This data was further corroborated with the air pollution data against the size and type of industries present in that city region to estimate air pollution arising from industrial activity (Cocchia 2014). Table 1 describes prominent industries present in the 18 non-attainment cities in Maharashtra.

Cities that had completed their emission inventories were also prioritised as air pollution mitigation strategies can then be focused on the contributing sources.

Stakeholder engagement

The process of selection is through stakeholder mapping technique, and the number was generally 1 nodal contact for each department or organisation. The responsible stakeholder representations are from the departments/organisation are RTO, Traffic Police, MCGM, MPCB, Ch. E. (Roads & Traffic)_MC GM, MMRDA, Representation from Department of Petroleum& Natural Gas & Oil marketing Companies, MMRDA, MSRDC, Department of Transportation, Superintend of Garden_MCGM, Assistant Commissioner (Wards)_M CGM, Representation from the Industry (Thermal Power Plant), MPCB, Industry Association from the States, Representation on the 'Daily Air Quality Public Information Dissemination System', Representation from the department of Road and Dust and Construction and Demolition, Municipal corporation representation dealing with the biomass burning

Table 1 Prominent industries present in the 18 non-attainment cities of Maharashtra (Singare et al. 2018)

Non-attainment cities in Maharashtra	Prominent industries present in the region
Akola	Sawmills
Amravati	(RMG) Textile, teak wood sawmills, cotton seed oil mills
Aurangabad	Rubber, automobile, foundry, leather, chemical
Badlapur	Chemical, pharmaceutical, plastics, powerlooms
Chandrapur	Fly ash, sawmills
Jalgaon	General engineering, plastics
Jalna	Leather, agri equipment, rolling mills, induction furnace
Kolhapur	Foundry, textiles
Latur	Printing
Mumbai	Chemical, general engineering, leather, electronics
Nagpur	Brick kilns, foundry, dal mills, engineering, re-rolling
Nashik	Auto engineering, fruit processing
Navi Mumbai	Chemical
Pune	Forging, casting, auto engineering
Sangli	Textile, RMG
Solapur	Textiles (power looms), terry towel, processing
Ulhasnagar	Textiles, food products (bakery units)
Thane	Paint, enamel, varnish, pharmaceuticals

and management, Project Management Unit Cell of State Pollution Control Boards, Academic and Research Institutions, Housing Association heads etc.

Stakeholder mapping techniques The stakeholder mapping is done using the available format questions termed as the 'Physical and Financial status of the action points from relevant departments and representations'. The authors have also used the already-existing city action plan to design the stakeholder mapping on the same.

The major action points for any cities with questionnaire are as follows:

a) What are the action points taken against non-compliance industry unit?
b) Are the specific body acting towards the reduction of the specific emission?
c) Are there enough monitoring stations available? What is the number of CAAQMS here?
d) What is the status of upgradation of air pollution control system?
e) Regular auditing of the emissions?
f) What is status of shift to renewables?
g) What is the status of use of DG sets in the industry area and the area nearby?
h) What is the status of using (i) new cleaner industries, (ii) new combustion technologies, (iii) use of flexi fuels, clean fuels etc.
i) What are the total number of brick kilns in the state, and what is the technology adaptation status of the kilns? (For examples: to zigzag from the ancient orthodox technology)

Phase 2 of the selection process included the collection and assessment of qualitative data which required stakeholder engagement. Urban local bodies and regulatory authorities were identified and mapped for the shortlisted cities. The interactions with the stakeholders were assessed based on various factors such as their willingness to collaborate, the steps they have taken towards air pollution mitigation and the presence of other donor agencies. As some criteria were less important than others, the scores for such were limited. The complete criteria for selection are given below along with the weightage for each parameter. The parameters were ranked from 1 to 5, 1 being least likely to be selected for work and 5 being most likely to be selected. The cities were then scored based on stakeholder consultation.

Stakeholder consultations

Stakeholder consultations were organised with various entities for a preliminary round of discussions to gauge interest and explore synergies. This consultation provided valuable insights and validated a lot of findings that came up during the desk research. We learned about the problems faced by the implementing agencies and recognised the needs of the urban local bodies. These meetings with the stakeholders informed our city selection process. The selection was based on a qualitative questionnaire that helped us determine the stakeholder's willingness, their priority work area, the scope for work, potential barriers for entry, area of work, technical capabilities and availability of funds with the implementation agency.

Ranking and selection of cities

Based on all of the data collected, the five shortlisted non-attainment cities were ranked and analysed to select two cities for project implementation. This selection was done by the weighted scoring method. The diagrammatic representation of selection criteria with phase 1 (desk review) and phase 2 (field interventions) is presented in Fig. 2.

Results and discussion

Scoring of the cities

Scoring for the parameters was done from 1 to 5, 5 being the highest chance of selection while 1 being the lowest based on weighted scoring methodology. The maximum scores for each of the parameters are given below (Table 2). The data representation in the form of average particulate matter concentration for each city is done, with all the available data points (i.e. the CAAQMS station's average or the NAQMS stations average, possible data availability of each in each of the places).

The important parameters selected for ranking and screening down of the cities were (i) population, (ii) density of industry, (iii) type of industrial clusters, (iv) number of industries in the cluster, (v) status of city action plan of the city, (v) types of pre identified intervention already been followed in the city, (vi) environmental pollution factors which includes criteria air pollutants PM10 and PM2.5, (vii) air quality index and (viii) presence of emission inventory of the city.

