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Special Issue 1.2021

The Emergency Plan for the use and management of the territory

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The cover image is a photo of the landslide that hit the municipality of Amalfi (Italy) in February 2021.

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Environmental quality of emergency areas. A methodology to assess shelter areas liveability

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Abstract

The types of risk that territories are facing today have greatly increased in recent years, having multiplied the damage that human activity has produced and continues to produce on the natural environment. With the aim to create a really resilient territory it is necessary to carry out an environmental quality assessment together with risk analysis, in order to build effective responses to the possible problems resulting from the changes in progress. This assessment should be integrated into the knowledge framework of existing planning tools, in particular as regards the Emergency Plan. Among the Plan contents, indeed, the identification of the areas for the accommodation of population affected by disaster is included. Nevertheless, currently localization criteria are mainly used, without considering the potential liveability of these areas. This document presents the first results of a research aimed at identifying and assessing the factors useful to ensure an adequate environmental quality of the shelter areas, defined following the comparative study of evaluation systems used in different countries. Research aims to provide opportunity for broader reflection on the relationship that needs to be established between these evaluation systems and planning tools, in respect of which there is at present almost total independence.

Keywords

Environmental quality; Assessment; Emergency planning.

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1. Introduction

There are whole regions in Europe and in the world that, due to their geographic location, have always been exposed to several types of natural risks such as seismic and volcanic ones (Gargiulo & Lombardi, 2016). Emergency planning has a fundamental role in fragile territories such as Italy, where a large proportion of the population is exposed to various risks1. Emergency Plan defines the set of operational intervention procedures to deal with any disaster expected in the territory. It is a dynamic, flexible, and constantly updated tool, having to take into account the evolution of land use planning and changes in the expected scenarios. The Plan in structured in several sections, among which the one related to emergency management is certainly the most characteristic. However, the analysis of the territory and the consequent construction of the knowledge framework is fundamental for the prefiguration of the scenarios and for the preparation of the related intervention activities linked to the occurrence of the expected disaster. In this regard, the assessment of the existing risks only is not enough to provide a comprehensive representation of the analysed territory (Papa et al., 2015). Cognitive action needs to be increased by further analysis that consider the environmental quality of the site, on the basis of which define its ability to adapt to change and to react to it. The definition of the environmental quality of the territory is useful for the identification of the so-called emergency areas, with special regards to the shelter areas, that are intended to accommodate population affected by disasters for a medium-long period. Currently, localisation parameters are mainly used for the identification of these areas, such as the proximity to the main road network, to the essential services, etc.

This study investigates parameters characterizing the environmental quality of a site through the comparison of different evaluation systems existing in the literature, and how the assessment of these parameters can relate to the existing emergency planning tool. Analysis results are tested on the shelter areas identified by the Emergency Plan of the city of Bologna, by evaluating if their environmental conditions are suitable to host people for medium/long time.

2. Background concerning environmental quality

The environmental quality of an area or of a territory determines its living conditions, ensuring the well-being and protection of human health. The assessment of environmental quality is very often put in the background or completely bypassed during the development of knowledge processes prior to the planned choices, because analysis is mainly focused on the type and extent of natural risks existing in the examined area. Data concerning risks exposure are indispensable components of the knowledge framework, nevertheless nowadays they represent a necessary but not sufficient condition for an adequate and integrated understanding of a territory. The environmental issue, indeed, is one of the greatest problems of the current century due to the serious consequences linked to the deterioration of the quality of life and the health problems that it entails (Orhan, 2012). It can be interpreted as the combined effect of individual elements, the diversity and multiplicity of which motivates the search for synthesis indicators that can streamline the analysis without causing an excessive loss of information (Aiello et al., 2015). However, no generally accepted conceptual framework or coherent system to measure and assess properly environmental quality aspects has been developed to date (Kazemzadeh-Zow et al., 2018).

Starting from these assumptions, the primary objective of the research was to create a "mosaic" of the various parameters that contribute to the definition of the environmental quality of a territory and to identify for each of them the most representative indicators, in order to provide an unified, analytical, and reliable evaluation method. A comparative analysis of the most relevant international and national voluntary certification systems

[1] In Italy 41% of the total population lives in in areas with medium or high seismic risk, 2% in areas with high landslide risk and 3% in areas with high flood risk (Trigila et al., 2015; Di Giovanni, 2016).

has been carried out with this aim[2]. A cross-study of European and national legislation has been carried out for each defined indicator, to obtain a regulatory reference regarding the related threshold values.
The study was developed through appropriate key questions, thanks to which the analysis and the results have been structured[3]. Following data emerged as response to key questions. The parameters characterizing environmental quality can be identified as follow: air quality, water quality, light pollution, noise pollution, heat island effect. Measurement indicators and related assessment method have been defined for each parameter (Tab. 1). Indicators in Tab. 1 express the environmental condition at the *t* time of the measurement (*state indicators*). Therefore, results of the assessment are not static but susceptible to change.

3. Materials and methods

3.1 Case studies

Shelter areas identified by Municipal Plan of Civil Protection of the city of Bologna (regional capital of Emilia-Romagna, Italy) have been selected as case studies. The choose was based on the data availability and on the representativeness of the city of Bologna, which plays a strategic role in emergency conditions being the heart of a metropolitan area populated by over a million inhabitants. The Plan identifies nine shelter areas (Fig. 1), which "must contain at least 500 persons and field services, not be exposed to risks and be equipped with all essential services, or in any case located close to electricity and water supply, and to pipelines for wastewater disposal" (Municipal Plan of Civil Protection of the city of Bologna, 2016). Areas identification criteria refers only to the risk conditions and functional equipment. The aim of this work is to verify if shelter areas identified by the Plan also meet the environmental quality requirements necessary to ensure satisfactory livability levels. The final output will be a synthesis map built through the assessments carried out by using indicators in Tab.1.

3.2 Methods

Work was structured following the flowchart in Fig. 2. Actions can be grouped in four "blocks": (i) literature critical analysis and related outputs, (ii) input dataset creation, (iii) statistical analysis, and (iv) final output.
The first block refers to that described in Section 2.
After the definition of parameters characterizing environmental quality and related indicators, the dataset relative to the case studies has been created. The data needed to measure indicators have been extracted from different sources. Indicators for which sufficient data were not available were excluded from the dataset. Subsequently, indicators for which there was no variability of data between case studies were also excluded from the consecutive analyses (Tab. 2).
Data integration, indeed, was developed through Principal Component Analysis (PCA) that is a statistical analysis technique that allows to integrate data from different sources, and to reduce the number of correlated variables into a smaller number of uncorrelated components (Principal Components, PCs) maintaining the most of the data variance (Jensen, 2005; Faisal & Shaker, 2017). The PCs are linear transformations of the initial variables, able to explain the maximum possible share of the total variability through appropriate vectors of weights (loadings) assigned to the initial variables.

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2 DGNB System Basics for Urban Districts/Office and Business Districts (Germany), BREEAM Communities (UK), CASBEE for Cities (Japan), LEED for Neighborhood Development (USA), ITACA Protocol at Urban Scale, and GBC Neighbourhoods Certification System (both Italian) have been analysed.

3 See Margiotta, N., Palermo, A. & Viapiana M.F. (2020). Qualità ambientale: metodologie di valutazione e strumenti di pianificazione. In M. Francini, A. Palermo & M.F. Viapiana (Eds.). *Il piano di emergenza nell'uso e nella gestione del territorio*, 307-321, Milano: Franco Angeli editore. ISBN 9788897190972 for a more detailed description of the carried out analysis.

