09.01 Environmental Justice 2021/2022

Overview

The term environmental justice refers to the type, extent and consequences of an unequal social distribution of environmental burdens and the underlying causes. It has been known for a long time and it is scientifically proven that a person's social situation is a factor that determines their state of health and influences their life expectancy. The first comprehensive evaluation of Berlin received nationwide attention. Since then, the connection between 'socio-economic status' and 'housing and living environment conditions', that are detrimental or even hazardous to health, has become much more of a focus in both environmental and health policy, as have their causal relations.

The pressure to act is increasing also for Berlin, due to far-reaching additional challenges. On the one hand, these are the result of the global effects of climate change that are becoming ever more noticeable. On the other hand, their causes also lie locally in challenges such as the requirement for more housing and the increased densification as a result thereof, especially in the inner city. An integrated approach of recording and assessing health-related environmental burdens combined with indicators that describe the social situation of the population is increasingly adopted by many municipalities and federal states. "It has not yet reached the point, however, where one can say that the environmental justice approach has been anchored securely at the federal and state levels" (translated from Difu 2022).

In order to establish a basis required for the further targeted development of action strategies in environmental and health policy, the State of Berlin has now extended the initial evaluation mentioned above with the latest available data. This serves both **as a first update and the beginning of a monitoring system that is to be updated continually in the future**.

During the updating process, it was necessary to build on established methods, on the one hand, and to take into account innovations in the field and adapt the methodology to current requirements, on the other. While these important measures complicate the comparison with the existing assessments from the years 2008-2015, they do, however, lay the foundation for much more frequent updates planned for the future, for the purposes of continuous monitoring.

The descriptions used here are largely based on the **report of the Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action (SenUMVK 2022) published as part of the Update 2021/2022, the perusal of which is recommended for a deeper understanding of the topic.**

The concept of environmental justice, as Berlin defines it, addresses the following questions:

- Which topics related to the environment are relevant to health and should be integrated in the context of Berlin's environmental justice approach?

- How can information, data and analysis results from the departments of Environment, Health, Urban Development, Urban Planning, and Social Affairs be aggregated to the level of the 542 planning areas (PLA)? How can they be combined to form an informative spatial and planning level?

- Which planning areas with health-relevant multiple burdens also have a high density of social problems? Which areas with multiple burdens also exhibit at least a 'predominantly simple residential area' and/or a high population density?

- May general statements or recommendations for action be derived for cross-departmental spatial planning and administrative action? May practical instruments be developed on the basis of the small-scale analyses of environmental burdens to complement the Berlin planning system?

The methodology of the Berlin environmental justice approach was developed further and adapted to environmental policy innovations as part of the first update. It shall complement the established urban monitoring systems in the State of Berlin with in-depth information in the future. Further, it shall provide a basis for defining fields of action.

As an instrument updated periodically, it will document the development of environmental justice in Berlin. By using this tool continually, any changes in the distribution of the burdens and their sources may be documented. Additionally, the impact of instruments and measures that have already been put in place may be evaluated.

Statistical Base

Berlin has comprehensive datasets for the areas of the environment, health, social affairs and the city (urban development). Generally, each of these is subject to topic-specific monitoring and publication, often required by law. The different areas are, to a large extent, thus reported on independently of each other, i.e. without any overlaps. The merging of different datasets due to the varying methodological approaches, diverging survey intervals and varying levels of detail poses a great methodological challenge.

