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Toward integrating subjective well-being in environmental health impact assessments for healthy urban living: a conceptual and methodological exploration☆

Xuan Chen [a,*], Gerard Hoek [a], Paul Frijters [b], Georgia M.C. Dyer [c,d,e], Stefan Gössling [f,g], Sasha Khomenko [c,d,e], Haneen Khreis [h,i], Eline Kolb [j], Natalie Mueller [c,d,e], Brigit Staatsen [k], Rafael Costa Simões De Vasconcelos [l], Daniel Saldanha Resendes [m], Elise van Kempen [k], Mathew P. White [n,o], Roel Vermeulen [a,p], Mark Nieuwenhuijsen [c,d,e], Ulrike Gehring [a]

[a] Institute for Risk Assessment Sciences, Utrecht University, Utrecht, Netherlands (the)
[b] Department of Social Policy, London School of Economics and Political Science, London, the United Kingdom of Great Britain and Northern Ireland
[c] Institute for Global Health (ISGlobal), Barcelona, Spain
[d] Department of Experimental and Health Sciences, Universitat Pompeu Fabra (UPF), Barcelona, Spain
[e] CIBER Epidemiología y Salud Pública (CIBERESP), Madrid, Spain
[f] Western Norway Research Institute, Trolladalen 30, 6886 Sogndal, Norway
[g] School of Business and Economics, Linnaeus University, 391 82 Kalmar, Sweden
[h] MRC Epidemiology Unit, University of Cambridge School of Clinical Medicine, Cambridge, the United Kingdom of Great Britain and Northern Ireland
[i] Texas A&M Transportation Institute, Texas A&M University System, College Station, TX, United States
[j] The Hague's Public Health Department (GGD Haaglanden), The Hague, Netherlands (the)
[k] National Institute for Public Health and the Environment (RIVM), Centre for Sustainability, Environment and Health (DMG), Bilthoven, Netherlands (the)
[l] Public Health Department, Região de Leiria Local Health Unit, Leiria, Portugal
[m] Public Health Department, Local Health Unit São José, Lisbon, Portugal
[n] European Centre for Environment and Human Health, University of Exeter Medical School, the United Kingdom of Great Britain and Northern Ireland
[o] Cognitive Science HUB & Urban and Environmental Psychology Group, University of Vienna, Austria
[p] Julius Center for Health Sciences and Primary Care, University Medical Centre Utrecht, Utrecht, Netherlands (the)

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ABSTRACT

Introduction: Environmental Health Impact Assessments (HIAs) can inform decisions about the health effects of policy-related changes in environmental exposures. Conventional health impact metrics, focusing on mortality, morbidity, and disability, neglect subjective well-being. We explored the need and feasibility of integrating well-being indicators such as happiness and life satisfaction into quantitative environmental HIAs.

Methods: Building on a multidisciplinary expert workshop and existing literature, we addressed (1) definitions and indicators of well-being, (2) pathways linking environmental exposures (air pollution, noise, extreme temperatures, and green space) to well-being, and (3) the strength of epidemiological evidence for these associations. We evaluated the challenges of integrating well-being indicators into environmental HIAs, and provided an exploratory example.

Results: We argue that including well-being in HIAs offers a more comprehensive view of health, aligning with policy goals focused on enhancing citizen's well-being. The literature identifies plausible pathways linking exposures to well-being, whilst epidemiological evidence for associations between environmental exposures and well-being is limited, but suggestive. We propose conducting exploratory HIAs integrating well-being, especially for green space (n = 16 epidemiological studies) and air pollution (n = 18). We outline two practical integration strategies: (1) report well-being impacts separately as Well-being-Adjusted Life Years, and (2) incorporate well-being into existing health indicators such as Quality-Adjusted Life Years or Disability-Adjusted Life Years.

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* Corresponding author.
E-mail address: x.chen4@uu.nl (X. Chen).

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Conclusions: Inclusion of well-being into quantitative environmental HIAs presents a more comprehensive representation of health and well-being beyond indicators focusing on morbidity and mortality. However, the epidemiological evidence base regarding environmental exposures and well-being warrants further expansion.

1. Introduction

More than half (55%) of the global population lives in urban areas, and this percentage is expected to increase to 68% by 2050 (United Nations, 2019). Urban environments have complex influences on health, offering economic, social, and healthcare opportunities, while also exposing residents to environmental stressors such as air and noise pollution, heat extremes, and limited access to green space (Bai et al., 2012; Ezzati et al., 2018).

The aim of this position paper is to advocate for the integration of subjective well-being into quantitative environmental health impact assessments (HIAs), which have so far been a main tool for urban disease burden estimation for environmental stressors. These HIAs have hitherto been confined to estimating disease-related health impacts of specific policies or intervention programs by assessing the impacts of targeted changes in these environmental exposures on populations' measured health.

Quantitative environmental HIAs using different models, such as the comparative risk assessment framework (Mueller et al., 2023), start with a policy or intervention proposal. Then, changes in exposure distributions are evaluated from the baseline or reference situation to various intervention scenarios by analyzing different pathways of how the intervention influences exposures (Bhatia and Seto, 2011; Reumers et al., 2021; Veerman et al., 2005). After mapping the exposure distributions and identifying the population at risk, the health impacts of the intervention are estimated by combining exposure scenarios and baseline disease rates with exposure-response functions (ERFs) for the exposure and health outcome pairs of interest from (meta-analyses of) epidemiological studies. Although well-being has been included in some qualitative or semi-quantitative HIAs (Burford et al., 2017; Green et al., 2021), most quantitative environmental HIAs focus primarily on physical health outcomes and clinical diagnoses of mental disorders classified using systems such as the International Classification of Diseases (ICD). As a result, subjective well-being remains largely overlooked, despite its centrality to the World Health Organization's (WHO) definition of health as a state of complete physical, mental, and social well-being (World Health Organization, 1948).