Parameter	Certification System	Reference indicators	Normative references	Measurement indicators	ID	Assessment method
Air quality	DGNB	SOC1.9	European Directive 2004/107/CE European directive 2008/50/EC D.Lgs. 55/2010	SO2 concentration NO2 concentration NOx concentration PM10 concentration PM2.5 concentration Pb concentration B6H6 concentration CO concentration As concentration Cd concentration Ni concentration C20H12 concentration	$SO2_{conc}$ $NO2_{conc}$ NOx_{conc} $PM10_{conc}$ $PM2.5_{conc}$ Pb_{conc} $B6H6_{conc}$ CO_{conc} As_{conc} Cd_{conc} Ni_{conc} $C20H12_{conc}$	The concentration values (µg/m3) of each pollutant are detected and compared with the related limit values, target values, and upper and lower assessment thresholds established by European directives.
	BREEAM	RE07				
	GBC-LEED	[-]				
	CASBEE	Q1.2.1				
	ITACA	5,06 5,07 5,08 5,09				
Water quality	DGNB	ENV1.7	European Directive 2000/60/CE as amended D.Lgs. 152/2006 as amended DM 260/2010	Surface water bodies ecological status Surfacewater bodies chemical status Groundwater bodies quantitative status Groundwater bodies chemical status	ES_SWB CS_SWB QS_GWB CS_GWB	Ecological status (high, good, moderate, poor, or bad) and chemical status (good or falling to achieve good) of surface water bodies and quantitative status (good or poor) and chemical status (good or poor) of groundwater bodies are detected and assessed.
	BREEAM	LE03				
	GBC-LEED	[-]				
	CASBEE	Q1.2.2				
	ITACA	5,02 7,03.4				
Light pollution	DGNB	SOC1.9	Standard UNI 10819 *Model Lighting Ordinance* (MLO) (Ida & IES, 2011)	Number of lighting structures according to standards/lighting structures total number	$Ls_{0\%}/Ls_{tot}$	Lighting structures present in the area are detected, and the percentage deviation between the number of lighting structures whose luminous flux has dispersion upwards below the permitted limits (0% according to the MLO) and the total number of lighting structures is assessed.
	BREEAM	SE16				
	GBC-LEED	Credit 17 of *Sustainable Infrastructure and Buildings* Category				
	CASBEE	[-]				
	ITACA	5,05				
Noise pollution	DGNB	SOC1.9	European Directive 2002/49/CE L. 447/1995 DPCM of 1 March 1991 DL 194/2005.	L_{den} mean value L_{night} mean value	L_{den_mean} L_{night_mean}	L_{den} and L_{night} value are detected. Mean values of noise indicators are calculated for the examined area, by weighting L_{den} and L_{night} values against the extent of the surfaces characterised by each noise level. Mean values are compared with the related limit values.
	BREEAM	SE04				
	GBC-LEED	Credit 16 of *Neighbourhood management and programming* Category				
	CASBEE	[-]				
	ITACA	[-]				
Heat island effect	DGNB	ENV1.5 SOC1.1	DM of 11 January 2017.	Albedo mean value	Alb_{mean}	Examined area is divided into homogeneous sub-zones and related solar reflection coefficient (Albedo) is identified. An Albedo mean for the area value is calculated, by weighting Albedo values against the extent of each homogeneous sub-zone.
	BREEAM	SE08				
	GBC-LEED	Credit 9 of *Sustainable Infrastructure and Buildings* Category				
	CASBEE	[-]				
	ITACA	4,04 7,02.3				