In contrast to individual in-depth analyses, the **Berlin environmental justice approach** seeks to provide a comprehensive overview of the situation as a whole, by analysing data available for different sectors and aggregating this data on a small scale. This small-scale level is based on the planning areas (PLA). With 542 areas, it is the most detailed of the three levels associated with the system of the living environment areas (LEA) in Berlin (as of January 1, 2021, cf. Fig. 1 and SenStadtWohn 2020). The planning areas are primarily used for city-wide monitoring, for example of the development of the housing market, environmental justice and social urban development. For Berlin as a whole, the average number of inhabitants per PLA is around 6,970 (as of December 31, 2018).
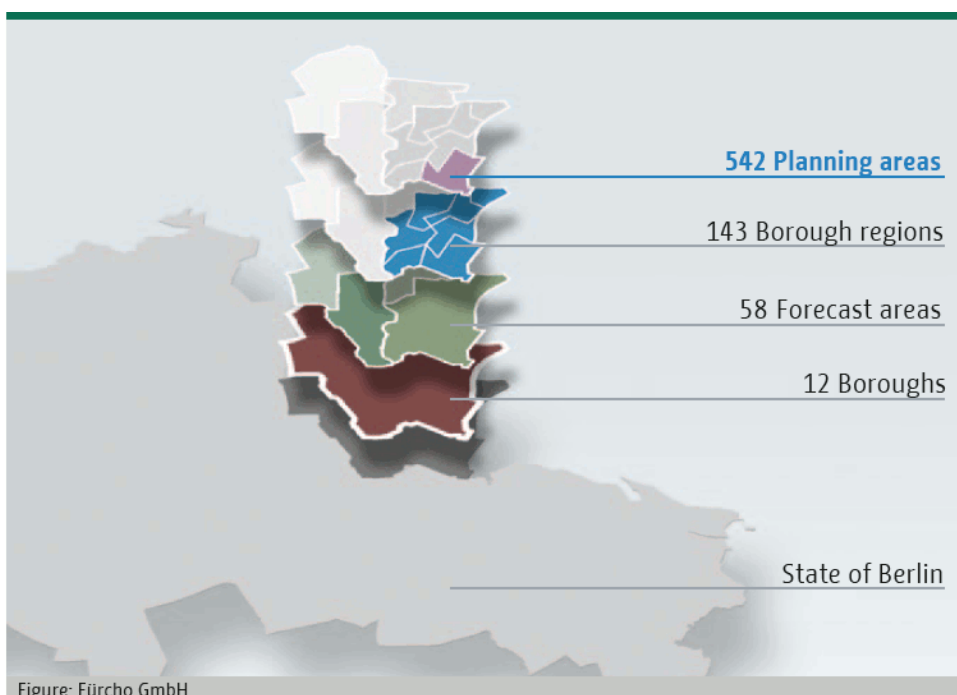

542 Planning areas

143 Borough regions

58 Forecast areas

12 Boroughs

State of Berlin

Figure: Fürcho GmbH

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Fig. 1: The three-level classification of the Living Environment Areas (LEA) in Berlin (Fürcho GmbH)

In addition to the following geospatial basis:

- Living Environment Areas (LEA), geospatial hierarchy "Planning Areas" (PLA), as of January 1, 2021

The following data bases were used for the 5 core indicators investigated:

- Core indicator **noise burden**: Strategic Noise Maps 2017, including recalculations of important noise reductions due to the closure of Tegel Airport effective from May 4, 2021, Senate Department for the Environment, Urban Mobility, Consumer Protection and Climate Action
- Core indicator **air pollution**: data from NO_2 measuring stations from 2019 and $PM_{2,5}$ modelled data from 2018, Senate Department for the Environment, Transport and Climate Protection
- Core indicator **thermal burden**: Climate Model Berlin, 2015 (Environmental Atlas), Map Evaluation Index of Physiological Equivalent Temperature (PET) and Map Distribution of Air Temperature, Senate Department for Urban Development and Housing
- Core indicator **green space supply**: "Analysis of the urban availability of green space (VAG)", 2020, Senate Department for the Environment, Transport and Climate Protection
- Core indicator **social disadvantage**: Social Urban Development Monitoring, 2021 (MSS), Senate Department for Urban Development, Building and Housing
- Berlin Environmental Justice Map: additional information
  - on **simple residential area**: Rent Index, 2021, Senate Department for Urban Development and Housing
  - on **population density** on December 31, 2021, Statistical Office for Berlin-Brandenburg.

The final illustration includes a layer of "predominantly uninhabited areas" that is superimposed on the spatial reference system of the PLA. The maps therefore focus on inhabited residential areas. "The category of "predominantly uninhabited areas" groups together outdoor uses (forest, water, agriculture), expansive green spaces, and non-residential building uses (commercial and industrial, traffic facilities, technical infrastructure)" (translated from SenSW 2019, p. 78).

Methodology

Content-based approach

The Berlin approach to assessing environmental justice mainly relies on the analysis and aggregation of available data. It is designed as a two-stage process with **five core indicators**:

- Noise burden
- Air pollution
- Thermal burden
- Green space supply
- Social disadvantage

and 3 **multiple burden maps** combining the individual assessments:

- Multiple Burden Map – Environment
- Multiple Burden Map – Environment and Social Disadvantage – and
- Berlin Environmental Justice Map.

"Three particular challenges may be identified in the process of merging these data sources: the sectoral data differs in their survey methodology, in their spatial depth and in their periodicity. For the Environmental Atlas, urban development policy planning areas were chosen as the smallest unit of analysis from the system of living environment areas (LEA). The sectoral data was then converted

accordingly. The heterogeneous data situation with regard to the survey methodology and spatial depth could thus be mitigated for the purposes of this analysis" (translated from SenUMVK 2022, p. 6).