Current HIA outcome indicators, such as Disability-Adjusted Life Years (DALYs) and Quality-Adjusted Life Years (QALYs), quantify the combined impact of morbidity and mortality but have limited capacity to account for positive emotional states or life satisfaction. DALYs, despite allowing for the comparison of the health impacts of different interventions affecting different exposures, are limited to a selection of health outcomes with available disability weights (ranging from 0 to 1, with 0 representing perfect health and 1 representing death), such as in the Global Burden of Disease (GBD) study (Charalampous et al., 2022). Disability weights are largely assigned to clinical diseases with an ICD code. QALYs, calculated using utility weights based on desire-fulfillment approaches (ranging from 0 to 1, with 0 representing dead or the worst possible state, equal to death and 1 representing perfect health), are generally determined using people's stated willingness to trade time in different health states (Gyrd-Hansen, 2005) or health-related quality of life measured by the EQ-5D instrument by the EuroQol Group (Devlin et al., 2020). Health outcomes without a clinical disease code and not included in the EQ-5D quality of life questionnaire are more challenging to include in DALYs or QALYs for HIAs and health burden estimations (Hänninen et al., 2014).

The WHO defined well-being as a positive state experienced by individuals and societies, influenced by various social, economic, and environmental exposures (World Health Organization, 2021a). Yet quantitative environmental HIAs rarely assess outcomes like positive emotions or subjective life evaluations. It has been argued that subjective well-being should be incorporated in health evaluations such as HIAs and should be considered in healthcare resource allocation (Dolan and White, 2007), as well as health cost assessments (Gössling et al., 2021).

This position paper was developed within the EU-funded Urban Burden of Disease Estimation for Policy Making (UBDpolicy) project (https://ubdpolicy.eu/) which aims to estimate the health impacts, socioeconomic costs, and benefits associated with major urban environmental exposures, including air quality, noise, lack of urban green spaces, extreme temperatures, and physical activity. One of the project's key objectives is to assess the need for, and feasibility of, integrating subjective well-being outcomes into quantitative environmental HIAs.

Following this aim of the project, the paper explores the conceptual basis and methodological feasibility of such an integration. We begin by reviewing key definitions and measurement approaches related to subjective well-being, followed by an evaluation of existing evidence linking environmental exposures to well-being. Drawing on a rapid literature review and expert workshop, we address the following guiding questions: (1) What are the definitions and measurement approaches for subjective well-being? (Section 3); (2) What are the potential pathways linking environmental exposures (e.g., air pollution, noise, temperature, green space) to subjective well-being? (Section 4); (3) What is the current epidemiological evidence regarding these associations? (Section 4); (4) What is the rationale for including well-being in HIAs? (Section 5); (5) How can subjective well-being be integrated into quantitative environmental HIA frameworks? (Section 6). Rather than separating empirical synthesis from conceptual interpretation, the paper is organized into distinct sections corresponding to the main thematic components: Section 3 presents the theoretical background on well-being, Section 4 combines results and discussion on pathways and epidemiological evidence linking exposures to subjective well-being; Section 5 develops the rationale for including well-being in environmental HIAs; and Section 6 combines results and discussion on methodological approaches and challenges for integrating subjective well-being into quantitative HIAs.

2. Methods

2.1. Rapid review of the evidence

To support the discussion of integrating well-being into HIAs, we conducted a review addressing three core objectives: (1) to summarize key conceptual definitions of subjective well-being; (2) to identify hypothesized and empirical pathways linking environmental exposures (air pollution, noise, extreme temperatures, green space) to well-being; and (3) to synthesize epidemiological evidence on associations between these exposures and subjective well-being. While systematic principles guided our search and screening process, the review does not meet the formal requirements of a systematic review or meta-analysis, consistent with rapid review methodologies (Tricco et al., 2015).

Separate structured searches were conducted for the three objectives. Search terms used are provided in Appendix 1.1 (Supplementary Materials). To manage the ubiquity of the term "well-being," searches were restricted to titles and abstracts. Searches focused on peer-reviewed literature in English and were published up to February 2024.

For objectives 1 and 2, we searched PubMed and Google Scholar to capture both empirical and conceptual work. We supplemented with reference chaining and key book chapters (e.g., Handbook of Well-Being

by Diener et al. (2018) to cover foundational literature. This process was iterative, tracking references and keywords to identify additional studies. The papers reviewed through this process are listed in Appendix 1.2 (Supplementary Materials).

For the epidemiological evidence of relationships between air pollution, noise, extreme temperatures and green spaces with well-being, we conducted a structured literature search using PubMed, supplemented by reference screening of relevant articles. Peer-reviewed original studies or reviews in English, addressing subjective well-being in relation to environmental exposures (air pollution, noise, temperature, green space), published up to February 2024 were included. Studies in languages other than English, those not measuring subjective well-being, or those focused exclusively on clinical mental health diagnoses without a subjective well-being dimension (e.g., health-related quality of life) were excluded.

All identified studies were screened for relevance based on title and abstract, with full-text review conducted when necessary. No formal duplicate screening or risk of bias assessment was performed, consistent with the objectives of a rapid narrative synthesis. Screening and data extraction were conducted by X.C. and independently reviewed by U.G. and G.H. A flowchart of assessment of eligible studies was included in Fig. A1.3 in Appendix 1.3 (Supplementary Materials). For eligible epidemiological studies, extracted data included study design, geographic location, sample size, exposure type, well-being outcome measures, and key findings.