Tab.1 Environmental quality parameters and assessment indicators

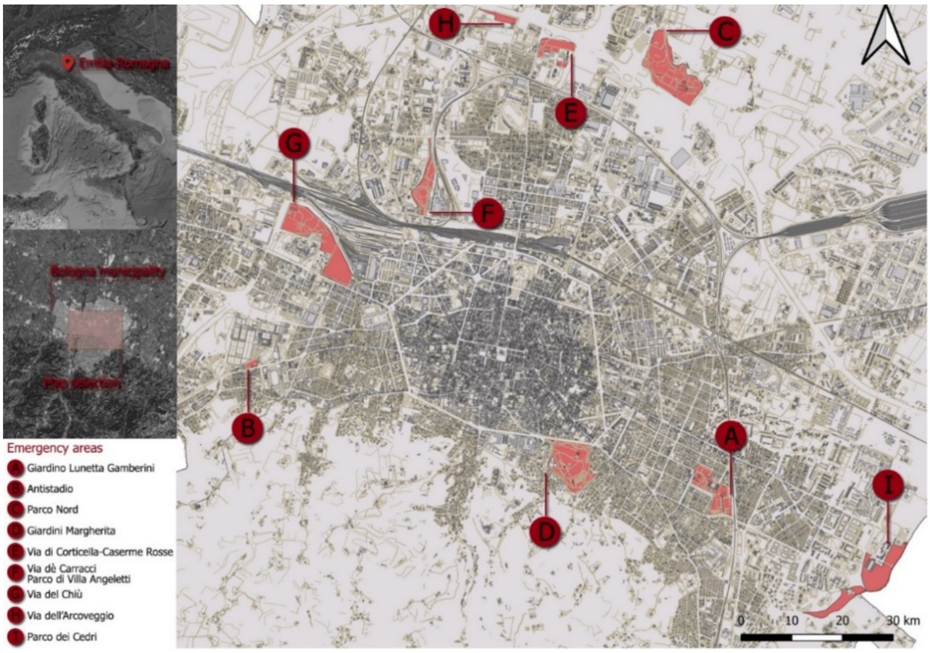


Fig.1 Localization of Bologna municipality and of shelter areas

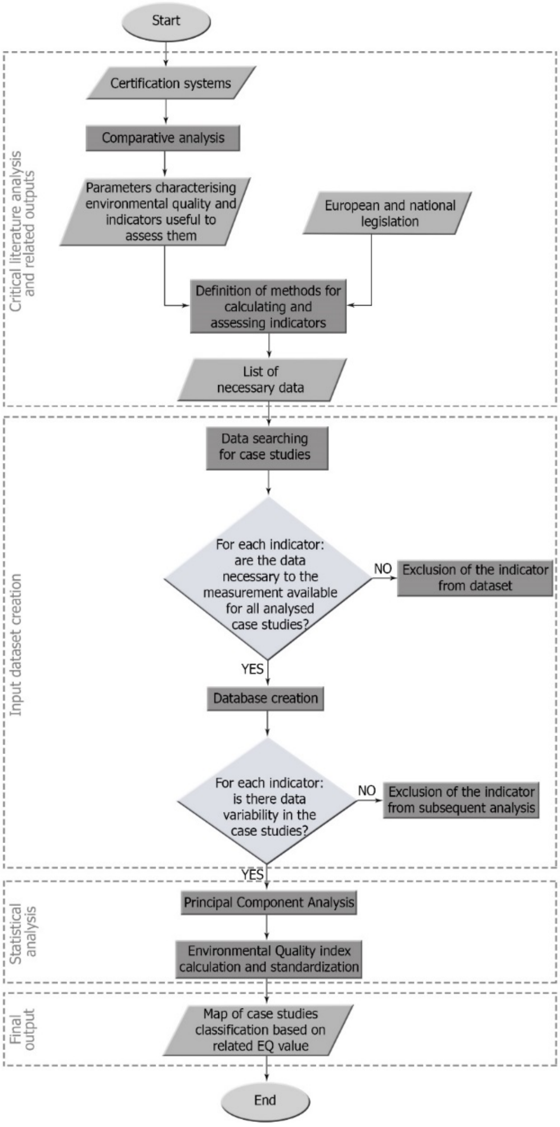


Fig.2 Overall flowchart

Parameter	Indicators	Source	Indicators excluded due to the lack of data	Indicators excluded due to the lack of variability in the data
Air quality	$SO2_{conc}$, $NO2_{conc}$, NOx_{conc}, $PM10_{conc}$, $PM2.5_{conc}$, Pb_{conc}, $B6H6_{conc}$, CO_{conc}, As_{conc}, Cd_{conc}, Ni_{conc}, $C20H12_{conc}$	*Regional agency of prevention, environment, and energy* (Arpae) of Emilia-Romagna	$SO2_{conc}$, NOx_{conc}, Pb_{conc}, $B6H6_{conc}$, CO_{conc}, As_{conc}, Cd_{conc}, Ni_{conc}, $C20H12_{conc}$	$PM10_{conc}$
Water quality	ES_SWB, CS_SWB, QS_GWB, CS_GWB	*Regional agency of prevention, environment, and energy* (Arpae) of Emilia-Romagna Water management Plan of Emilia-Romagna, retrieved from minERva web portale	[-]	ES_SWB, QS_GWB
Light pollution	$Ls_{0\%}/Ls_{tot}$	Google Earth Pro	[-]	[-]
Noise pollution	L_{den_mean}, L_{night_mean}	Strategic noise map of Bologna Agglomeration	[-]	[-]
Heat island effect	Alb_{mean}	Google Earth Pro	[-]	[-]

Tab.2 Data source and excluded indicators

The PCA requires the building of the covariance matrix between variables (indicators). When – as in this case – variables have different measurement units Pearson correlation matrix is used, in which each element *ij* (Pearson correlation index) is the ratio of the covariance of the variables *i* to *j*, and the product of the standard deviations of the two variables:

$$\rho_{ij} = \frac{\sigma_{ij}}{\sigma_i * \sigma_j} \tag{1}$$

For this reason, variables (indicators) with zero standard deviation (no variability) have been excluded. Then the eigenvalues and eigenvectors of the correlation matrix are calculated, and the number of PCs to be used is defined by using three Heuristic criteria. Based on the first criterion, the number of PCs to choose is equal to the number of eigenvalues that represent 80-90% of the total variance. According to the second criterion (Kaiser's rule) only PCs with an eigenvalue greater than 1 are chosen. Finally, based on the third criterion PCs to the left of the Scree Plot "elbow" point are chosen. The environmental quality index (EQ) is calculated as a linear combination of the product of the selected PCs scores and relative variance percentages, as proposed by Musse et al. (2018) and Li & Weng (2007):

$$EQ_i = \sum_{j=1}^{n} PC_{j\_score} * v_j \tag{2}$$

Where EQ_i is the environmental quality index of the *i*-th shelter area, j is the number of selected PCs, PC_{j_score} is the score of the *j*-th PC and v_j is the variance percentage explained by the *j*-th component. EQ values are standardised using the following formula (Zhong et al., 2020):

$$EQi_{stand} = \frac{EQi - min\{EQ\}}{max\{EQ\} - min\{EQ\}} \qquad \text{i } (1, 2, \ldots, 9) \tag{3}$$

Where EQi_{stand} is the standardized environmental quality index of the *i*-th shelter area. The EQi_{stand} values are finally classified into five classes, referring to ranking used by the DGNB, BREEAM and GBC-LEED certification systems: bad ($EQi_{stand} \leq 0.35$), poor ($0.35 < EQi_{stand} \leq 0.55$), fair ($0.55 < EQi_{stand} \leq 0.65$), good ($0.65 < EQi_{stand} \leq 0.80$), and very good ($0.80 < EQi_{stand} \leq 1$).

4. Results and discussion

4.1 Parameters analysis

Air quality

The information necessary for the assessment of air quality refers to 2018, due to the data made available by Arpae (Regional agency of prevention, environment, and energy) of Emilia-Romagna. Normative references (Tab. 1) require air quality to be assessed based on the concentration levels of 11 pollutants: NO_2, NOx, PM^{10}, $PM^{2.5}$, Pb, B_6H_6, CO, As, Cd, Ni, C_20H_{12}. However, NOx concentration values are only available for three shelter areas, B6H6 and CO concentration values are not available for any area, and concentration values concerning Pb, As, Cd, Ni and C_20H_{12} are only available for Giardini Margherita area, within which a monitoring station is installed. Due to the lack of data, only three indicators have been included in the assessment (Tab.3). Fig.3 synthetizes data concerning NO_2 and $PM^{2.5}$ atmospheric concentration. Data retrieved from monitoring stations have been referred to areas of representativeness defined according to the Technical Report *Criteria for EUROAIRNET* (Larssen, Sluyter & Helmis, 1999) based on the type of monitoring station.

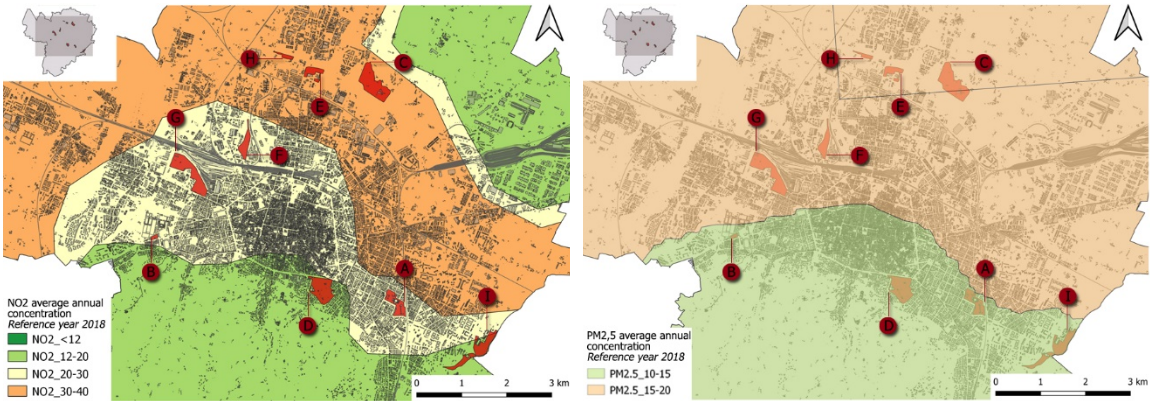
Concentration values are compared to related limit or target values and threshold ones (Tab.3).

From the comparison it can be noted that: (i) NO_2 concentration is below the lower assessment threshold only in one of the nine areas (Giardini Margherita); in the others it is between the lower and upper assessment threshold or close to the limit value (Parco Nord, Via di Corticella - Caserme Rosse, Via dell'Arcoveggio); (ii) concentration values of PM^{10} are higher than the upper assessment threshold in all the areas; (iii) in no area PM2.5 concentration is below the lower assessment threshold; it is between the lower and upper assessment threshold in three areas (Giardini Lunetta Gamberini, Antistadio, Giardini Margherita) and between the upper assessment threshold and the limit value in all the others.