In the **first step** of the analysis, the data on the three core indicators "air pollution", "noise burden" and "thermal burden" was analysed and consistently assigned to the characteristics "high", "medium" or "low" on an ordinal scale, according to the health risk. The other core indicators "green space supply" and "social disadvantage" were classified similarly in three levels, without a health-related weighting, however.

In a **second step**, the individual core indicator maps focusing on one theme each were merged to illustrate the distribution or overlap of the environmental burdens ("Integrated Multiple Burden Map – Environment") as well as the environmental burdens including social vulnerability ("Integrated Multiple Burden Map – Environment and Social Disadvantage"). At planning area level, the two maps present a range starting from PLA without any core indicator exhibiting a high burden up to PLA with four- to fivefold burdens (cf. Fig. 2).
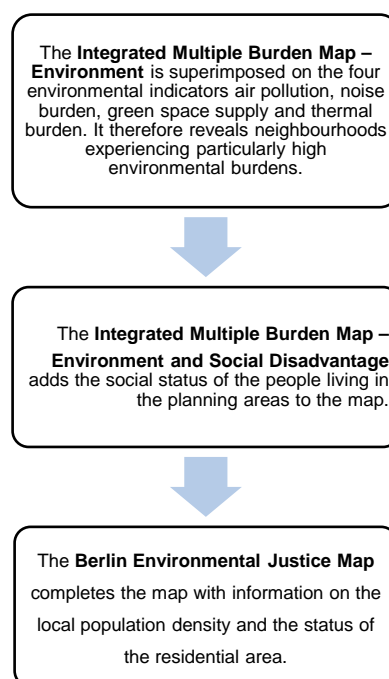
The **Integrated Multiple Burden Map – Environment** is superimposed on the four environmental indicators air pollution, noise burden, green space supply and thermal burden. It therefore reveals neighbourhoods experiencing particularly high environmental burdens.

The **Integrated Multiple Burden Map – Environment and Social Disadvantage** adds the social status of the people living in the planning areas to the map.

The **Berlin Environmental Justice Map** completes the map with information on the local population density and the status of the residential area.

Fig. 2: Merging the core indicators to form the two multiple burden maps and the Berlin Environmental Justice Map (according to SenUMVK 2022)

The multiple burden factor was thus determined for each planning area by aggregating those core indicators that were assigned to category 3 ("low"/ "poor"/ "high"). The number and distribution of areas with multiple burdens as well as the burdens causing them are therefore straightforward and transparent.

The determination of the status based on the **two-stage Berlin environmental justice monitoring system** hence provides an overview of the environmental quality in the 542 planning areas of the city. In the future, this will also include comparisons to the analyses of previous years.

Core indicator noise burden

Noise refers to sound events which are perceived as disturbing and/ or detrimental to well-being and health due to their individual characteristics. Especially in urban areas, noise is a key factor affecting health. Depending on the extent, period and length of exposure, noise immission may cause direct or indirect health effects.

Physiological impact	Psychological impact
Hearing loss Vegetative dysfunction Cardiovascular problems Cardiovascular symptoms Increased blood pressure Reduced depth of sleep Headache	Disturbance Stress, nervousness Sadness Disrupted communication Impaired performance Irritation Psychosomatic symptoms
Social noise impact	Economic noise impact
Impaired communication Judgment of other people Reduced willingness to help Aggression Social segregation	Rent and property prices Noise protection cost Health cost Production loss Spatial planning cost

Tab. 1: Key noise effects (FOEN 2009)

The strategic noise maps for the metropolitan area of Berlin of the year 2017, compiled in accordance with the requirements of the 34th Federal Immission Protection Ordinance (BImSchV), as well as European legal requirements formed the data basis for the information on noise pollution in the planning areas. According to Article 47c of the Federal Immission Protection Act (BImSchG), noise maps must be reviewed every five years and updated if necessary. All noise maps of the survey year 2017 are published on the Geoportal of the State of Berlin (search by keyword "strategic noise map").

The overall noise map "Strategic Noise Map: Facade Level Total Noise L_N (Noise Index Night) 2017 (Environmental Atlas)" was used to assess noise pollution in the context of the environmental justice approach. It presents the investigated traffic noise sources as totals (level addition) at night (from 22:00 to 06:00), going beyond the requirements of the Environmental Noise Directive. "For this purpose, the noise levels measured at each facade point at night and the corresponding population counts were referred to and summed up for the respective planning areas. With the help of the total population figure of a planning area, a (person-)weighted mean of the noise levels could thus be generated for each planning area" (translated from SenUMVK 2022).