While our approach was structured in scope, this review does not follow formal systematic review or meta-analysis protocols. Rather, it serves as a selective synthesis of key epidemiological findings relevant to the relationship between environmental exposures and subjective well-being. The goal was to qualitatively assess the body of evidence in terms of type and size of studies including the geographical distribution. We anticipated that the state of the research did not allow a formal evidence synthesis.

Data extraction results were compiled into summary tables (see Supplementary Materials), facilitating thematic narrative synthesis by exposure and outcome type. Due to the limited study base, diversity of exposure and subjective well-being measures, a meta-analysis was not feasible, and the synthesis focuses on qualitative patterns and identified evidence gaps.

2.2. Workshop and discussions

A multidisciplinary UBDpolicy workshop was held in March 2024 to bring together researchers and stakeholders to discuss the need for and approaches to integrating well-being outcomes into quantitative environmental HIAs.

The workshop convened approximately 40 participants, including academic researchers and applied experts from the fields of public health, epidemiology, HIA, environmental science, psychology, economics, and urban planning. In addition, stakeholders from municipal and regional health authorities, national public health institutes, and international organizations participated. This included both in-person and virtual attendees, fostering a cross-disciplinary and cross-country exchange of perspectives. The workshop program included expert presentations, structured breakout sessions, and moderated group discussions. Key discussion topics included: definitions and measurements of subjective well-being relevant for HIA; evidence and methodological challenges in linking environmental exposures to well-being; data needs and gaps; practical value of incorporating well-being in policy-oriented HIA.

Insights and outcomes from this workshop informed the development of the conceptual framework and recommendations presented in Sections 5 and 6 of this paper. The full workshop program is available on the UBDpolicy website, and a list of participants is provided in Appendix 2 (Supplementary Materials), subject to participant consent.

3. Well-being: definitions, theories, and measurements

Before exploring the potential impacts of environmental exposures on well-being, we want to clarify what we mean by "well-being". In the literature, we identified multiple candidate concepts and measures of well-being (Linton et al., 2016). The currently limited evidence on the relationship between well-being and environmental factors is partly due to challenges in defining and measuring well-being. There is broad consensus that personal well-being is a complex construct, encompassing positive emotions, life satisfaction, a sense of fulfillment, and effective functioning (Dodge et al., 2012; Ng and Fisher, 2013). Two principal approaches have emerged in conceptualizing well-being: hedonic well-being, which emphasizes pleasure and happiness, and eudaimonic well-being, which focuses on meaning, purpose, and self-realization (Ryan and Deci, 2001).

3.1. Dimensions of well-being

There are various terms of well-being, and we included a glossary of well-being terms and definitions in Table 1. In general, individuals with better emotional well-being (hedonic approach) tend to evaluate life more positively. Additionally, those with better psychological or social well-being (eudaimonic approach) are able to function more effectively in their daily lives (Bodeker et al., 2020). The details on hedonic and eudaimonic approaches are listed in Appendix 2.

Subjective well-being (also known as personal well-being), sometimes referred to as hedonic or emotional well-being (hedonic approach), revolves around individuals' own evaluations of their life satisfaction and happiness, regardless of specific material possessions or circumstances. It also serves as a comprehensive term of the diverse assessments that individuals make about their lives, including life evaluations, emotional states (affect), and broader aspects of psychological flourishing (eudaimonic approach), which encompass experiences, physical health, well-being, and related conditions (OECD, 2013a; Ryff and Keyes, 1995).

3.2. Well-being is not the absence of mental illness

The WHO defines mental health as a state of well-being wherein individuals realize their potential, cope with life's normal stresses, work productively, and contribute to their community (Bodeker et al., 2020). It is important to distinguish between well-being, poor mental health, and mental illness. Good mental health is typically described as an individual's emotional, psychological, and social well-being. Having a high emotional and psychological/social well-being is called flourishing (Keyes, 2007). Conversely, poor mental health (sometimes called languishing) involves experiencing stress, feeling overwhelmed, having difficulty coping with challenges, or simply not feeling emotionally or psychologically well. Mental illness refers to diagnosable conditions that significantly affect a person's thinking, feeling, mood, behavior, or ability to relate to others (Allen et al., 2014). Individuals with poor mental health may not receive a formal diagnosis of mental illness. Additionally, individuals diagnosed with a mental illness can still experience periods of physical, mental, and social well-being (Westerhof and Keyes, 2010). A study from the Netherlands found that 68.4% of individuals with a mental disorder reported that they had felt happy during the past four weeks, challenging the perception of mental health solely in terms of psychopathology absence (Bergsma et al., 2011). Therefore, there is a necessity for comprehensive health and well-being frameworks that recognize both dimensions and offer more nuanced understandings of the state of health and well-being at the population level.

Despite mental health being operationalized as emotional, psychological, and social well-being, previous epidemiological research mostly focused on mental illness rather than well-being. This focus has been driven by viewing mental health through a lens of harm and dysfunction

Table 1
Glossary of well-being.