Shelter area	Pollutant	Concentration value[4] (μg/m³)	Limit value[4] (μg/m³)	Upper assessment threshold[4] (μg/m³)	Lower assessment threshold[4] (μg/m³)
Giardino Lunetta Gamberini	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Antistadio	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Parco Nord	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Giardini Margherita	NO_2	12-20	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Via di Corticella – Caserme Rosse	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via dè Carracci – Parco di Villa Angeletti	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via del Chiù	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via dell'Arcoveggio	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Parco dei Cedri	NO_2	12-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12

Tab.3 Pollutant atmospheric concentration values in shelter areas

[4] Annual mean, that is 90 % of the one hour values or (if not available) 24-hour values over the year.



(a) (b)

Fig.3 (a) NO_2 and (b) $PM^{2.5}$ atmospheric concentration

Water quality

Water quality in shelter areas is assessed by analysing the ecological and chemical status of the surface water bodies, and the quantitative and chemical status of the groundwater bodies.

The definition of the ecological and chemical status of water bodies belonging to a specific river basin allows to evaluate the achievement of the quality objectives established by Directive 2000/60/EC (Arpae of Emilia-Romagna, 2019). In Italy, DM 260/2010 establishes the technical criteria for the classification of the ecological and chemical status of surface waters. The ecological status of a water body is classified according to the lowest class resulting from monitoring data relating to the physicochemical supporting, chemical and biological elements. In Bologna metropolitan area 30 pickup stations were monitored in 2018, all of these located in Reno Basin. Data concerning monitoring stations of interest for shelter areas[5] were collected from the Arpa of Emilia-Romagna (Arpae) website. The other useful data have been found by the Water Management Plan contents retrieved from minERva web portal.

Arpae assesses following parameters to define the ecological status:

- the three-year mean value of the LIM_{eco} descriptor (*Pollution Level by Macrodescriptors for Ecological Status*), defined according to the concentrations of Ammoniacal Nitrogen, Nitric Nitrogen, Total Phosphorus and Dissolved Oxygen (100 - % O_2 saturation);
- the status assigned to the specific pollutants contained in Table 1/B of Annex 1 to DM 260/2010, which contains substances not included in the list of priorities and for which annual average quality standards (SQA-MA) are defined (Arpae of Emilia-Romagna, 2019). Only substances for which there is evidence of significant emissions in the water bodies are monitored;
- the resulting state of individual biological elements (benthic macroinvertebrates, benthic diatoms, and river macrophytes).

The DM 260/2010 provides for the monitoring of priority substances (P), priority hazardous substances (PP) and substances included in the list of priorities (E) for the definition of the chemical status of surface water. The environmental quality standards are defined both in terms of Average Annual Value (SQA-MA) and Maximum Allowable Concentration (SQA-CMA) in Table 1/a of Annex 1 to the DM. Section A.4.6.3 of the DM represents the reference for the attribution of chemical status. Only substances which have been shown by pressure and impact analysis to be emitted, discharged, released, or leaked in the catchment area or sub-catchment area have been monitored (Arpae, 2019).

[5] Monitoring stations related to for surface water bodies in whose sub-basin at least one of the shelter areas falls have been analysed. Surface water, indeed, is taken for civil and irrigation purposes.

Tab. 5 summarizes data concerning surface water bodies related to water catchments in which at least one shelter area falls (Fig. 4a). The three-year reference period is 2014-2016, as at the time of writing data for the 2017-2019 three-year period have not yet been published (only the partial provisional states referring to the single year are available). Chemical status is good for all surface water bodies analysed, while ecological status is sufficient only for two ones (in whose sub-basins the areas of shelter of Via del Chiù, Antistadio and Parco dei Cedri fall), and poor for all the others. Verbal evaluations were converted to numerical values according to the correspondences in Tab. 4.

Ecological status classes	**Corresponding numeric value**
high	4
good	3
moderate	2
poor	1
bad	0
Chemical status classes	**Corresponding numeric value**
good	3
falling to achieve good	0

Tab.4 Correspondences used for the numeric conversion of surface water ecological and chemical status classes

Water body ID	**Reference station by grouping**	**Ecological status**	**Corresponding numerical value**	**Chemical status**	**Corresponding numerical value**	**Related shelter area**
0600000000009 ER	06002100	Moderate	2	Good	3	Via del Chiù Antistadio
0616000000001 ER	06002700	Poor	1	Good	3	Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio Via di Corticella-Caserme rosse
0616000000002 ER	06002700	Poor	1	Good	3	
0617000000001 ER	06002800	Poor	1	Good	3	Parco Nord Giardini Margherita Giardino Lunetta Gamberini
0620020000007 ER	06003200	Moderate	2	Good	3	Parco dei Cedri

Tab.5 Surface water bodies ecological and chemical status and corresponding numerical values

With regards to groundwater bodies, European Directive 2000/60/EC provides for their monitoring through two networks, one for the definition of quantitative status and the other for the definition of chemical status. In the municipality of Bologna there are 25 groundwater status monitoring stations, distributed among the various types of aquifer identified in accordance with D.Lgs. 30/2009.

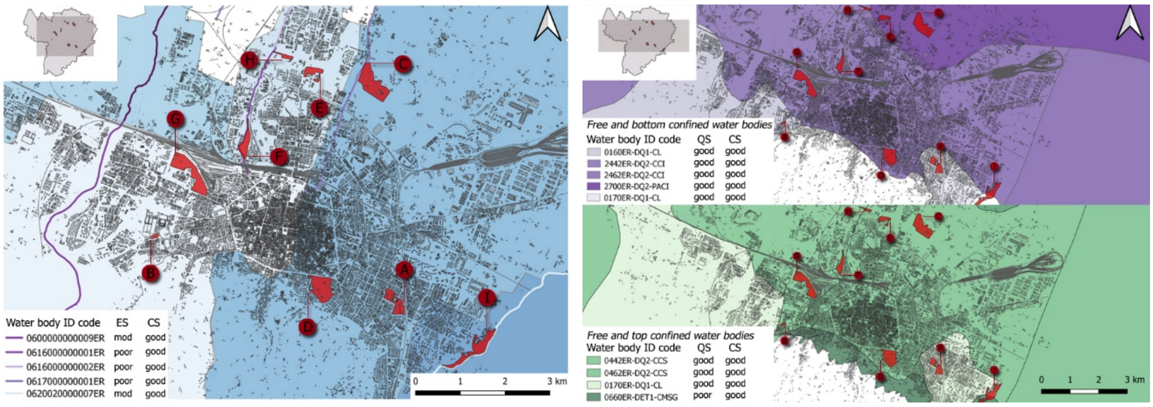
Quantitative status monitoring is carried out to provide a reliable estimate of available water resources and to assess their trend over the time, in order to verify whether the variability of charging and the sampling regime are sustainable over the long term.

Chemical status monitoring is articulated in surveillance monitoring, which is carried out according to previous knowledge of chemical status, and of vulnerability and renewal rate of each water body, and in the operational one, which is programmed for groundwater bodies that risk not reaching good status. As for surface waters, Arpae provides data on the quantitative and chemical status of groundwater with reference to the three-year period 2014-2016 (Tab. 6 and Fig. 4b). The conversion of the verbal evaluation into numerical value was carried out according to the correspondences in Tab. 4. An average weighted on the territorial extent associate to each groundwater body has been calculated for areas associated with more than one groundwater body. The status of groundwater is assessed as good for all examined groundwater bodies except for the mountain conoid that partially affects the area of Parco dei Cedri, whose quantitative status is assessed as poor.