In order to assign the determined means for each planning area to the three assessment categories "low/ medium/ high burden", a subdivision into quartiles was carried out. The 'best' 25% of the values were represented by all population- and planning area-related nighttime means of up to 41.8 dB(A), the 'worst' 25% exceeded the threshold of 44.5 dB(A) (cf. Fig. 3).
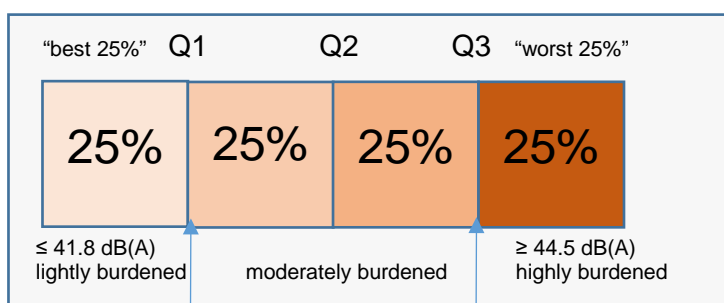

Fig. 3: Assessment categories (in quartiles) for the core indicator noise burden

Core indicator air pollution

Both particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) are still considered health-relevant substances in the context of air pollution, despite the successful reduction of emissions (cf.

Environmental Atlas Map 03.12.1 "Long-term Development of Air Quality"). They were therefore also included in the assessment here.

There was a strong focus on the pollutant NO_2 during the analysis phase and the intersection with the planning areas, as NO_2 is affected much more by local Berlin sources and as it may also be influenced locally.

"Since NO_2 varies much more based on its location, a land use regression analysis was used here. The data of the meanwhile almost fifty NO_2 measuring points was statistically interpolated on a regular 100-metre grid, also taking into account the building structure (Floor Space Index and Site Occupancy Index) and the traffic volume. This method reflects the geographical structure of the NO_2 field very well" (translated from SenUMVK 2022).

From the NO_2 data, area-weighted means were calculated for each planning area, following a similar approach to that of noise burden. These were then assigned to four equally sized quartiles. The decisive thresholds that define the pollution categories "low" and "high" were also set to 25 % and 75 % of the data (cf. Fig. 4).
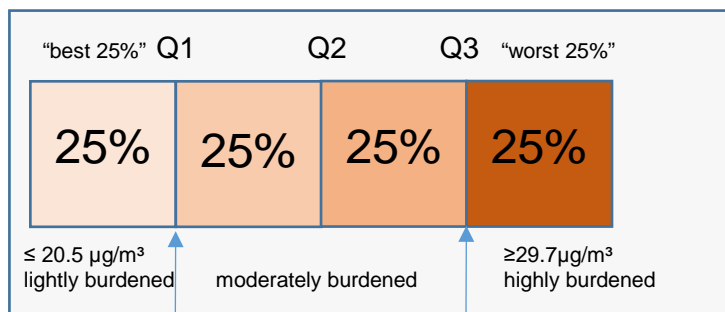

"best 25%" Q1   Q2   Q3 "worst 25%"

| 25% | 25% | 25% | 25% |

≤ 20.5 µg/m³
lightly burdened   moderately burdened   ≥29.7µg/m³
highly burdened

Fig. 4: Assessment categories (in quartiles) for NO_2 for the core indicator air pollution

Core indicator thermal burden

The analysis data of the [2015 Climate Model Berlin](#), which is available in a 10*10 m² grid, was used as the basis for evaluating "summer heat stress" as an influencing factor. Deviating from the methodology of 2008-2015 pilot project, the situation was assessed both during the day, at the time of the sun's highest point (2pm) and at night (4am). This split was made with regard to human health, as the following criteria are particularly important in the assessment of the local bioclimatic situation:

degree of heat stress during the day,

potential for sufficient cooling at night, and

existence of recreational areas in close proximity.

"The bioclimatic index PET (Physiological Equivalent Temperature) is used to assess thermal comfort during the day. It is a scientific standard taking into account the most important meteorological factors that affect the body. It is measured in degrees Celsius (°C) and may be assigned to different levels of thermal stress" (translated from SenUMVK 2022, p. 9).

To assess the situation at night, however, the modelled distribution of air temperature was used for technical reasons (at night, there is no solar radiation, which is an important component required for using PET).

The z-transformation statistical method was used as the main transformation approach to standardise the model data for PET and air temperature. This has the advantage of facilitating the comparison of values, determined by a variety of 'measuring instruments' (in this case evaluation parameters), which is adapted to the investigated area (Berlin). There is no absolute comparability, however, between these results and those of other regions, as the former refer to deviations from the local Berlin mean.