Terms	Definition and Comments
Well-being (WB)	• A positive state experienced by individuals and societies, influenced by various factors like social, economic, and environmental conditions. • Includes personal well-being and society's well-being.
Personal well-being (PWB)	• A good, satisfactory, and desirable state of personal existence or life. It represents a personal aspect of the quality of life (Musek and Polic, 2014).
Society's well-being	• A positive state of societies that can be evaluated by its resilience, ability to take action, and readiness to overcome challenges.
Hedonic well-being (HWB)/ emotional well-being (EWB)	• Focuses on how individuals assess their own lives emotionally (affective well-being/ affect).
Eudaimonic well-being (EWB)/ psychological well-being (PWB)	• Focuses on certain needs and qualities for individual's psychological growth and development and fulfilling these needs allows a person to achieve their full potential such as meaning and purpose in life, having supportive social relationships, and experiencing a sense of mastery.
Social well-being	• Individuals' quality of relationships and interactions within society including individuals feel connected to their communities and society, perceiving themselves as valuable contributors to the common good. • Often seen as part of eudaimonic well-being.
Resilience	• The ability to maintain or recover one's well-being in challenging circumstances.
Subjective well-being (SWB)	• A comprehensive term for diverse assessments individuals make about their lives, including life evaluations, emotional states (affect), and broader aspects of psychological flourishing (eudaimonia).
Objective well-being (OWB)	• Based on a set of factors that address individuals' fundamental needs, without requiring input from individuals to form an overall assessment of their quality of life. • Can be assessed at both the individual and societal levels.
Mental health	• A state of well-being where individuals realize their potential, cope with life's normal stresses, work productively, and contribute to their community.
Mental illness	• Diagnosable conditions that significantly affect a person's thinking, feeling, mood, behavior, or ability to relate to others.
Poor mental health/ languishing	• Involves experiencing stress, feeling overwhelmed, having difficulty coping with challenges, or simply not feeling emotionally or psychologically well.
Positive mental health / Flourishing	• Positive emotions • Positive psychological functioning • Positive social functioning

Reference: Diener, E., Oishi, S., & Tay, L. (2018). Handbook of Well-Being.

(Bodeker et al., 2020), which is the logical lens of a health business model. Furthermore, a substantial body of literature exists on the connections between the environment and mental illness, encompassing various clinical mental and behavioral disorders such as depressive disorder (ICD-10 F32) and generalized anxiety disorder (ICD-10 F41) (Borroni et al., 2022; Chen et al., 2023; Coventry et al., 2021; Liu et al., 2021; Meadows et al., 2024; Rautio et al., 2018; Thompson et al., 2023). Consequently, HIAs currently include poor mental health and mental illness (e.g., depressive disorder, and generalized anxiety disorder) rather than well-being. Due to the lack of evidence on the impact of environmental risk factors on well-being—particularly regarding its positive dimensions, which represents a major knowledge and practice gap—this paper focuses on positive aspects of well-being and explores outcomes related to positive functioning and health.

3.3. Commonly used subjective well-being measurements

Measurements of subjective well-being rely on individuals' self-reports through (sets of) questions, where subjects reflect on their overall life or specific domains thereof, such as work and health, comparing them to their personal standards for a fulfilling life (Eid, 2008). A previous systematic review of empirical studies examining subjective well-being found 60 unique measurement scales, with the most frequently encountered domains including emotions (39 scales), social relations (17 scales), life satisfaction (13 scales), physical health (13 scales), meaning/achievement (9 scales), and spirituality (6 scales) (Lindert et al., 2015). Table 2 presents examples of the well-being indicators identified in the evidence review that are commonly used in surveys. These indicators assess slightly different domains of well-being, posing challenges for direct comparisons.

Subjective well-being can be measured with various instruments, including Cantril's Ladder (OECD, 2013b), the 5-item World Health Organization Well-Being Index (WHO-5), UK Office of National Statistics four subjective well-being questions (ONS4) and the Satisfaction With Life Scale (SWLS) (Diener et al., 1985) **(**Table 2**)**. Among these, Cantril's Ladder stands out as one of the most widely used subjective well-being measures, with data collected annually in over 140 countries as part of the Gallup World Poll (Bjørnskov, 2008) and reported in the World Happiness Report (Helliwell et al., 2023). The WHO-5 is also a commonly used subjective well-being measurement tool based on positive mood (good spirits, relaxation), vitality (being active and waking up fresh and rested), and general interest (being interested in things) **(**Table 2**)**. These instruments measure subjective well-being in one of the following domains, such as affective (emotional), cognitive (evaluative) well-being following the hedonic approach, or psychological functioning following the eudaimonic approach. The "World Database of Happiness" serves as a comprehensive repository of scientific research findings and aggregated indicators related to happiness, particularly in terms of life satisfaction, dating back to 1984 (Veenhoven, 2004). Bureaus of statistics implementing well-being measures have also gone for more single-item measures that focus on how people evaluate their current lives, leading to the importance of how satisfied people are. For example, the UK Treasury and other government entities have adopted a single evaluative measure ("life satisfaction"), which denotes a judgment by individuals about their whole lives rather than an experienced state (MacLennan et al., 2022).

3.4. Measurements of broader well-being

A wealth of measurements of broader societal well-being, encompassing social, economic, and environment, are available aggregated into composite measures (though usually with entire ad-hoc weights, and with the elements in the indices being a rich collection of inputs, outputs, and societal arrangements, many of which are ambiguous in terms of interpretation). As for 'objective' well-being indicators, we provide examples of those indicators in **Table A3.1** in Appendix 3 in the Supplementary Materials. These broader well-being measurements are based on basic human needs and rights, including aspects such as adequate access to food, physical health, living environment, education, and safety.

Although composite societal well-being metrics provide a systematic means to compare societal well-being across different historic and geographical contexts, their inclusion in quantitative environmental HIAs poses challenges. Due to their multifaceted nature, the integration of diverse factors and lack of standardized metrics, analyzing the specific effects of environmental exposures on well-being becomes complicated. Moreover, since environmental exposures and health measurements are already embedded in some of these broader indicators, calculating the

Table 2
Examples of subjective well-being measurements that are frequently used in surveys.