Water body ID	Water body name	Monitoring station ID[6]	Quantitative status	Corresponding numerical value	Chemical status	Corresponding numerical value	Related shelter area
0160ER-DQ1-CL	Reno-Lavino conoid - free	SQ: BOE9-00 SC: BO20-00 BO47-01 BOE9-01 BOF0-00 BOH5-00 BOH6-00	Good	3	Good	3	Antistadio
2442ER-DQ2-CCI	Reno-Lavino conoid – bottom confined	SQ: BO20-01 BO30-00 SC: BO20-01 BO30-01	Good	3	Good	3	Via del Chiù Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio
2462ER-DQ2-CCI	Savena conoid – bottom confined	SQ: BO50-00 BO50-01 BO50-02 SC: BO50-02 BOH3-00	Good	3	Good	3	Via dell'Arcoveggio Giardini Margherita Parco dei Cedri
2700ER-DQ2-PACI	Alluvional Plain – bottom confined	SQ: BO78-01	Good	3	Good	3	Parco Nord Via di Corticella-Caserme rosse Via dell'Arcoveggio
0170ER-DQ1-CL	Savena conoid - free	SC: BO52-01	Good	3	Good	3	Giardino Lunetta Gamberini Parco dei Cedri
0442ER-DQ2-CCS	Reno-Lavino conoid – top confined	SQ: BOF8-00 SC: BO17-01	Good	3	Good	3	Via del Chiù Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio
0462ER-DQ2-CCS	Savena conoid – top confined	SQ: BO32-00 SC: BO32-00 BOA3-00 BOH4-00	Good	3	Good	3	Via dell'Arcoveggio Via di Corticella-Caserme rosse Parco Nord Giardini Margherita
0170ER-DQ1-CL	Savena conoid - free	SC: BO52-01	Good	3	Good	3	Giardino Lunetta Gamberini Parco dei Cedri
0660ER-DET1-CMSG	Mountain conoid	[-]	Poor	1	Good	3	Parco dei Cedri

Tab.6 Groundwater bodies quantitative and chemical status and corresponding numerical values

6 Only monitoring stations located in the municipality of Bologna are listed in the Table. SQ: quantitative status monitoring stations. SC: chemical status monitoring stations.



(a) (b)

Fig.4 (a) surface water bodies status and relate river basins; (b) groundwater bodies status

Light pollution

The use of unscreened lighting structures that direct part of the luminous flux directly to the sky is the main cause of light pollution. For this reason, standards and regulations to limit the phenomenon of light dispersion with regards to public lighting have been developed in recent years. Several studies have also shown that prolonged exposure to artificial night light inhibits melatonin production and this may cause sleep disorders and cancer (Garcia-Saenz et al., 2020; Kogevinas et al., 2018; Aubè et al., 2013).

Light pollution may therefore damage human health.

Several Italian regions have enacted laws aimed at reducing light pollution in recent years, and have introduced a special urban planning tool called Town Development Plan for Municipal Lighting (PRIC). It aims to assess the consistency and maintenance status of public lighting systems and to provide for the consequent adjustment, replacement and increase of existing light points (Santonico, 2011)[7].

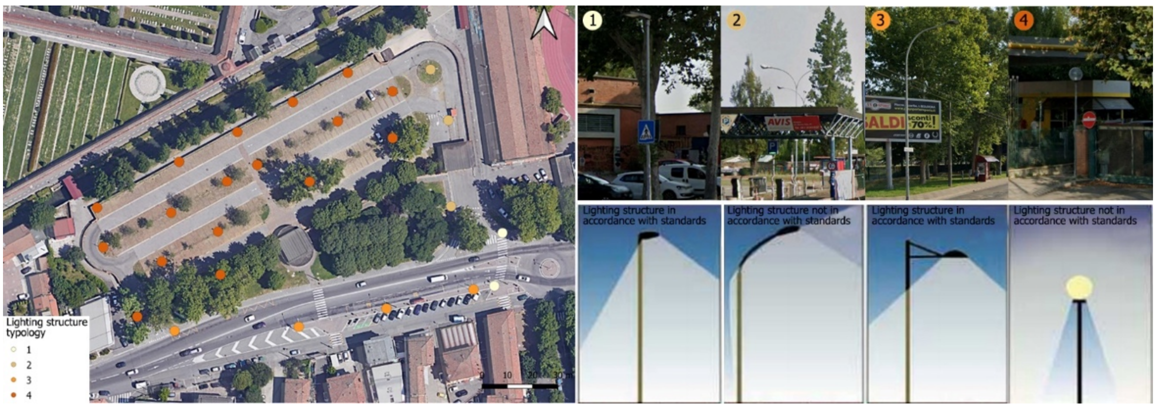


Fig.5 Lighting structures localization and typology in the Antistadio area (lighting structures reference images source: www.cielobuio.org)

Regulations provide for the emission values directed upwards allowed. In most cases, no light intensity greater than 0 cd/klm (candles per kilolumen) is allowed for angles greater than 90° (horizontal plane).

The Model Lighting Ordinance (MLO) (Ida & IES, 2011) also sets maximum luminous intensity values beyond the horizontal plane. The Ordinance provides for a lighting zones classification in five categories depending on

[7] Regions that do not have their own regulations refer to UNI 10819:1999, which prescribes the permitted percentages of average upward luminous flux.

their use. Since shelter areas are spaces used for people stay, these belong to LZ-2 class[8]. Table C-2 of the Users' Guide of the MLO considers a maximum percentage of light emission allowed above the horizontal plane equal to 0% in this zone.

The number and type of lighting structures located within each area and along its perimeter roads (Tab. 7) have been identified through the Google Earth Pro software in order to obtain the light pollution indicator. Only four shelter areas are characterized by a percentage of lighting structures according to standards higher than 50%, as they are partially adjacent to some of the roads object of the relamping operation started by the City Council in 2018. Fig. 5 shows as example the analyses carried out for Antistadio area.

Shelter area	**No. of lighting structures** Ls_{tot}	**No. of lighting structures according to standards** $Ls_{0\%}$	**Percentage deviation** $Ls_{0\%}/Ls_{tot}$ **(%)**
Giardino Lunetta Gamberini	84	36	42.85
Antistadio	26	6	23.08
Parco Nord	131	22	16.79
Giardini Margherita	141	60	20.10
Via di Corticella – Caserme Rosse	73	51	69.86
Via dè Carracci – Parco di Villa Angeletti	92	77	83.69
Via del Chiù	87	68	78.16
Via dell'Arcoveggio	24	20	83.33
Parco dei Cedri	116	36	31.03

Tab.7 Light pollution assessment in shelter areas

Noise pollution

Noise pollution is "the introduction of a level of noise into the environment which causes disturbance to rest and human activities, danger to human health, deterioration of ecosystems, property, monuments, and of the environment or that interferes with the normal functions of the environment" (art. 2 of L. 447/1995). Transport infrastructure are the mainly noise pollution source in the cities. High noise levels may cause psycho-physical illnesses even serious (Gargiulo & Romano, 2011). Within the European Community, data on noise pollution levels should be collected and presented according to comparable criteria (Directive 2002/49/EC). This requires the use of shared descriptors and methods to align acoustic mapping. With this aim, Directive introduces two indicators: the day-evening-night noise level (L_{den}) and the night noise level (L_{night}). With respect to these parameters, the Italian Legislator has not yet issued decrees that allow the conversion of the limit values identified by national legislation (LVA for airport noise, LA_{eq} day and LA_{eq} night for the other infrastructure) into the corresponding limit values of L_{den} and L_{night}. Nevertheless, Emilia-Romagna Region has introduced its own methodology to carry out this conversion through the Guidelines for the drafting of strategic noise maps. In this study reference was therefore made to the L_{den} and L_{night} indicators as they were in line with the latest European noise regulations.