The assessment focused on blocks predominantly used for residential purposes. For the daytime assessment, however, blocks containing larger segments used for working (commerce, industry, public use, administration) as well as the public road area were also included (i.e. 'spatial setting'). The blocks and block segments were selected based on the area types of the Environmental Atlas (Map 06.08 "Urban Structure, Area Types Differentiated", SenStadtWohn 2015).

Both times of assessment, day and night, as well as their spatial settings were transferred to a 4-level ordinal scale comprising the classes "very favourable", "favourable", "less favourable" and "unfavourable".

The day and night assessments were merged based on a logical "if-then" relationship to consolidate any occurring combinations into an overall assessment. This process was carried out at the level of differentiated building blocks.

For the final aggregation to the planning area level, the affected blocks and their categories were added up on an area-averaged basis. They were then transferred to the three impact levels of the environmental justice approach using intervals.

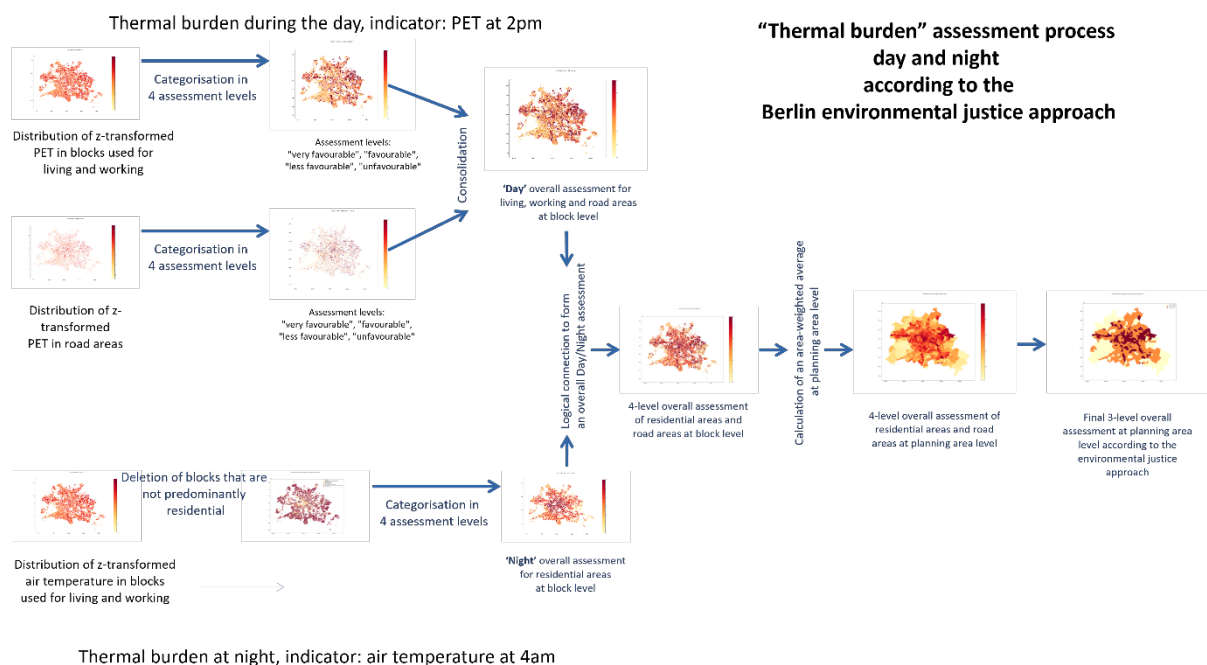Figure 5 illustrates this process with a diagram.

Fig. 5: "Thermal burden", day and night, assessment process according to the Berlin environmental justice approach (according to AfS 2021)

Core indicator green and open space supply

The current version of the "Analysis for the availability of green space", which is presented and described in detail in the Environmental Atlas Map 06.05 "Availability of Public, Near-residential Green Spaces 2020", forms the basis for analysis here.

Those analysis results could be integrated directly into the environmental justice approach.

"These block-specific levels of urgency were aggregated to the planning areas, taking into account the respective population size. The result is again a classification into three categories: ranging from "very good / good" and "medium" to "poor / very poor / not supplied". The available green space and the population size were therefore decisive only; the quality of the green spaces was disregarded" (translated from SenUMVK 2022).

Core indicator social disadvantage

The analysis was based on the results of the city-wide Social Urban Development Monitoring (MSS) here, which has been used to assess and provide information on the social situation of the population at the level of the planning areas since 1998. This is part of the framework of a continuous "urban monitoring system" that is updated every 2 years.

Both current and previous results of the MSS are available online in the Geoportal (only in German) of the State of Berlin.