The allotment of the score is done in two phases; the maximum score that can be allotted to any parameter is kept as 5. The importance of all the eight parameters in contributing to the city air quality was then marked accordingly in a scale of 1 to 5. Citing an example particulate matter (PM10 and PM 2.5) of any city is the prime indicator of the pollutants' level in the city, so is scaled 5 and in the same way the presence of city action plan which is important but does not affect significantly in the selection process is given a score of 2 (Please refer to table

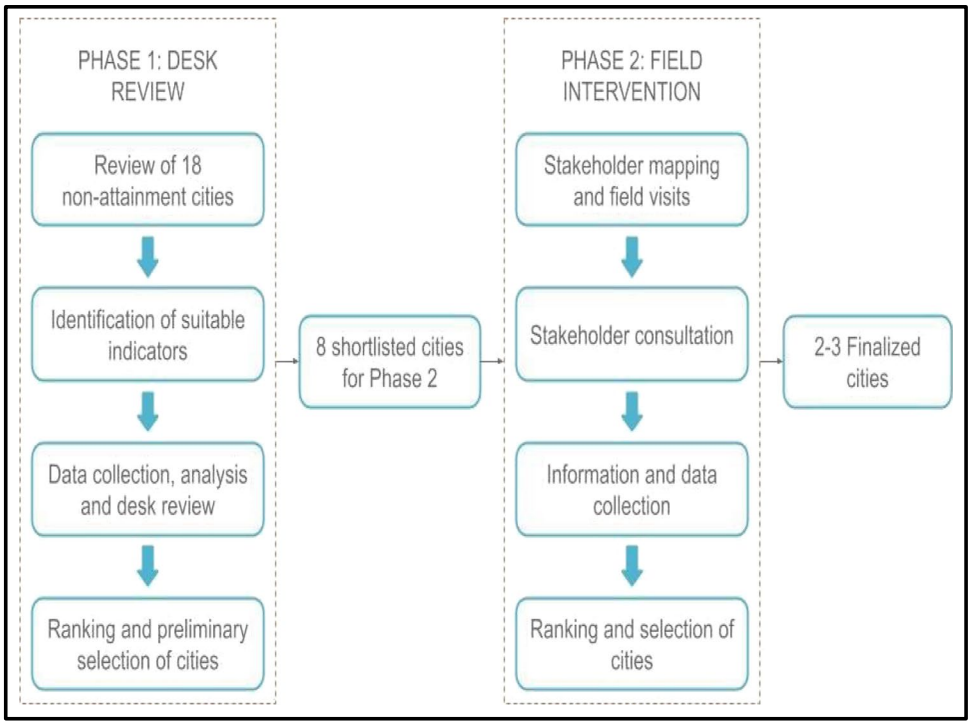

Fig. 2 Selection framework for shortlisting 18 non-attainment cities

Table 2 Maximum scores for each of the parameters

Parameter	Score	Score distribution
PM10 (μg/m^3)	5	100 μg/m^3 = 5; 70+ μg/m^3 = 4; 50+ = 3
AQI with respect to PM2.5 and PM10 (for 24 hours)	5	Unhealthy = 5; unhealthy to sensitive groups = 4; moderate = 2
Population in the cities	4	20 lakhs+ = 4; 10 lakhs+ = 3; 1 lakhs+ = 2
Size of the industrial cluster	4	2000+ = 4; 1000+ = 3; 500+ = 2; >500 = 1
Types of industries	4	Air polluting industries and processes = 4; other industries = 3
Presence of emission inventories	4	Yes = 4; no = 0
Presence and review of City Air Action Plans	2	Yes = 2; no = 0
Recommended intervention under the City Action Plans for industries	2	Presence of industrial interventions = 2; absence of industrial interventions = 0

S1 for the score allotment, in the supplementary sheet). These discrete marking schemes are purely based on the assumptions of each factor that will affect the entire ranking and are based on literature surveys on air pollution related parameters and its importance.

In the second phase of granular marking within the highest obtained marks the 8 parameters were selected and score allotment was done. For example, the parameter population was given a score of 4 in the first phase and on the second level granular scoring population above 20 lakhs are given a score of 4, above 10 lakh a score of 3 and above 1 lakh is 2. For more details on granular scoring, please find Table S2.

The results of the analysis for the AQI with respect to PM2.5 and PM10 (for 24 h) for the 18 non-attainment cities in Maharashtra showed that all of the cities exceed well above the WHO standard for air quality. Notably, Navi Mumbai had the highest concentration for PM2.5 while also having the lowest concentration of PM10 for (period data was sampled). Each city was then scored as per the scoring criterion mentioned above. Annual standard for PM2.5 and PM10: 5 μg/m^3 and 15 μg/m^3 (Recommended: in 2021). Daily 24-h average standard for PM2.5 and PM10: 15 μg/m^3 and 45 μg/m^3 (Recommended: in 2021). Figure 3a shows the PM 10 and PM 2.5 level at different 18 non-attainment cities at Maharashtra. However, PM 2.5 monitoring stations are not available at every cities. Jalna andd badlapur do not have PM 2.5 monitoring centres. The data were taken from CPCB and MPCB sites.