L_{den} and L_{night} levels related to shelter areas were extracted from the strategic noise map provided by the Emilia-Romagna Region in 2017 as part of the cognitive framework of the Action Plan of the Agglomeration of

8 Class LZ-2 includes areas of human activity where residents and users vision is adapted to moderate light levels. Lighting is generally used for safety and practical reasons but is not necessarily uniform and continuous. LZ-2 includes multi-family residential uses, schools, churches, hospitals, commercial and/or business areas, neighbourhoods serving recreational and playing fields and/or mixed-use development with a predominance of residential uses.

Bologna[9]. The mean value of the L_{den} and L_{night} descriptors has been calculated for each area, weighed against the extent of the surfaces characterised by each noise level (Tab. 8). Fig. 6 shows as example the levels of L_{den} and L_{night} relative to the Antistadio area.

(a) (b)

Fig.6 Strategic noise map concerning (a) L_{den} levels and (b) L_{night} levels in Antistadio area

Shelter area	L_{den_mean} dB(A)	L_{night_mean} dB(A)
Giardino Lunetta Gamberini	58.9	46.9
Antistadio	69.2	60.7
Parco Nord	73.4	65.4
Giardini Margherita	62.3	47.7
Via di Corticella – Caserme Rosse	72.8	64.8
Via dè Carracci – Parco di Villa Angeletti	58.7	50.7
Via del Chiù	61.3	54.0
Via dell'Arcoveggio	82.5	75.2
Parco dei Cedri	66.3	59.4

Tab.8 L_{den} and L_{night} mean values in shelter areas

Shelter areas can be considered as mainly residential areas, due to their use in emergency phase. For this land use class current national legislation provides noise emission limits corresponding to 52.7 dB(A) for L_{den} and 42.0 dB(A) for L_{night}. As showed by Tab. 8 these limits are exceeded in all the analysed areas. In no shelter area is therefore guaranteed adequate acoustic comfort.

Heat island effect

Urban heat island effect (UHI) is the phenomenon that determines a microclimate warmer within urban areas than the surrounding rural areas. High temperatures have several negative consequences including the increase in mortality rate (Santamouris, 2016). UHI is mainly caused by high incident radiation and by the high absorption coefficient of materials used for horizontal exterior coatings and roofing.

Each surface, indeed, has a more or less high capacity to absorb heat. This capacity is measured by the coefficient of solar reflection (Albedo): when its value increases (maximum to 1) the amount of heat reflected by the surfaces increases; conversely, low Albedo values characterize surfaces able to absorb a large amount of solar energy (Tab. 9).

[9] Strategic noise map is obtained by summing the contributions deriving from road, railway, and airport noise source. The map is different from the noise classification of the municipal territory, which represents the noise limit values to be respected in the different acoustic zones.

In this study, heat island effect is assessed by analysing the solar reflection capacity of horizontal surfaces. Shelter areas have been divided into homogeneous sub-areas and the relative Albedo has been assigned to them. A mean Albedo value was then calculated for each shelter area as the average of the solar reflection coefficients weighed with respect to the extent of related surfaces (Tab. 10). Fig. 7 shows as example the horizontal surfaces identified in Antistadio and in Giardini Margherita areas and related Albedo.

Surface	Coefficient of solar reflection (Albedo)[10]
Unpaved road	0.04
Water	0.07
Asphalt	0.1
Concrete	0.2
Dark roof	0.25
Light roof	0.35
Grass	1

Tab.9 Coefficients of solar reflection (Albedo) of several surfaces

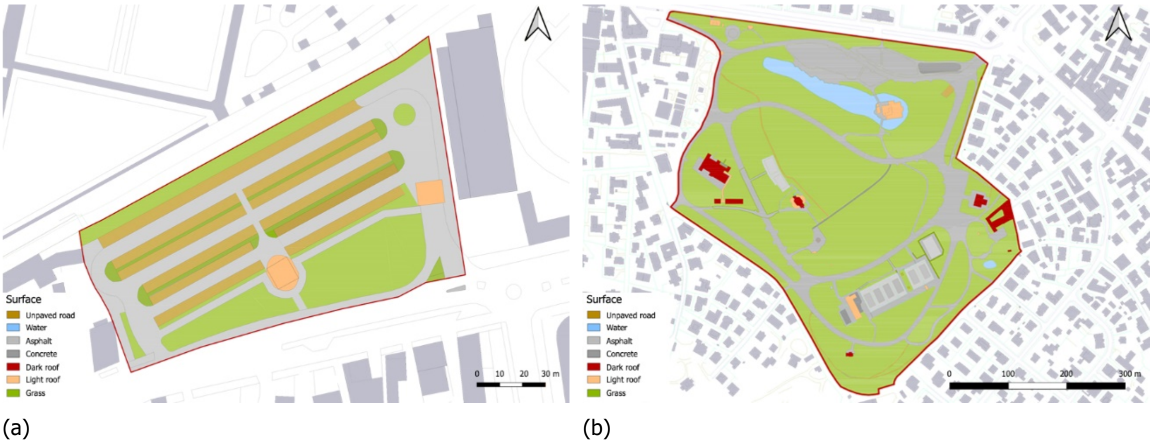


Fig.7 Homogeneous sub-zones and related Albedo in (a) Antistadio and (b) Giardini Margherita areas

Albedo mean value is rather high in the examined areas, since they are mostly public parks and so characterized by a large presence of grass, which corresponds to the maximum value of the coefficient of reflection. Lower Albedo mean value is that of Antistadio area because it is used as a parking space in non-emergency conditions and consequently it is mainly characterized by asphalt surfaces. The microclimate of this area may therefore be uncomfortable in the summer season.

4.2 Final output: environmental quality index

As explained in Section 3.2, the overall environmental quality index of shelter areas is calculated by using PCA. Three variables ($PM10_{conc}$, CS_SWB, and CS_GWB) were excluded from the PCA as they have equal value in all nine areas and therefore there is no variability in data distribution (zero standard deviation). Pearson's correlation matrix among the nine variables with non-zero standard deviation was then calculated (Tab.11). The PCA results are shown in Tab.12, Tab.13 and Fig.8.

[10] Albedo characteristic values in the Table are those used by the ITACA Protocol at Urban Scale for the evaluation of the indicator 7,02.3. Albedo of water surfaces is provided by UNI 8477.