The current results of 2021 were used for the environmental justice approach. They cover the observation period between 2019 and 2020.

The following three index indicators form the basis for the representations of status and dynamics (two-year development) and for the calculation of the status and dynamics index:

- – unemployment (according to SGB II (Social Code – Book II)),
- – transfer payments of the non-unemployed (according to SGB II and XII), and
- – child poverty (according to SGB II of under 15-year-olds) (SenSBW 2022).

 "The Environmental Justice Atlas is based on the status index: the higher the proportions of unemployment, receipt of transfer payments and child poverty in the planning areas, the lower their status index. The dynamics of these areas are not taken into account. The categories "low" and "very low" were combined to reduce the number of result categories from four to three.
Planning areas with fewer than 300 inhabitants are excluded from the index calculation in order to avoid small-scale distortions (in the Social Urban Development Monitoring of 2021, this affected five planning areas)" (translated from SenUMVK 2022, p. 10).

Consolidating the core indicators into multiple burden maps and the Berlin Environmental Justice Map

Environmental justice must be considered as a multidimensional topic; it requires an integrated analysis and a consolidated representation of different environmental burdens, but also of environmental resources in their socio-spatial distribution.

As a result of the two-stage environmental justice monitoring, the following (integrated) multiple burden maps were developed (cf. Fig. 2):

1. "**Integrated Multiple Burden Map – Environment**",
   it shows the four multiple burdens related to the environment (core indicators air, noise, thermal burden and green space supply)

2. "**Integrated Multiple Burden Map – Environment and Social Disadvantage**",
   it expands the first map by the fifth core indicator social disadvantage,

3. "**Berlin Environmental Justice Map 2021/ 2022**",
   in addition to the five core indicators, it also illustrates the degree to which the inhabitants are affected (number of inhabitants in the planning areas) and the status of the residential area.

The "**Integrated Multiple Burden Map – Environment**" is superimposed on and aggregates the four environmental core indicators per planning area. The core indicators, air pollution, noise burden, thermal burden and green space supply, are included in the evaluation as individual burdens if they are assigned to the worst of the three categories with regard to the burdens related to the planning area. This highlights those planning areas in particular that are subject to burdens based on multiple factors. Multiple environmental burdens may not only have an additive, but also a cumulative effect here.

In order to visualise where the burden of environmental factors coupled with social disadvantage is concentrated, the "Multiple Burden Map – Environment" was expanded to include the component of social disadvantage ("low status index") ("**Integrated Multiple Burden Map – Environment and Social Disadvantage**").

The approach taken thus far **cannot take into account** the individual exposure and vulnerability of the individual, for example physiological factors (such as genetic disposition, metabolism) and individual health behaviour. Therefore, "exposure may lead to differing health effects despite the same intensity. This depends on the vulnerability of the individual, which may modify the 'exposure effect'". (BZgA online 2022, only in German).

The "**Berlin Environmental Justice Map 2021/ 2022**", which concludes the methodology of the Berlin environmental justice approach, overlays the environmental and social stress factors with the number of affected persons (areas with more than 10,000 inhabitants per square kilometre [km²]) and the identification of planning areas with predominantly simple residential character (more than 66% of the affected addresses). These identifications may also be used to prioritise within the highly burdened areas (threefold burdened and more) according to the urgency of action.

Spatial focus on inhabited areas

Berlin's environmental justice approach focuses on areas where inhabitants live and spend time. Areas located outside residential areas, such as forests, large parks and recreational facilities, as well as areas used as workplaces, also play a key role in a city-wide context, but are omitted from the environmental justice maps. For this purpose, the map layer "largely uninhabited areas" is superimposed on the map overviews.

Relevance and limitations of the methodological approach:

Just like any other data, environmental data may have different backgrounds. This is particularly the case if the data originates from a variety of topics, especially with regard to the following points:

- method of collection and analysis of individual data (measuring, modelling, estimating),
- are there predetermined federal / EU-wide limits or is the data compared in relation to the investigated areas?
- spatial resolution of the original data and spatial reference of the target statement;
- the time interval between recurrent updates; and
- methodological and other technical developments in the course of the update cycles.

These conditions already complicate the comparison of different versions of a single topic. Naturally, they would affect a comparison of different environmental, health and social topics linked by a common approach even more.

On the other hand, the great potential that a multifactorial comparison holds in terms of indications to counteract inequalities caused by environmental burdens and social disadvantage needs to be appreciated. The State of Berlin in its current "level of environmental justice" is the "target area". A relative comparison of planning areas, based on a categorisation ranging from "good" to "poor", appears to be a reasonable approach to provide data that may support (spatial) priorities for action strategies in Berlin.