Measurement	Domain(s) / interpretations	Question	Response
Happiness (Diener et al., 2018)	Affective-emotional, evaluative well-being	Question: Overall, do you think your life is happy?	Respondents rate their happiness on a scale of 0 to 10, with 0 indicating complete unhappiness and 10 indicating complete happiness.
The 5-item World Health Organization Well-Being Index (WHO-5) (Topp et al., 2015)	Affective-emotional	• I have felt cheerful and in good spirits. • I have felt calm and relaxed. • I have felt active and vigorous. • I woke up feeling fresh and rested. • My daily life has been filled with things that interest me.	Participants rate how often they felt the same as the items describe in the past two weeks from 0 (none of the time) to 5 (all of the time).
Satisfaction With Life Scale (SWLS) (Diener et al., 1985)	Cognitive-evaluative: Overall satisfaction with life, evaluative well-being	• In most respects, my life is virtually perfect. • My living conditions are excellent. • I am satisfied with life. • Up to now, I have achieved the most important things in my life. • If I could start my life again, I would change hardly anything.	Respondents are asked to rate each item on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree).
Life satisfaction (Frijters and Krekel, 2021)	Cognitive-evaluative: Life evaluation, evaluative well-being	Question: All things considered, how satisfied are you with your life as a whole?	Respondents rate their life satisfaction on a scale of 0 to 10, with 0 indicating completely not satisfied and 10 indicating completely satisfied.
Cantril's Ladder or "Cantril's Ladder of Life Scale" (OECD, 2013b)	Cognitive-evaluative: Life evaluation, evaluative well-being	Question: Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. Suppose we say that the top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. If the top step is 10 and the bottom step is 0, on which step of the ladder do you feel you personally stand at the present time?	Respondents answer on a scale of 0 to 10.
Personal Well-Being Index (PWI) (International Wellbeing Group, 2024)	Cognitive-evaluative: Overall life satisfaction, evaluative well-being	Questions about satisfaction with life, with standard of living, health, personal relationships, feeling of safety, feeling part of the community, future security.	Respondents rate their satisfaction with each domain on a scale from 0 (completely dissatisfied) to 10 (completely satisfied).
UK Office of National Statistics four subjective well-being questions (ONS4) (Dolan and Metcalfe, 2012)	Affective-emotional, cognitive-evaluative.	• Overall, how satisfied are you with your life nowadays? • Overall, to what extent do you feel that the things you do in your life are worthwhile? • Overall, how happy did you feel yesterday? • On a scale where 0 is "not at all anxious" and 10 is "completely anxious", overall, how anxious did you feel yesterday?	Responses rated on a 0-10 scale ranging from 1 (not at all) to 10 (completely).
Warwick and Edinburgh Mental Well-being scale (Tennant et al., 2007)	Affective-emotional, cognitive-evaluative, psychological functioning	A regular version (14-item scale) and a shorter version (7-item scale) e.g. I've been feeling optimistic about the future.	None of the time/ Rarely/ Some of the time/ Often/ All of the time.

objective well-being burden directly attributable to specific environmental exposures in HIAs is not feasible. The weighting of different components in these combined measurements also complicates translating well-being impacts into actionable policies. Therefore, this paper focuses on subjective rather than objective well-being for potential integration into HIAs.

3.5. Importance of well-being in public policies

Well-being is increasingly recognized as a crucial metric for public policies, offering valuable insights that go beyond traditional health and economic indicators. Well-being metrics can also help set policy priorities by identifying which areas most significantly impact the population's quality of life. Frijters et al. (2020) further argued that policymakers must target areas where interventions can effectively raise the well-being of individuals, especially those experiencing low levels of well-being.

In current urban policy practice, more and more city surveys of inhabitants' preferences and opinions include well-being. Objective well-being indicators such as the Brede Welvaart Indicator (BWI; Broad Well-Being Indicator) have been developed to broaden policies to include more dimensions of welfare than just the narrow economic indicators beyond economic performance (Rijpma et al., 2025). A review proposed several urban planning strategies for improving subjective well-being in cities. For example, providing high-quality communal spaces for residential complexes will promote social interaction between neighbors, stronger neighborhood social cohesion, and well-being for residents (Mouratidis, 2021). Incorporating well-being into HIAs and other frameworks potentially allows policymakers to make more

informed decisions. This approach ensures that policy choices not only address immediate public needs but also align with the broader goals of enhancing the population's life satisfaction. By placing human well-being in policy evaluation, governments can better serve their populations, creating positive feedback loops between policy, health, and societal resilience.

4. Environmental exposures and well-being: conceptual pathways and evidence

4.1. Conceptual pathways: linking environment, well-being, and health

While the importance of well-being in public policy is increasingly recognized, and there are theoretical frameworks for the link between different environmental exposures and well-being, the focus of environmental epidemiologists is still largely limited to the physical and mental illness effects of the environment. For example, the notion of socioecological psychology as proposed by Oishi (2014) assessed humans' cognitive, emotional, and behavioral adaption to physical, interpersonal, economic, and political environments and well-being. In this section, we focus specifically on external environmental exposures (air pollution, noise, extreme temperatures, and green spaces) and well-being for environmental HIAs. We evaluate evidence for plausible pathways underlying the relationships between external environmental exposures, including air pollution, noise, extreme temperatures and green spaces, and well-being. Despite the availability of broader well-being frameworks, our analysis concentrates on (1) direct pathways between these environmental exposures and well-being, and (2) the indirect pathways where environmental exposures affect well-being via effects on physical or mental health. Fig. 1 shows the simplified conceptual framework showing the pathways that we discuss, including indirect links between environmental exposures of interest (i.e. air pollution, noise, extreme temperature and green spaces), physical/mental health, and well-being, and potential plausible direct pathways from these exposures to well-being.