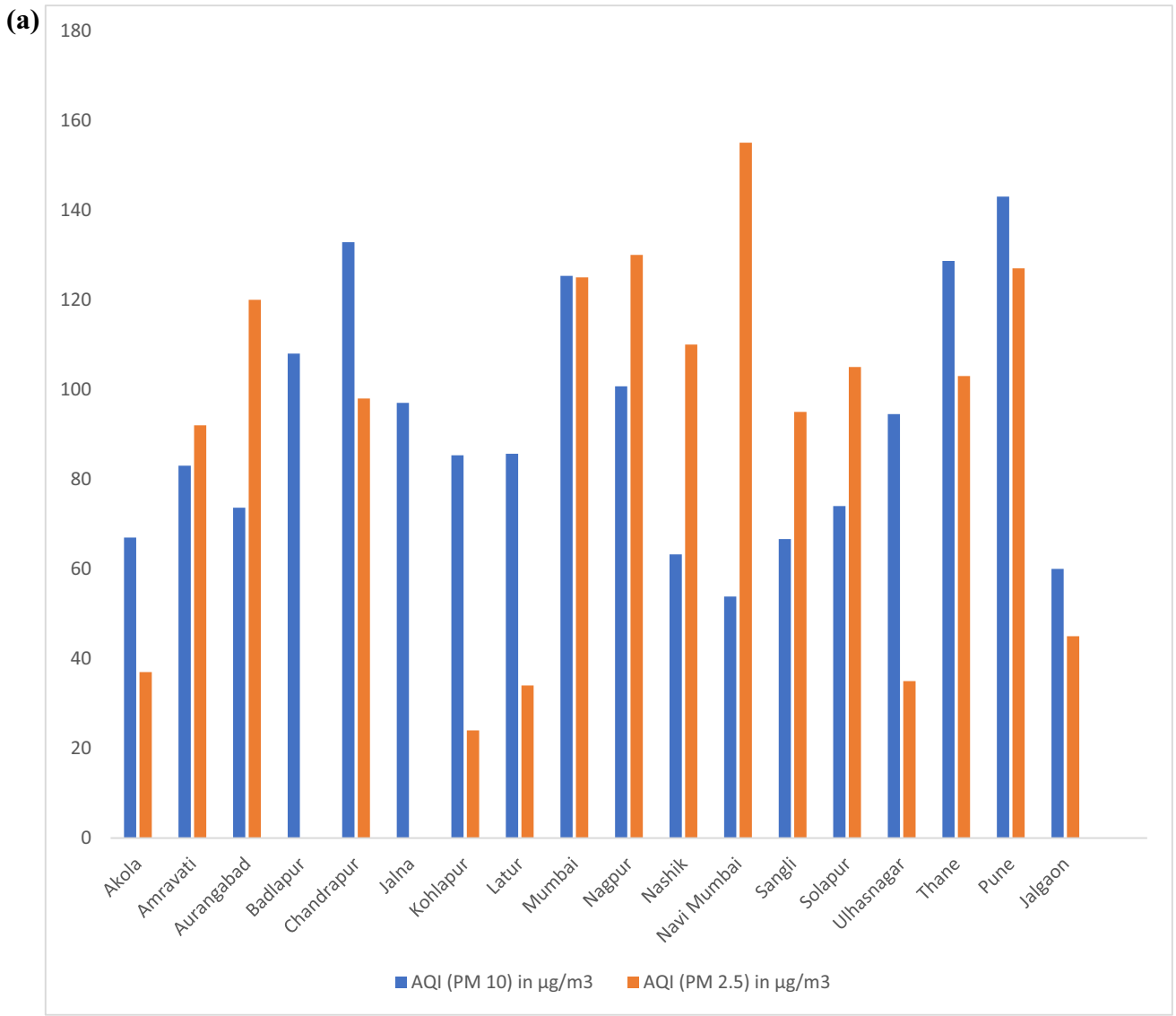

Figure 3 **a** AQI in the 18 non-attainment cities, with respect to PM2.5 and PM10 (Sources: https://cpcb.nic.in/displaypdf.php?id=bWFudWFsLW1vbml0b3JpbmcvTG9jYXRpb25fZGF0YV8yMDE5LnBkZg==https://www.mpcb.gov.in/sites/default/files/air-quality/AIRQualityReport20192022102020.pdf; https://www.iqair.com/in-en/india/maharashtra). **b** Industry-specific actions points for the non-attainment of the cities (Source: https://prana.cpcb.gov.in/#/clean-air-city/list)

Checklist preparation based on industries

In reviewing the industry component for the City Action Plans, an exploration of the potential synergies with government agencies who are tasked with the implementation of the proposed actions. These activities include action against location-specific emissions reduction, installation and Upgradation of Air Pollution Control Systems, Regular audits of stack emissions, Promoting cleaner industries, etc. These are potential areas where the development sector can support the respective stakeholders and help them achieve these targets. The common action points which local and state agencies view as priority actions were selected and plotted against all the cities whose city action plans have a special focus on industrial air pollution mitigation; it is given in Fig. 3b below.

Ranking of cities—1st phase of selection

The 18 non-attainment cities were ranked based on quantitative and qualitative parameters ranging from air quality, emission inventories, demographics, industry footprint and city

(b)