Most likely, the methodology and procedure will need to be 'gently' developed further for future updates of the environmental justice approach, always with the goal of providing a transparent description of the methods used, to support the aspects of monitoring and evaluation of mitigating measures (see also SenUMVK 2022, Chapter "Umweltgerechtigkeit: Grenzen der Aussagekraft" (Environmental justice: limitations of validity), p. 11, only in German).

Analysis results for the entire city and the boroughs

The data analysis is compiled in a comprehensive set of maps and published in the Geoportal as thematic maps. This both involves work on the five-part core indicator approach and the aggregated multiple burden maps that are based on it, which merge the individual topics quantitatively and

qualitatively. The three integrated multiple burden maps form the heart of Berlin's integrated environmental justice monitoring.

The statistical analyses are presented and described below, divided into those relating to the individual core indicators and the multiple burden maps – the entire city and the boroughs – as well as analyses for each individual borough.

Results in a city-wide comparison

Core indicator:	Number of highly burdened PLA, absolute and in %	Number of highly burdened PLA with low status index, absolute and in %[1]
Noise	136 (25.1)	19 (13.9)
Air pollution	136 (25.1)	28 (20.6)
Thermal burden	170 (31.4)	37 (21.8)
Green space supply	136 (25.2)	35 (25.8)

[1] The percentages are related to the absolute number of the 95 planning areas with a low to very low status index.

Tab. 2. Number of highly burdened planning areas according to the core indicators and status index in Berlin (as of: 2021/ 2022 Monitoring Environmental Justice)

The correlation of these multiple environmental parameters with the social index indicates their relationship, i.e. the degree of environmental **in**justice, in Berlin.

Thus, planning areas that are subject to two, three or even four environmental burdens have a significantly higher proportion of low and very low status indices. In contrast, more than 25% of PLA without any environmental burden are characterised by a very high/ high index. If one includes medium indices, too, more than 80% of the affected PLA are covered (see Fig. 6 from SenUMVK 2022).
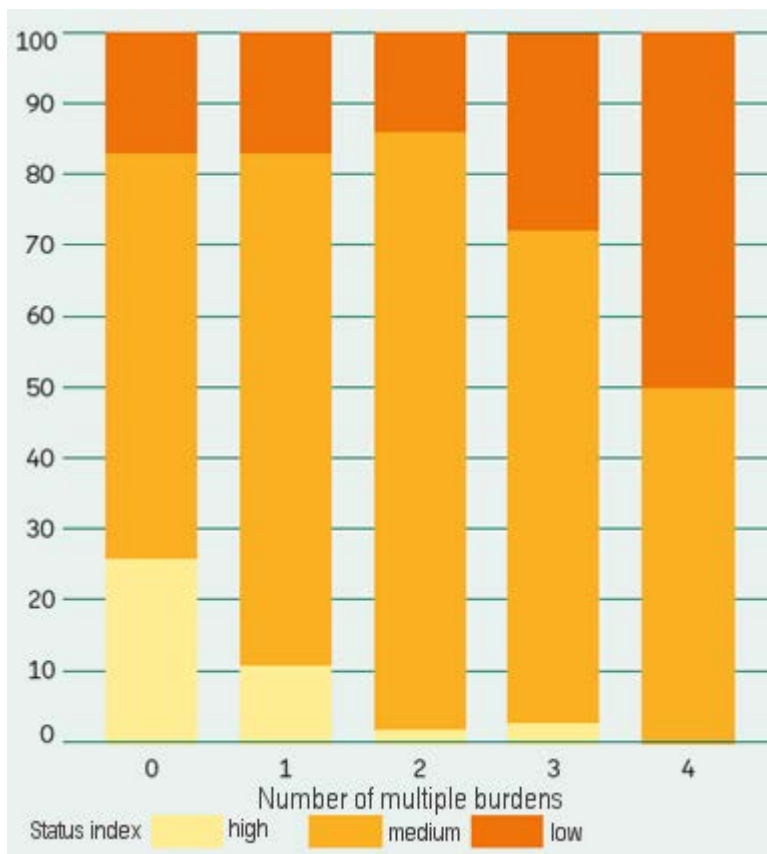
Fig. 6: Social problem density by number of environmental burdens per planning area (PLA) (as of: 2021/ 2022 Monitoring Environmental Justice) (SenUMVK 2022)

Cumulating the means of the categories of the 5 core indicators, as well as the categorised population density/ km² and the number of multiple burdens affecting the Berlin boroughs, a distribution emerges that highlights the boroughs within the City Rail Circle Line, i.e. primarily Mitte and Friedrichshain-Kreuzberg, as districts with the highest burdens on average (cf. Figure 7). The summed means of the two boroughs are close together and largely exhibit numbers well above 2 for each indicator.