Shelter area	Homogeneous sub-zone	Albedo of homogeneous sub-zone	Homogeneous sub-zone surface (m²)	Homogeneous sub-zone surface as percentage on the shelter area surface (%)	Alb_{mean} of shelter area
Giardino Lunetta Gamberini	Unpaved road	0.04	20,046.07	12.41	0.80
	Water	0.07	[-]	0	
	Asphalt	0.1	23,050.83	14.27	
	Concrete	0.2	1,632.39	1.01	
	Dark roof	0.25	6,501.14	4.01	
	Light roof	0.35	8,525.23	5.28	
	Grass	1	101,822.40	63.02	
Antistadio	Unpaved road	0.04	3,131.62	21.36	0.55
	Water	0.07	[-]	0	
	Asphalt	0.1	7,033.63	47.97	
	Concrete	0.2	[-]	0	
	Dark roof	0.25	[-]	0	
	Light roof	0.35	286.65	1.96	
	Grass	1	4,210.18	28.71	
Parco Nord	Unpaved road	0.04	4,931.42	1.73	0.76
	Water	0.07	[-]	0	
	Asphalt	0.1	8,302.23	2.92	
	Concrete	0.2	71,268.96	25.02	
	Dark roof	0.25	908.04	0.32	
	Light roof	0.35	5,722.07	2.01	
	Grass	1	193,685.54	68.00	
Giardini Margherita	Unpaved road	0.04	1,633.39	0.69	0.78
	Water	0.07	7,712.67	3.27	
	Asphalt	0.1	6,076.06	2.58	
	Concrete	0.2	53,595.25	22.72	
	Dark roof	0.25	3,270.16	1.39	
	Light roof	0.35	2,316.39	0.98	
	Grass	1	161,296.15	68.37	
Via di Corticella – Caserme Rosse	Unpaved road	0.04	3,529.53	2.68	0.73
	Water	0.07	[-]	0	
	Asphalt	0.1	14,908.85	11.34	
	Concrete	0.2	16,812.45	12.79	
	Dark roof	0.25	8,469.30	6.44	
	Light roof	0.35	3,341.15	2.54	
	Grass	1	84,430.27	64.21	
Via dè Carracci – Parco di Villa Angeletti	Unpaved road	0.04	7,132.60	6.50	0.96
	Water	0.07	6,170.49	5.62	
	Asphalt	0.1	[-]	0	
	Concrete	0.2	4,818.83	4.39	
	Dark roof	0.25	19.55	0.02	
	Light roof	0.35	18.90	0.02	
	Grass	1	91,578.30	83.45	
Via del Chiù	Unpaved road	0.04	9,128.42	2.64	0.88
	Water	0.07	2,526.17	0.73	
	Asphalt	0.1	13,251.45	3.84	
	Concrete	0.2	30,014.20	8.69	
	Dark roof	0.25	3,451.74	1.00	
	Light roof	0.35	6,582.51	1.90	
	Grass	1	280,551.39	81.2	
Via dell'Arcoveggio	Unpaved road	0.04	[-]	0	0.98
	Water	0.07	[-]	0	
	Asphalt	0.1	586.60	2.17	
	Concrete	0.2	55.82	0.21	
	Dark roof	0.25	[-]	0	
	Light roof	0.35	17.07	0.06	
	Grass	1	26,397.32	97.56	
Parco dei Cedri	Unpaved road	0.04	8,184.53	3.45	0.87
	Water	0.07	10,037.46	4.22	
	Asphalt	0.1	13,439.96	5.66	
	Concrete	0.2	12,530.06	5.27	
	Dark roof	0.25	1,638.41	0.69	
	Light roof	0.35	5,676.86	2.39	
	Grass	1	186,116.6	78.32	

Tab.10 Mean values of coefficient of solar reflection (Albedo) of shelter areas

	NO_{2conc}	$PM^{2.5}_{conc}$	ES_SWB	QS_GWB	$Ls_{0\%}/Ls_{tot}$	L_{den_mean}	L_{night_mean}	Alb_{mean}
$NO2_{conc}$	1.000							
$PM2.5_{conc}$	0.437	1.000						
ES_SWB	-0.358	-0.158	1.000					
QS_GWB	0.327	0.316	-0.500	1.000				
$Ls_{0\%}/Ls_{tot}$	0.353	0.956	-0.151	0.247	1.000			
L_{den_mean}	0.737	0.185	-0.157	0.045	0.072	1.000		
L_{night_mean}	0.781	0.290	-0.022	-0.044	0.183	0.968	1.000	
Alb_{mean}	0.055	0.545	-0.261	-0.165	0.652	-0.023	0.044	1.000

Tab.11 Pearson's correlation matrix among variables used in PCA

	Eigenvalue	% of variance	Cumulative %
λ1	3.319	41.49	41.49
λ2	2.065	25.81	67.30
λ3	1.433	17.91	85.21
λ4	0.808	10.10	95.31
λ5	0.212	2.65	97.96
λ6	0.132	1.65	99.61
λ7	0.003	0.04	99.65
λ8	0.028	0.35	100.00
Total	8.000	100.00	

Tab.12 Eigenvalues of Pearson's correlation matrix and related percentage of variance

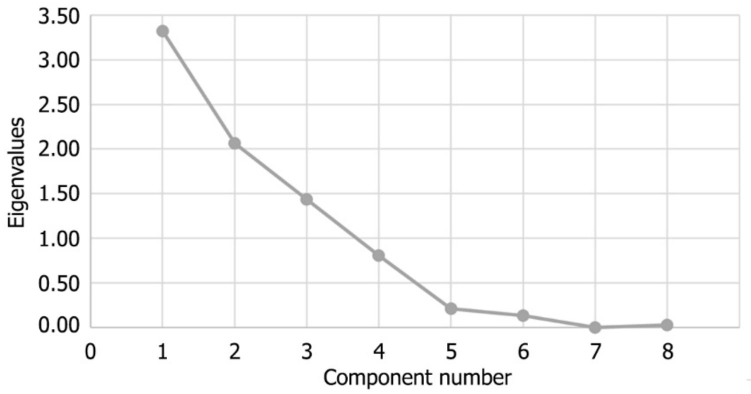


Fig.8 Eigenvalues Scree Plot

	PC1	PC2	PC3
NO_{2conc}	-0.463	-0.260	-0.116
$PM^{2.5}_{conc}$	-0.427	0.355	0.115
ES_SWB	0.225	-0.106	0.558
QS_GWB	-0.197	0.106	-0.690
$Ls_{0\%}/Ls_{tot}$	-0.392	0.434	0.158
L_{den_mean}	-0.378	-0.469	0.099
L_{night_mean}	-0.401	-0.430	0.229
Alb_{mean}	-0.237	0.436	0.314
Eigenvalue (λ)	3.319	2.065	1.433
% of variance	41.49	25.81	17.91

Tab.13 Loadings of maintained PCs following the use of Heuristic criteria

According to the first and the second Heuristic criterion the first three PCs should be maintained, as they represent more than 80% of the overall variance, and the three related eigenvalues are greater than 1 (Kaiser's rule). According to the third Heuristic criterion the first five components should be maintained, as in the Scree Plot there is a sharp change of slope ("elbow" of the curve) at the fifth eigenvalue. Since two of three Heuristic criteria give the same result, it was decided to use three PCs (Tab. 13). PC1 considers mainly atmospheric quality, as it has good negative correlations (loadings) with $NO2_{conc}$ (-0,46) and $PM2.5_{conc}$ (-0,43).
PC2 considers mainly comfort levels offered by the areas, as it has good positive correlations with $Ls_{0\%}/Ls_{tot}$ (0,43) and Alb_{mean} (0,44), and good negative correlations with L_{den_mean} (-0,47) and L_{night_mean} (-0,43).
Finally, PC3 represents mainly surface and ground waters conditions, as it has higher correlations with ES_SWB (0,56) and QS_GWB (-0,69).
The environmental quality index (EQ) of the nine shelter areas was obtained by combining the scores of the PCs with their variance percentages, by using equation (2) (Tab. 14). The EQ values have been standardised using equation (3) and subsequently classified according to the ranges described in Section 3.2 (Fig. 9).