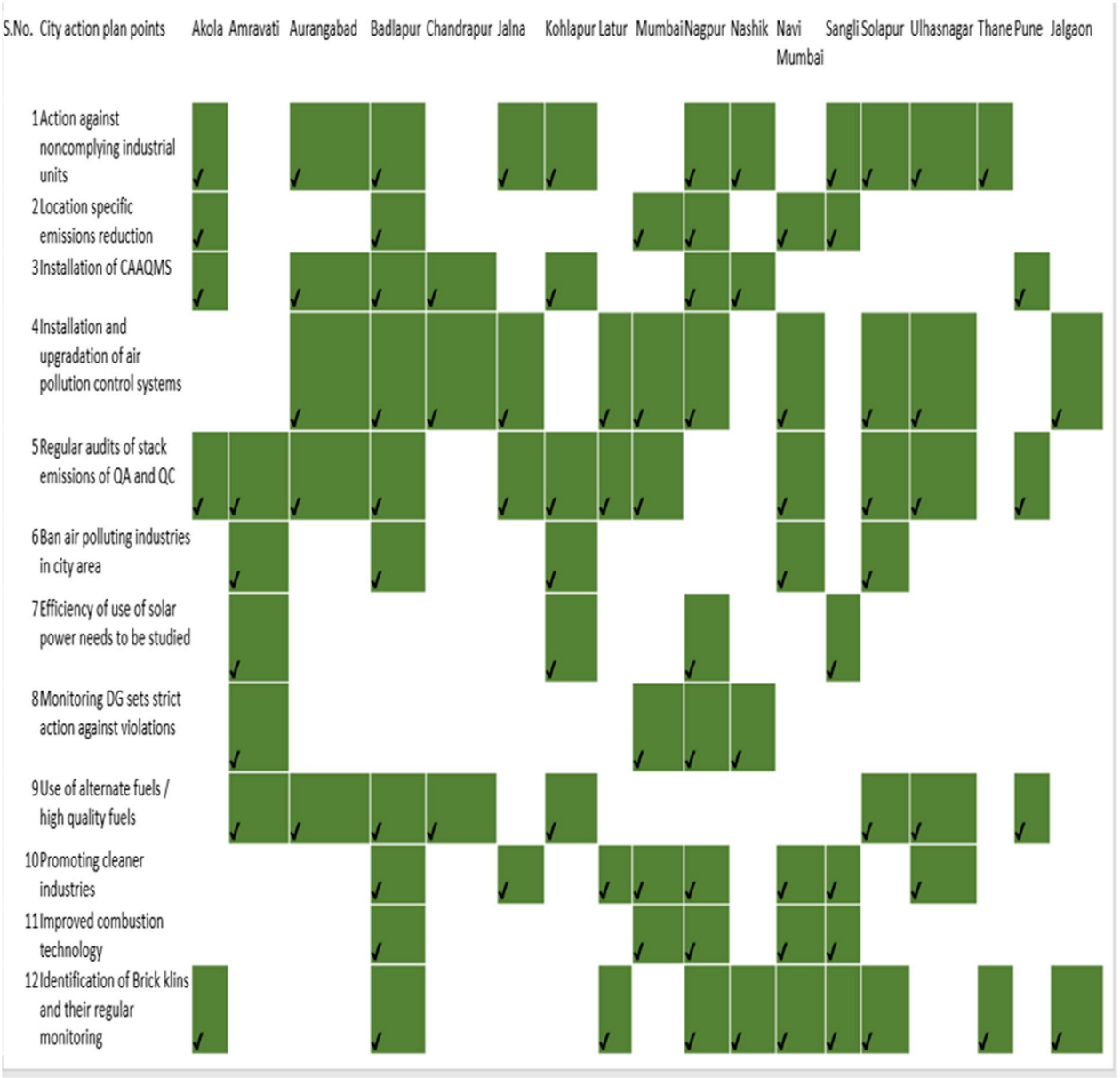

Figure 3 (continued)

action plans. Figure 4 below shows the ranking of the cities. The results show that Mumbai, Nagpur and Aurangabad are the top three cities which scored the highest points respectively, while Thane scored the least points (which is in part because of the absence of certain data points), Jalgaon scored the second lowest and Akola, Amravati and Latur tied for the third lowest-scoring cities. As there are issues with data availability in the cities, a normalisation technique was being used while doing the comparison. This screening and ranking of the cities are done strategically to disburse funds and go for a strategic air pollution management scheme. This objective of this screening is to understand and start working on the 5 most vulnerable cities in Maharashtra which is deeply affected by the air pollution problem. The stakeholders' contribution, technical ability and wilful attitude is important to decide for developing a framework for the city level AQM. Therefore, decision-making was dependent on the questionnaire that was used during the second phase of the study, where different relevant stakeholders are involved. Table 3 shows status of cities in the area of air quality management.

Eight out of 18 non-attainment cities were selected based on secondary data analysis, and stakeholder consultations.

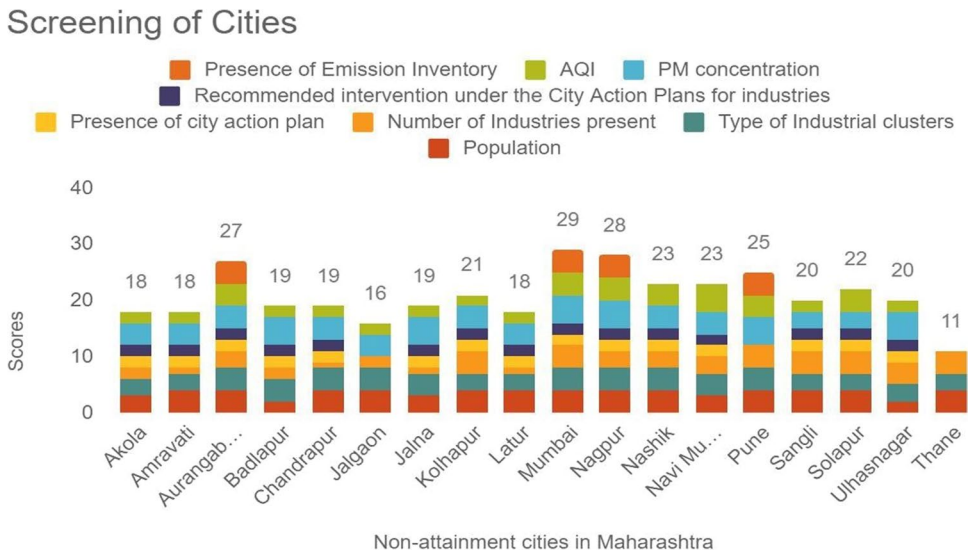

Fig. 4 Analysis of the 18 cities in Maharashtra

These cities include air shed regions that present high-impact potential for clean air interventions in cities, and industries. The list includes the following (list provided in alphabetical order):

- Aurangabad
- Kolhapur
- Mumbai
- Nagpur
- Nashik
- Navi Mumbai
- Pune
- Solapur

These eight cities were further evaluated in the second phase of the selection process for ground-truthing and stakeholder consultations. Besides this, the potential for airshed formation was also evaluated as a qualitative criterion to shortlist cities. Few cities are having extensive geographical spread and thus an effective airshed formation becomes complex, along with other factors in place; these cities were dropped off because of the said reason.

The screening is done in two phases. In the 1st phase, a maximum of scoring/weightage is given to each parameter and normalisation are done to this scoring based on their contribution to the AQI/pollutant concentration.