Direct pathways

Direct effects occur when effects of environmental exposures on well-being are not mediated by physical or mental illness. There are plausible mechanisms for direct effects of air pollution, noise, extreme temperature, and especially green spaces on well-being.

For **air pollution**, research on its link with subjective well-being is still in the early stages (Levinson, 2020). However, growing evidence suggests that air pollution may influence mood and cognitive function through its effects on brain development and neural pathways. A randomized controlled experimental crossover study found that reducing indoor $PM_{2.5}$ levels may result in improvements in cognitive performance skills (Zhou et al., 2024). Studies have also found that air pollution exposure is associated with increased emotional and behavioral disorders as well as structural and functional changes to fronto-limbic brain regions across the lifespan (Herting et al., 2019; Zundel et al., 2022). Therefore, air pollution effects on the brain could also lead to potential changes in moods. There is also emerging evidence of direct effects on subjective well-being. For example, psychophysical experiments conducted in China and the UK found that subjective well-being changes negatively with increasing air pollution (Li et al., 2019). Several economic studies have examined the relationship between air pollution and subjective well-being, using measures such as life satisfaction (Welsch, 2006; Zhang et al., 2017) and happiness (Levinson, 2012).

Plausible pathways have also been proposed for associations of **noise and air pollution** with subjective well-being (Dzhambov et al., 2018; Fujiwara and Lawton, 2020). Exposure to **noise** from different sources acts as a stressor that can potentially influence multiple organ systems and can contribute to psychosomatic effects or disorders (Hahad et al., 2024). When sounds are perceived negatively, they can trigger increased stress hormone levels, blood pressure, and heart rate, and result in negative physiological and psychological effects (Hahad et al., 2019). Cognitive and emotional stress responses are key mechanisms through which noise affects well-being, for example, the activation of a physiological stress response to nighttime sleep disturbance (Sørensen et al., 2024), annoyance (van Kamp et al., 2020), and mood deterioration (Pirrera et al., 2010). Conversely, soundscape approaches, which involve masking unwanted sounds with pleasant or desired ones, have been shown to support mood recovery and improve emotional well-being (Gilmour et al., 2024).

Temperature is associated with human cognition, affect, and (potentially) behaviour. Evidence from previous observational and experimental studies suggests that core temperature at approximately 37°C, variations in ambient and skin temperature can influence social perception and motivation. Specifically, lower temperatures tend to evoke a greater need for social connection, whereas higher temperatures may enhance feelings of social closeness and sociability (Fischer et al., 2024). In the case of extreme temperature conditions, temperature can be linked with subjective well-being (Chen et al., 2024; Maddison and Rehdanz, 2011). It has been found that subjective well-being is affected by acute temperature more than by the average temperature over the day (Tsutsui, 2013). However, it has also been hypothesized that there is no direct causation from climate to life satisfaction; instead, people might choose to live in certain climates because of their individual characteristics, such as personality traits, preferences, or socioeconomic status. Moreover, studies have shown that although individuals may experience relatively consistent psychological responses to temperature, there are substantial differences across people in their preferred thermal comfort levels (Meidenbauer et al., 2024). While some evidence supports an association between temperature and well-being, this relationship appears to be less direct and less robust than that observed for other environmental exposures, such as green spaces.

Several frameworks exist for the potential link between **green**

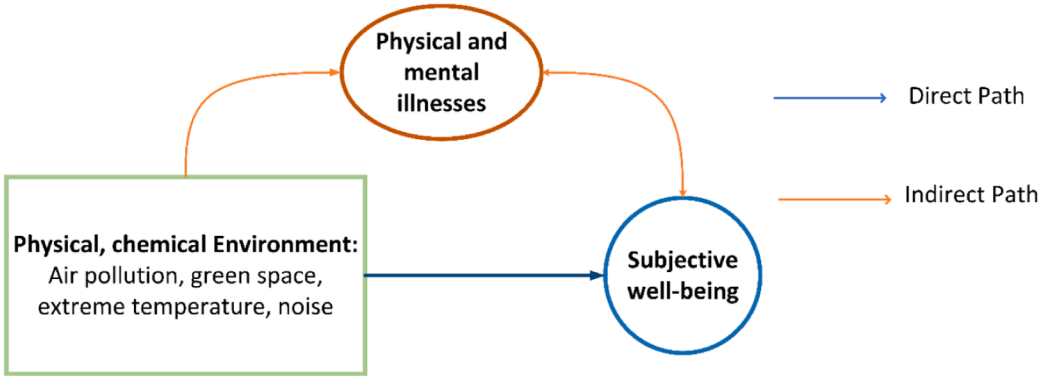

Fig. 1. Simplified conceptual pathways of the relationship between the environment and subjective well-being.

spaces/nature contact and well-being. The proposed mechanisms are similar to the mechanisms proposed for potential effects on general health and include increased physical activity, more social contact, reduced stress, and better air quality (Hartig et al., 2014). A detailed framework has also been proposed linking biodiversity to health, illustrating the importance of the perception of green (Marselle et al., 2021). We note that while plausible pathways have been identified, the evidence for the relative importance of several of these pathways is not yet clear (Marselle et al., 2021). A large cross-sectional survey from 18 countries illustrated the importance of recent visit frequency to green and blue spaces for physical activity, social contact, and subjective well-being (Elliott et al., 2023). Conceptual diagrams of the relationships of biodiversity (Bratman et al., 2024) with health and well-being were also developed for other natural factors, such as blue spaces (White et al., 2020).