This means that, generally, the burdens of each of their PLA were categorised as either medium or poor. Mitte is home to 11 of the 19 most polluted planning areas. In Friedrichshain-Kreuzberg, 25 out of 36 planning areas, with a combined 67 percent of the borough's inhabitants, are facing a twofold or threefold burden; a very high number, compared to the rest of the city.
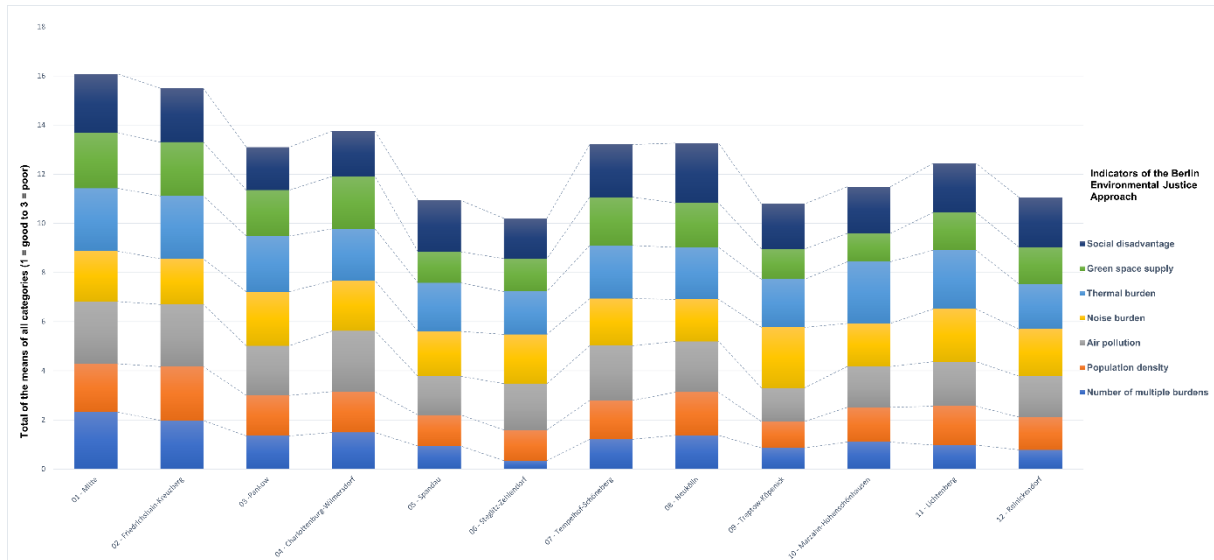
The categories of the indicators and the population density, summed up by borough, represent the following qualitative ratings:

value 1 = low burden (good situation or high status index), 2 = medium burden, 3 = high burden (poor situation or low/ very low status index);

Population density categories:

value 1 = > 10,000 inhabitants/ km², 2 = 10,000 to < 20,000 inhabitants/ km², 3 = 20,000 and more inhabitants/ km².

Fig. 7: Stacked means of the categories of the core indicators, the population density and the number of multiple burdens per borough (as of: 2021/ 2022 Monitoring Environmental Justice)

Spandau, Steglitz-Zehlendorf and Treptow-Köpenick are the boroughs that are quantitatively least affected by the investigated environmental burdens.

Treptow-Köpenick is the 'leader' when it comes to air quality and green space supply. In terms of social burdens, it is also one of the least affected boroughs.

Spandau stands out with an equally very good green space supply. Air pollution and the climate are largely unproblematic, especially in the outer areas of Hakenfelde, Gatow and Kladow.

Steglitz-Zehlendorf takes first place in the overall assessment according to Figure 7, i.e. the added means of the individual categories result in the lowest total number. What is particularly striking is the considerably lower number of multiple burdens compared to the rest of Berlin, which indicates a large spread of unburdened or only slightly burdened PLA. Only 4 of the 44 planning areas, clustered around the service area of Schloßstrasse, are subject to twofold burdens. There are no PLA with predominantly simple residential areas, which also makes it a unique borough in Berlin.

For more in-depth information on the boroughs, please refer to the comprehensive report on the updated data and maps of the Berlin Environmental Justice Concept. It presents each of Berlin's boroughs in a detailed profile (SenUMVK 2022).

The figures used in the report to compile the borough-specific pie charts are attached as spreadsheets to the data linked to Figure 7 in the Environmental Atlas in the list of Figures and Tables on Environmental Justice 2021/ 2022.

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