The parameters being (a) PM10 (μg/m^3), (b) AQI with respect to PM2.5 and PM10 (for 24 h), (c) AQI with respect to PM2.5 and PM10 (for 24 h), (d) population in the cities, (e) size of the industrial cluster, (f) types of industries, (g) presence of emission inventories and (h) presence and review of City Air Action Plans (i) Recommended intervention under the City Action Plans for industries. A total score of 30 is being distributed in a normalised way accordingly in the parameters and a desk assessment is done to allot a score for each. The cities scored accordingly with respect to the score distribution chart. These total scores and normalisation are followed using OECD-Environment Working Paper No. 1 (Nicholls et al., 2008).

In the second phase, the availability of the qualitative and quantitative answers by the stakeholders for the second phase questions is taken to give score (Table 3b) to refer.

Stakeholder's consultation outcome

The consultations were conducted keeping in mind the capacity required to execute on the mandates of the

Table 3 Status of cities in air quality management

Sr. no.	Air shed regions	Presence of air quality Management committee	Priorities	Assistance required	Technical capacity	Team bandwidth	Availability of funds	Replication feasibility	Presence of other agencies
1.	Aurangabad	–	Aligned	No	High	Medium	Low	Low	Yes
2.	Kolhapur	No	Aligned	Yes	Medium	Medium	Medium	High	No
3.	Mumbai	Yes	Aligned	No	High	High	High	Low	Yes
4.	Navi Mumbai	Yes	Aligned	Yes	Medium	Low	Medium	Medium	Yes
5.	Pune	No	Aligned	Yes	Medium	Low	High	Low	Yes

NCAP. The Air Quality Management Committee is a requirement put forth by the CPCB to oversee the implementation of the city action plans. Thus, its formation and functioning are critical to the success of the programme. Other important questions gauged the areas which the urban local body has prioritised and whether they are aligned to the organisation's work and expertise, their willingness to work with an organisation and whether they require such technical assistance, their own technical expertise to tackle problems associated with air pollution mitigation, the available human resources on the team and the availability of funds to implement the interventions. The questions on replication feasibility and the presence of the other agencies are more related to the organisation than the urban local body, as replication of the activities in other geographies provides expansion of the organisation's current projects and opens the door to more funding opportunities while the presence of other agencies governs the feasibility of expanding operations in a saturated region.

Ranking based on stakeholder's consultation

The 5 shortlisted cities were further analysed by seeking inputs from the local government agencies, institutions, air experts to finalise the cities and surrounding air shed regions that need implementation of air pollution mitigation strategies on priority. The selection was based on a qualitative questionnaire that helped us determine the stakeholder's willingness, their priority work area, the scope for work, potential barriers for entry, area of work, technical capabilities and availability of funds with the implementation agency. Based on stakeholder consultations, and data collected from the outreach activities, five cities were further ranked and analysed to select two cities for project implementation. This selection was done by the weighted scoring method.

Figure 5 shows the ranking of the short-listed cities. The explanation for criteria is mentioned below. The analysis and the ranking or selection of the cities are based on two step processes, i.e. desk assessment and the later one with field interventions and sets of questionnaires for the stakeholder members from each of the cities. After a screening of 8 cities was done from the whole lot of 18 NCAP cities, a subset questionnaire was given to the 8 cities to understand their willingness to work against air pollution for the cities (the stakeholders mainly being the Municipal Corporation Office representations, in the State). The questionnaire mainly consists of 9 questions (mainly in a qualitative format), to understand. The parameter (mentioned reasons) which is mostly responsible for the pollutants in the city is given the prime important and vice versa.

The parameters for the ranking taken includes in the two phases are (a) PM10 (μg/m^3), (b) AQI with respect to PM2.5 and PM10 (for 24 h), (c) AQI with respect to PM2.5 and PM10 (for 24 h), (d) population in the cities, (e) size of the industrial cluster, (f) types of industries, (g) presence of emission inventories, (h) presence and review of City Air Action Plans and (i) recommended intervention under the City Action Plans for industries.

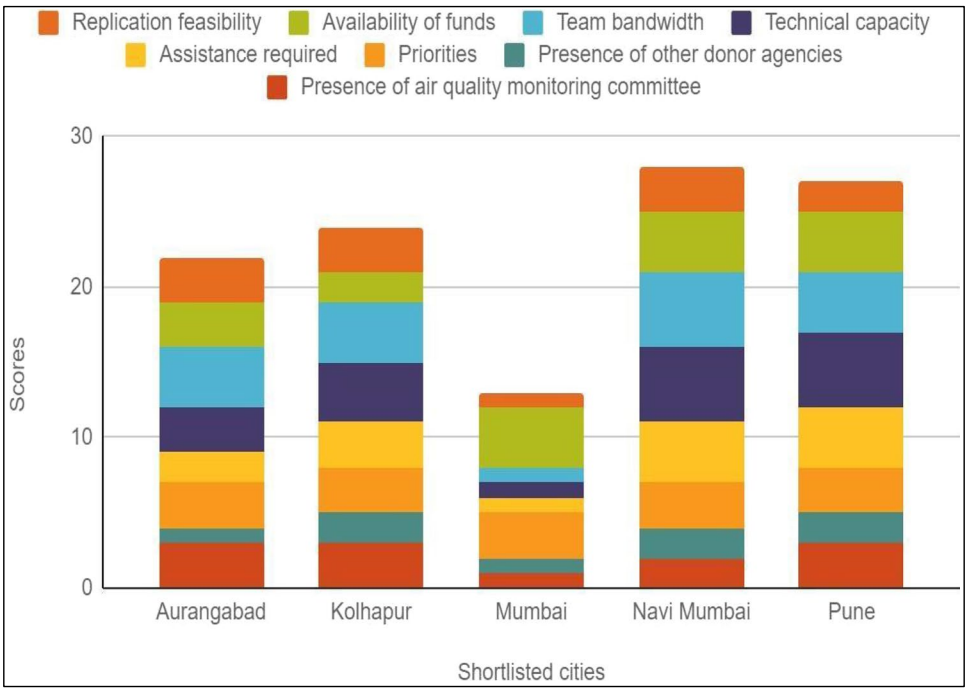

Fig. 5 Ranking of the short-listed cities

Screening in the second phase includes:

a) Number of airshed regions: Total number of airshed regions present in the city, area of airshed region and other important meteorological parameters?
b) Presence of air quality: What is the monthly average concentration of particulate matter observed for all the monitoring stations for a year?
c) Priorities: Does air pollution stands as one of the major priorities for the corporation office? If to rank between city major pollution issues like air pollution management, wastewater management, solid waste management, electronic waste management, plastic waste management etc., what rank will be given to air pollution problem.
d) Assistance required: What is the area where the relevant stakeholders think that they will need assistance to curb and mitigate air pollution problem? Please write from most required assistance to least required assistance.
e) Technical capacity: What is the technical capacity existing with the organisation/board/stakeholder to work towards managing the air quality of the airshed/particular city? Is there any resource allocated to work on the specific matter of air pollution.
f) Team bandwidth: If the answer for the (e), i.e. technical capacity, is yes, please specify a number.
g) Availability of funds: What are the total allocated funds available for the city, kindly give an approximate budget for each of the area heads of expenditure?
h) Replication feasibility: Air pollution management framework is a long-term initiative by the Indian Government, how can the strategic activities already planned for the cities can be used in other cities to mitigate air pollution?
i) Presence of other agencies: Are other non-profit or government funded agencies working in the city to fight the air pollution issues? If yes what kind of activities are covered under the same, (for example resource allocation in the form of PMU's etc)? How can this data be used to avoid duplicity, and synergy formation between aligned agencies.
j) Management committee: Is the management pro-active towards the issue? Mention 4 activities that the management take towards reducing air pollution in the city?

Based on the analysis, the airshed regions of Navi Mumbai and Pune scored the highest for project implementation as these airshed regions met all the criteria that would aid an organisation to implement a successful programme. Navi Mumbai and Pune are expanding cities that require assistance and their technical capacities built as their internal team bandwidth and human resource is considerably lacking when compared to the size of the cities and their surrounding airshed regions. However, the air pollution problem in the Navi Mumbai city region is more complex in comparison to Pune due to the industrial activities of adjoining cities of Thane, Kalyan, Ambernath, Dombivli and Ulhasnagar. The pollution potential of industrial sectors in Pune is comparatively lower compared to the Navi Mumbai region given the industry type. Meetings with the city officials from the urban local bodies in Navi-Mumbai, Thane, Ambernath and Kalyan further validated the need for capacity building, and technical assistance to accelerate air pollution mitigation strategies. The summary of primary consultations is presented in Table 4 below.

Proposed interventions—discussion on work required work activities

In a conversation with the municipal corporations and estimates, there is scope to quantify and work on different sectors to reduce the air pollution in the city and airshed region of Navi Mumbai and Pune city respectively. Some of the work includes traffic management, solid-waste management, scaling up of renewable sources and other clean and green energy sources in the city. Moreover, there is no study to date that has shown the economic loss and health risk to such an immense population caused by the criteria pollutants for Navi-Mumbai, Pune and their corresponding airshed regions. These major areas where significant intervention points were to be addressed were the rationale behind the selection of Navi Mumbai and Pune (Purohit et al. 2019). Researchers have also proposed the following potential set of activities and interventions in the cities of Navi Mumbai and Pune with further plans to replicate the work in other selected non-attainment cities in Maharashtra. Table 5 shows the overview of interventions and activities.

World research status in 'air quality management' and 'National Clean Air Programme' domain

The Scopus database, one of the most trustworthy research databases, has been chosen as the data source for this study. In this study, the keywords like 'Air Quality Management', 'National Clean Air Programme' and 'Mitigation Strategies' in different combinations were used for searching the relevant articles on the Scopus database with institutional login id over the past years to till date (9 August 2022). The search was kept specific to simulate the relevant keywords only from publication's article title, keywords and abstract. The search was made using keywords 'National Clean Air Programme' and it showed 657 articles in the Scopus database. There were only 2 articles found till date with the mentioned 3 keywords 'Air Quality Management', 'National Clean Air Programme'

Table 4 Summary of stakeholder interactions for Navi Mumbai and Pune

Sr. no.	Air shed regions	Municipal Corporations	Presence of air quality monitoring committee	Presence of other organisations	Priorities	Assistance required	Technical capacity	Team bandwidth	Availability of funds	Replication feasibility
1.	Navi Mumbai	Ambernath	No	No	SWM, STP, renewable energy	Yes, technical and project viability	Medium	Low	Yes	High
2.	Navi Mumbai	Badlapur	No	No	SWM, STP	–	Low	Low	–	High
3.	Navi Mumbai	Kalyan-Dombi vali	No	No	Pollution (air, water, noise)	Yes technical (air, water and noise)	High	Low	Yes	High
4.	Navi Mumbai	Ulhasnagar	No	No	SWM	Yes	Low	Low	–	High
5.	Navi Mumbai	Thane	No	No	–	Yes	Low	Low	–	High
6.	Pune	Pimpri-Chinch wad	No	–	–	Yes	Low	Low	–	High

and 'Mitigation Strategies'. To get more specific articles relevant with the present study, keywords like 'National Clean Air Programme' and 'Mitigation Strategies' were used for another search, and only 8 articles were found in the Scopus database. Similarly, another search was made using 'National Clean Air Programme' and 'Air Quality Management'; it showed 81 articles only. Hence, we proceeded the analysis with this 81 articles data. The .csv file was downloaded from the Scopus database. VOSviewer (version 1.6.18), an open access software tool for performing bibliometric analysis, was used in the present study. Further, Scopus data analyses were saved and used to show the world research status in this domain.