Indirect pathways of external environment and well-being

Previous reviews describe strong negative associations between subjective well-being and factors such as poor health, separation, unemployment, and lack of social contact (Dolan et al., 2008). In the context of environmental HIAs, it is specifically important to clarify the role of physical and mental illnesses as mediators of the relationships between environmental exposures and well-being, since these health dimensions are already incorporated into HIAs. Accordingly, this paper emphasizes the indirect pathway through which the external environment influences well-being via impacts on physical and mental health. We also acknowledge that relationships between the environment and well-being are shaped by broader contextual factors such as social cohesion and community dynamics, which, while important, are beyond the scope of this paper (Mitchell et al., 2015).

Many studies have documented associations of air pollution, noise, and green spaces with poor physical health (Browning et al., 2022; Khraishah et al., 2022; Münzel et al., 2021; Rajagopalan et al., 2024). Previous reviews also summarized mental health issues that have been studied in relation to air pollution, noise, extreme temperature, and green spaces (Alarcón Garavito et al., 2024; Reuben et al., 2022; Thompson et al., 2022; Wilker et al., 2023). There are also interconnections between poor physical and mental health and subjective well-being (Iorfino et al., 2024). Poor health can lead to reduced subjective well-being, while good well-being can mitigate physical health impairments. Chronic conditions such as coronary heart disease, arthritis, and chronic lung disease are often associated with increased rates of depression and reductions in both hedonic and eudaimonic aspects of well-being. Conversely, subjective well-being, particularly positive life evaluations and a strong sense of purpose, may play a protective role in health outcomes. Evidence suggests that higher levels of well-being are associated with improved survival rates, independent of age, sex, and baseline physical health, underscoring the bidirectional relationship between psychological well-being and overall health (Steptoe et al., 2015).

4.2. Evidence on environmental exposures and subjective well-being

The search process yielded 605 articles related to environmental exposures and well-being. From these, 45 studies were identified that specifically examined associations between subjective well-being and the exposures of air pollution, noise, extreme temperatures and green spaces. A summary of these studies is presented in Table 3, with further detail available in Appendix 4 (Tables A4.1–A4.4).

Most of the identified studies focused on the associations of green spaces or nature and air pollution with subjective well-being and used a cross-sectional design (Table 3). In terms of subjective well-being measurements, most studies used a single item about life satisfaction (n = 21) or happiness (n = 13); five studies used the WHO-5 scale, three studies used the Warwick and Edinburgh Mental Well-Being Scale, and three studies used the four ONS well-being questions (ONS4). The remaining studies used different tools.

Table 3
Summary of identified epidemiological papers on associations between environmental exposures and subjective well-being.

Environment exposure	ntotal	n by study design				n by study size			n by well-being measurements						
		Cohort	Cross-sectional	Ecological	Time-series	<1000	1000-10000	>= 10000	Happiness question	Life satisfaction question	Warwick and Edinburgh Mental Well-being scale	WHO-5	MHC-SF	ONS4	Personal Well-Being Index
Air pollution	18	1	15	2	0	2	7	7	10	9	0	0	0	0	0
Noise	6	0	6	0	0	4	1	1	1	4	0	1	0	1	0
Extreme temperatures	5	0	4	0	1	0	2	3	1	3	0	0	0	0	0
Green spaces	16	3	12	1	0	4	6	5	1	5	3	4	1	2	1
n total	45	4	37	3	1	10	16	16	13	21	3	5	1	3	1

For **air pollution**, the majority of the eighteen studies (n = 11) included particulate matter ($PM_{2.5}$ or PM_{10}, **Table A4.1**, Appendix 4 in the supplementary Materials). Two studies used nitrogen dioxide (NO_2), and three studies included sulfur dioxide (SO_2). Four studies used perceived air pollution (Herrera and Cabrera-Barona, 2022; Honold et al., 2012; Song et al., 2020; Xia et al., 2022). Most studies were of moderate to large size (more than 1,000 subjects) and primarily conducted in Asia (n = 11); four studies were conducted in Europe, two in Southern America, and one on a global scale. This setting contrasts significantly with the evidence base for the associations between air pollution and physical health, which includes numerous large-scale cohort studies conducted worldwide. All studies reported a negative association between air pollution and subjective well-being. The four studies that specifically focused on perceived air pollution found that higher levels of perceived air pollution were associated with lower subjective well-being (Herrera and Cabrera-Barona, 2022; Honold et al., 2012; Song et al., 2020; Xia et al., 2022).

We identified six epidemiological studies that assessed the association between **noise** and subjective well-being (**Table A4.2**, Appendix 4 in the Supplementary Materials). While annoyance is one of the most frequently studied effects of noise and represents a negative dimension of well-being, it was not included in the epidemiological evidence review because our focus is on positive aspects of well-being. The studies we identified generally found that higher levels of noise exposure or perceived noise were associated with decreased subjective well-being. Many current studies relied on self-reported noise perception, often using the same questionnaires to assess both exposure and well-being. Moreover, the variation in perception-based exposure measures makes comparisons across studies difficult. The predominance of cross-sectional designs limits interpretation, as lower well-being may lead individuals to remain at home more often and perceive noise as more disturbing.

Only five studies examined the association between **temperature** and subjective well-being, all employing cross-sectional designs and focusing on ambient temperature (**Table A4.3**, Appendix 4 in the Supplementary Materials). The findings suggest a curvilinear relationship, with larger deviations from a baseline temperature, often indicative of extreme heat or cold, being associated with reduced subjective well-being (Li and Hu, 2025; Maddison and Rehdanz, 2011).