	PC1	**PC2**	**PC3**	**EQ_{stand}**
Giardino Lunetta Gamberini	-75.352	-30.695	20.609	0.90
Antistadio	-76.737	-50.263	22.134	0.61
Parco Nord	-82.650	-59.387	20.977	0.34
Giardini Margherita	-63.857	-40.182	18.565	1.00
Via di Corticella - Caserme Rosse	-105.132	-34.041	29.745	0.28
Via dè Carracci - Parco di Villa Angeletti	-94.996	-12.657	28.547	0.79
Via del Chiù	-94.889	-17.838	29.216	0.72
Via dell'Arcoveggio	-118.311	-37.107	35.291	0.00
Parco dei Cedri	-76.068	-43.924	24.751	0.74

Tab.14 PCs scores and EQ_{stand} values for shelter areas

As shown by Fig. 9, The EQ_{stand} of three shelter areas (Via dell'Arcoveggio, Via di Corticella - Caserme Rosse, Parco Nord) falls into the bad class. According to the proposed methodology, this means that these sites do not guarantee adequate comfort and safety conditions for human health. It is interesting to note that the three areas are located close to each other. They are located in the northern zone of Bologna, where the worst environmental quality conditions are recorded compared to the rest of the city. Another aspect to consider is that all three areas are bordered by the highway, which is a significant noise source both day and night. Results thus show that shelter areas identified by the Emergency Plan to accommodate the population living in the northern of the city would not be able to guarantee conditions suitable for the people stay, especially with regard to air and noise pollution.

5. Conclusions

The experimentation of the proposed methodology in the Municipality of Bologna confirmed the thesis supported by this study. Results demonstrate the usefulness of providing planners and operators of the Civil Protection an environmental zoning of the municipal territory, in order to facilitate the identification of the areas most suitable for the shelter and the stay of populations displaced due to the occurrence of disasters. Experimentation final output, indeed, highlighted that three of the nine shelter areas identified by Emergency Plan are not able to ensure environmental condition suitable for the more or less prolonged stay of people.
This is caused mainly by the excessive proximity to the highway, which results in high levels of noise both day and night, and in the increase in the concentration of air pollutants. The fact that all three areas with the worst

EQ are located in the northern part of the city constitutes a disadvantage for the population living in this area, because in emergency case it would be hosted in places with characteristics much worse than those designated to accommodate citizens of Bologna central area.

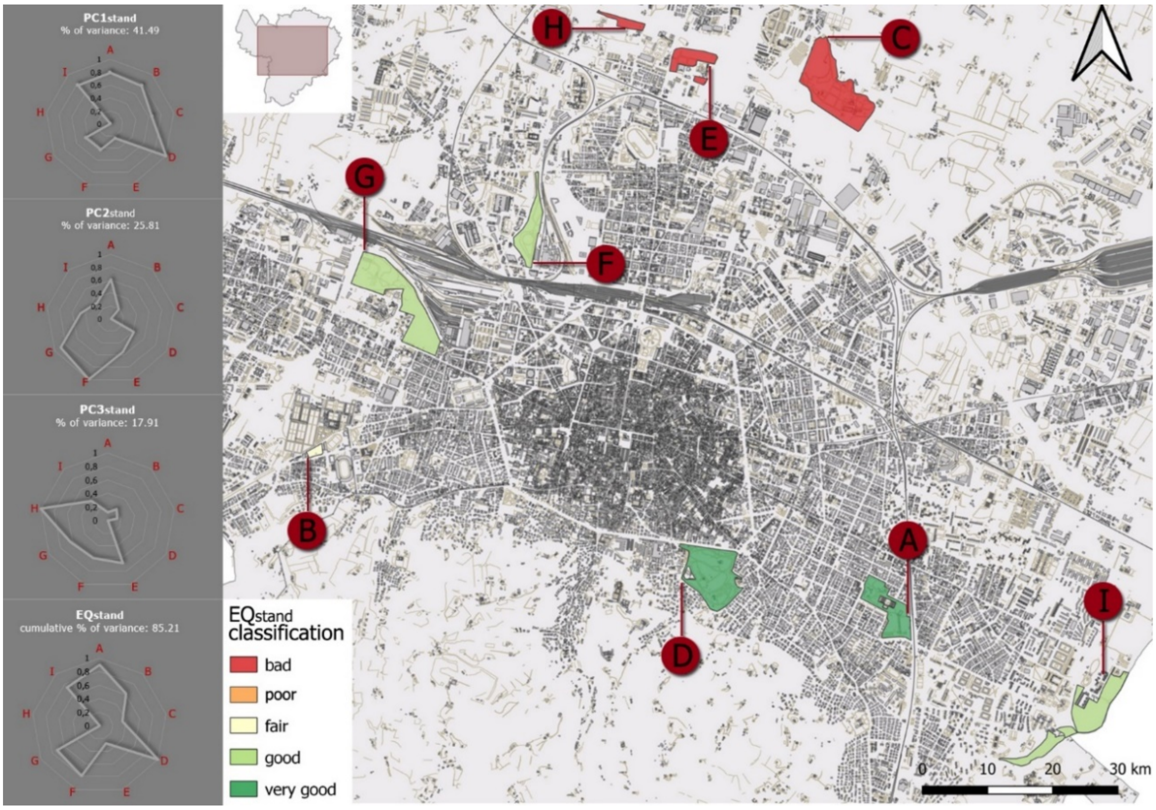


Fig.9 Graphs of PCs standardized scores and of EQ_{stand}; shelter areas classification based on EQ_{stand} values

This aspect should be considered by the future emergency planning. The model proposed in this study could be replicated in other municipalities, allowing a more accurate identification of the shelter areas in the planning phase but also the evaluation of those already identified by current Emergency Plan.

Neverthless, two issues need to be highlighted. First, in this study the classification of the shelter areas is based on a comparison of their EQ_{stand}. This technique shows its potential when there is a set of alternatives to choose from, in this case when the identification of sites with better and worse environmental conditions allows to decide where to locate shelter areas. However, it is useful that future studies concern at defining a threshold value for environmental quality, in order to exclude from subsequent evaluations areas that do not reach sufficient EQ values to ensure adequate levels of environmental comfort.

Secondly, we are aware that environmental quality cannot be the only discriminating factor in the choice of the shelter areas. Accessibility and strategic location, as well as the absence of risks, are fundamental elements in this respect. Environmental assessment may seem to be of secondary importance in relation to them. Nevertheless, it should be considered that shelter areas often host evacuated citizens for much longer periods of time than planned ones. For this reason, it is necessary to think about new forms of relationship between the Emergency Plan and the territorial analysis, which ensure the involvement of all the components characterizing territory through a dynamic, cognitive, active, and continuously updated approach.

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Image sources

Fig.1: Authors' elaboration;

Fig.2: Authors' elaboration;

Fig.3: Authors' elaboration;

Fig.4: Authors' elaboration;

Fig.5: Authors' elaboration;

Fig.6: Authors' elaboration;

Fig.7: Authors' elaboration;

Fig.8: Authors' elaboration;

Fig.9: Authors' elaboration.

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