The distribution of articles over the year (1974 to Aug, 2022) in National Clean Air Programme' and 'Air Quality Management' domain was observed over Scopus Database. A very few articles (2–5) got published in this domain yearly. Only in 2021, the focus on this research domain has sharply increased and published 7 articles in this domain. In the present year, also only 1 published article was found in this domain. It entails there is a scope to emphasise on this research area more to overcome air pollution programme and thereby climate change issues (Supplementary figures 1) issues. The major authors are Stepp, C (4 published articles) and Hamilton, H (3 published articles) in this domain (supplementary figure 2).

This entails that developed country like USA (47articles) has focused more on this research area followed by developing country India (7 articles) (Supplementary figures 1, 2, 3).

The downloaded .csv file from Scopus database (with 81 articles) was imported into VOSviewer for bibliometric analysis. The data filtration was initiated to remove redundant, unrelated keywords. A full counting method was preferred during this analysis. The minimum occurrence of a keyword was kept at 5 times for the keywords mapping process. Among 820 keywords, 26 keywords met the threshold. Supplementary figures 1, 2 and 3 show the major keywords connection among other keywords. The major keywords were found to be air quality, air pollution, laws and legislations, environmental management, air quality standards, etc. The major 2 keywords occurrences and total link strength were found to be air quality (29 occurrences with 147 total link strength) and air pollution (17 occurrences with 110 total link strength) (Fig. 6).

Limitations of the work

This study involved two major parts (a) desk review and (b) field interventions. The major part involved in the desk review is taking a scientific approach of screening down the cities on environmental parameters which includes

Table 5 Overview of interventions and activities

Strategic interventions	Activities	Expected outcomes
Strengthen the clean air ecosystem/institutions (Bhushan et al., 2020)	Facilitate formation of Air Quality Monitoring Cell (AQMC) Draft the Terms of Reference (ToR) for the AQMC Develop an easy-to-implement monitoring system to facilitate data collection. Empanel technical experts to support effective implementation of the city action plan. Capacity building of local institutions Conduct public awareness campaigns	A fully functional AQMC City action plan progresses. Overall reduction in PM2.5 pollution
Air quality monitoring and health impact assessment (Gulia et al., 2018)	Gather publicly available air quality data. Support concerned authority with Identification of key hotspots of exposure Establish baseline. Technical support to enhance local data collection capacity IT-enabled system for an enhanced monitoring approach Conduct health risk assessment using remote sensing-based tools to establish health benefits from the project interventions	Enhanced air quality measurement and monitoring
Skill development to ensure long term sustainability of initiatives (Gulia et al. 2018)	Conduct a skill gap analysis Develop curriculum for skilling Clean Air stakeholders and practitioners on APCTs, air quality monitoring and health risk assessment through close consultation with concerned stakeholders.	Increased availability of skilled clean air practitioners and city officials Implementation of city action plan accelerates

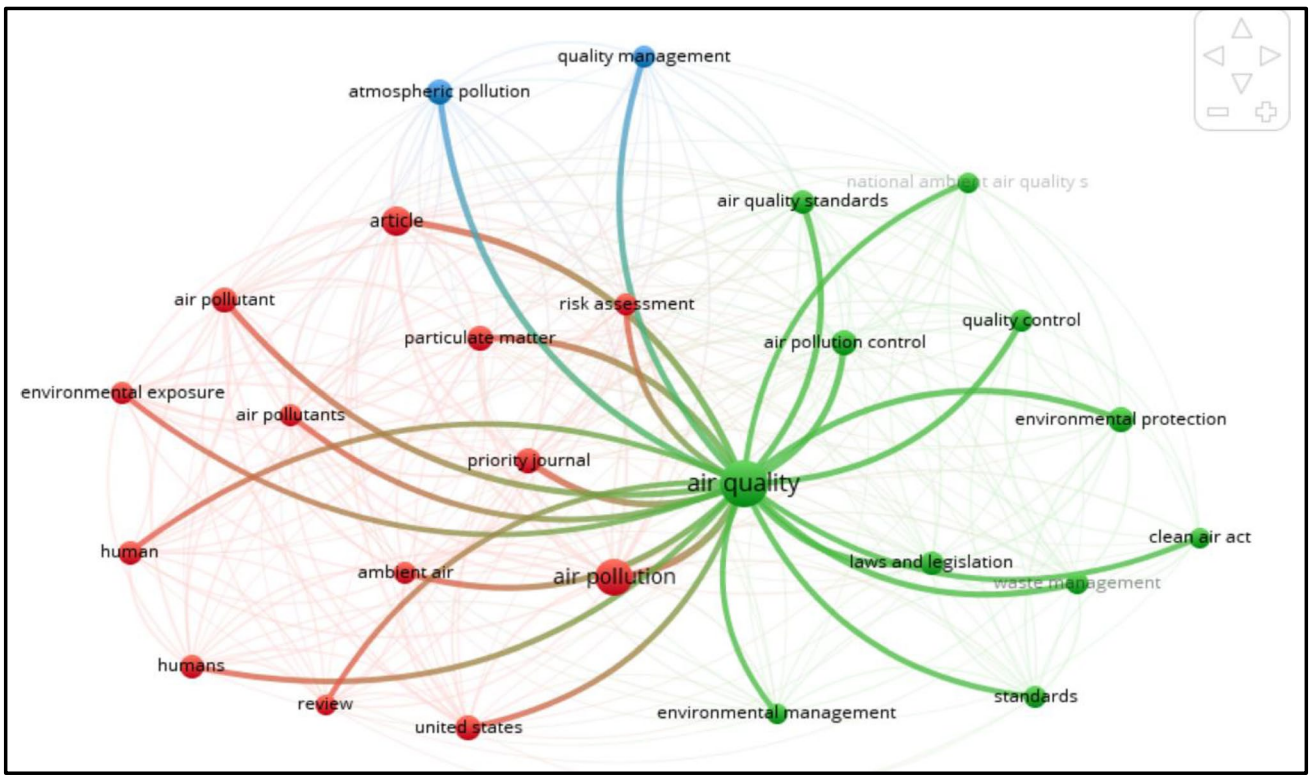

Fig. 6 The major keywords connection among other keywords

meteorology, pollutants' concentration, industrial presence etc. The field interventions included stakeholders' consultations from the ULB's which added in the gauging the potential needs and work feasibility to work in the city. The major limitations that were identified in the process of this selection/management process are jotted down below:

a) The unavailability of frequently updated datasets is an important limitation that we faced during the study. For example, the PM2.5 data and PM 10 data are scarcely available from the CPCB site. CAAQMS and manual monitoring data had to be taken judiciously.
b) Segregation of industries (e.g. heavy, light, highly-polluting and less-polluting) in the particular industrial cluster is quite difficult due to the unavailability of data related to air emissions.
c) Presence of outdated data for census and population, outdated Emission Inventories for the cities with no scientific justifications and the city action plans with lots of data gaps and knowledge improvement.
d) Stakeholder consultations are the effective part, where an understanding of the willingness of the administrative city officials are to be marked for starting the implementation programme, coordination in these processes is quite a time-consuming and hectic.
e) The lockdown scenario in the state of Maharashtra had slowed down the process of seeking virtual and in-person meetings as the majority of the resources were being directed towards covid relief and response.
f) There are very less studies in the landscape with the air quality management in the Indian Scenario and we need more of them in the coming future to reduce the pollution level to 20–30%.

Air quality management actions and policy interventions taken globally: research recommendations which are now added to the manuscript includes:

i. Tackling transboundary pollution necessitates regional cooperation, which demands a strong political will backed by a methodical, scientific approach. To make a case for the same, institutions and stakeholders must work together.
ii. Controlling domestic air pollution sources must be a top priority for all the region's nations, which necessitates domestic policy changes. At the sub-national and city levels, it is also necessary to mainstream linkages between urban growth and air quality. Sector-specific policies are critical to make timely progress in each sector.
iii. Governments, academics, industry and community organisations must work together effectively. This is crucial for supporting and putting into practise social and behavioural solutions.
iv. In South Asia, 61% of the population is exposed to indoor biomass burning-related household air pollution (for cooking and heating). In nations like India, where the flagship Pradhan Mantri Ujjwala Yojana scheme is promoting the use of LPG, this model is gradually shifting. Early research points to benefits in people's health as a result.
v. Governments, academic institutions, business organisations and community organisations must work together effectively. To adopt and support social and behavioural solutions, this is crucial.
vi. Air pollution from homes linked to indoor biomass burning is a concern for 61% of the population in South Asia (for cooking and heating). Countries like India, where the flagship Pradhan Mantri Ujjwala Yojana scheme is promoting the usage of LPG, are witnessing a steady shift in this approach. An improvement in human health is suggested by preliminary investigations.
vii. Measures that could lower PM2.5 levels include switching to cleaner BS-VI fuel, setting up regulatory monitoring stations in all industries, industry-specific solutions (such as cleaner zigzag technology in brick kilns), building peripheral highways to ease traffic in urban areas and using 'happy seeders' to combat crop residue burning. Early results indicate that these actions are successfully lowering PM2.5 levels in India's National Capital Region.
viii. A broad range of air pollution issues affecting all countries in the region need to be addressed, national scale regulatory action with a thorough transnational approach is required.
ix. Creating, analysing and communicate accurate area activity representative information, air pollution monitoring networks must be sufficiently dense and sensitive to meet the minimal criterion for optimum spatial coverage. An accurate set of measurements and data, as well as monitoring, are required to produce solid scientific evidence and to enable unambiguous messaging for policy and decision-makers.
x. Advisory to decrease the monitoring gap in these nations efficiently and affordably, it is necessary to research and strengthen the use of alternative monitoring methods (supplementing and alongside, not in place of, traditional compliance monitoring).
xi. Allowing the local authorities to narrate their own tales. Political leaders will have a better knowledge of the issue if local experts are included in the process of obtaining evidence.
xii. Improved access to pertinent and/or cutting-edge technologies, coupled with pertinent training and research from around the globe and within the region, are all necessary to increase regional capability

xiii. Countries must abandon the use of fossil fuels and quicken the switch to renewable energy sources.
xiv. To decrease the monitoring gap in these nations efficiently and affordably, it is necessary to research and strengthen the use of alternative monitoring methods (supplementing and alongside, not in place of, traditional compliance monitoring).
xv. Allow local authorities to narrate their own tales. Leaders will have a better knowledge of the issue if local experts are included in the process of obtaining evidence.
xvi. Countries should invest in clean technology, like those used in transportation, energy production and agriculture, to enhance air quality (such as moving to solar or low sulphur fuels). Changes must be made to guarantee that strategies for enhancing air quality have both financial and health benefits. The business community, as well as the regional and local levels, needs to adopt co-beneficial incentives. For instance, incentives must be given to traders, tiny foundries and other similar informal economic enterprises so they may both take responsibility for problems and contribute to better air.
xvii. Cities in the region must shift their transportation priorities away from reliance on personal vehicles and towards public mass transit networks to improve air quality.
xviii. It is necessary to take an interdisciplinary approach, which South Asia currently generally lacks. A shared understanding of the sustainability dilemma and the development of a common scientific foundation are necessary before nations can collaborate to identify the best solutions. Science- and evidence-based solutions are more likely to be effective, efficient and transformative.
xix. A favourable environment for the promotion of clean energy-related technology can be created via preferential taxes. For instance, market-based tools like preferential pricing for clean vehicles and higher taxes for vehicles that emit pollution can help to significantly influence demand. The tax collected may be used to fund greener solutions or mitigation measures.

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Author contributions AD is involved in the conceptualisation, writing and reviewing the manuscript. AG is involved in the supervision, writing and reviewing the manuscript.

Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication The correspondent authors and all the co-authors give their consent for publication of this manuscript.

Conflict of interest The authors declare no competing interests.

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