For **green spaces**, the majority of the studies (n = 8) are from Europe, with two from the North America, one from Asia, one from Australia, and four on a global scale. Most studies used a cross-sectional design (n = 12), while three studies used a cohort design, and one employed an ecological study design (**Table A4.4**, Appendix 4 in the Supplementary Materials). Most studies included between 1,000 and 10,000 subjects. Exposure to green spaces or nature can occur through neighborhood settings (e.g., home), indirect encounters, or intentional visits. Various measurements of objectively or self-perceived greenness or nature were used, such as NDVI, nature diversity, and the presence of forests. Most of the studies (15 out of 16) reported that more green spaces or nature, either objectively measured or through more nature contact/visits, was associated with better subjective well-being. Eleven studies used objectively measured green spaces, and six of these found a positive association between increased greenness or nature and better subjective well-being. One study identified a U-shaped relationship between objectively measured green spaces and well-being measured by the Warwick-Edinburgh Mental Well-being Scale (Geary et al., 2023). Three studies specifically focused on the perception of greenness or nature as an exposure metric (Cleary et al., 2019; Fleury-Bahi et al., 2023; Li et al., 2023) and found that higher perceptions of greenspace were associated with better subjective well-being. While measures of nature exposure, such as the amount of green spaces within a certain buffer around the home address, were consistently related to overall life satisfaction, nature visits tend to be more strongly correlated with subjective well-being (Fian et al., 2024). All eight studies that used nature contact/visit information found that more active contact with green spaces, such as spending more time in nature, is related to increased subjective well-being (Bratman et al., 2024; Fian et al., 2024; Holt et al., 2019; McDougall et al., 2024; Pasanen et al., 2023; White et al., 2017, 2019, 2021). These findings suggest that active engagement with nature may offer greater benefits than passive exposure alone, though benefits may plateau beyond a certain threshold (White et al., 2019). Conducting a meta-analysis of the relationship between greenspace and subjective well-being is challenging due to the diversity of endpoints used for measuring well-being, varying definitions of greenspace, and the relatively modest evidence base.

In summary, the evidence from epidemiological studies of the associations of air pollution and green spaces with subjective well-being is at least suggestive, despite the heterogeneity in methods used to measure exposure, outcomes and the use of cross-sectional designs. For exposure measures, a few studies used self-reported exposures, such as perceived air pollution, which is challenging to be included in quantitative HIAs. The varied outcome measures and exposure definitions make it difficult to combine results in a meta-analysis at this stage to derive exposure-response functions for well-being. For noise, the studies that evaluated subjective well-being also suggest an association. For temperature, the evidence is limited.

There is a need for more epidemiological studies to quantify associations between the environment and well-being. Specifically, standardized and harmonized measurements for subjective well-being, such as the WHO-5, and environmental exposures, should be consistently applied across studies, even if they included other tests and instruments in addition to standard ones, to enable comparability and future meta-analysis. Also, more epidemiological cohort studies, which use state-of-the-art objective exposure assessment methods such as modelling, which enables an individual-level exposure measurement, are needed to provide a more comprehensive understanding of how different exposures are associated with subjective well-being.

5. Rationale to include well-being in environmental HIAs

Building on the workshop discussions from the experts and stakeholders as well as previous literature, we argue that there are multiple compelling reasons for the integration of well-being into quantitative environmental HIAs.

Firstly, well-being should be included as it includes aspects of health that both individuals and societies care about but which are not included in measures for physical health and mental illness that are currently already integrated into quantitative HIAs (Kosīte et al., 2025; Vidal Yañez et al., 2023). Unlike commonly used health indicators that focus primarily on morbidity and mortality, well-being also encompasses positive aspects of health, aligning with the WHO's comprehensive definition of health. Equally important, a more expansive notion of health is actually mandated by the original 1948 health definition, which remains in place today, stating, “Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.” Yet, in the current QALY and DALY measures, there is no room for social well-being, and mental well-being is reduced to a few severe mental health problems, not general mental functioning. By including a more expansive notion of well-being as conceived by individuals, one does more justice to the actual WHO definition of health itself. Physical illness and well-being can coexist and be mutually influential. In addition, it is important to recognize that mental illness and well-being can also coexist, and individuals without mental illness can experience low well-being, while those with mental illness can still experience high well-being (Westerhof and Keyes, 2010).

Secondly, aligning policy objectives with well-being enhancement is essential since the ultimate goal of city policymaking should be to promote the well-being of its citizens (Frijters and Krekel, 2021). The US Declaration of Independence mentions the ‘pursuit of happiness’ as an inalienable right, not the pursuit of physical health (National Archives, 1776). Tracking the well-being impact of policies and interventions

plays a critical role in urban planning and fostering healthy urban living (WHO, 2008). Integrating well-being into environmental HIAs can also help illustrate the distributional well-being effects of exposure changes, thereby identifying which population groups benefit most and supporting an equity-oriented approach from a positive aspect.

Thirdly, some environmental exposures, such as access to green spaces, have been shown to influence well-being through several pathways, providing a basis for their consideration in HIAs (section 4.1). If well-being impacts that are not measured and quantified, the well-being impacts of urban spaces and environmental policies might be overlooked or reported only in qualitative terms, potentially undervaluing their importance and hindering a comprehensive assessment of the true impact of various urban interventions. By integrating well-being into quantitative environmental HIAs, policies can be better designed to reflect and address the needs of the population's positive experiences and emotions and foster a more comprehensive approach to public health and urban development.

6. Including well-being in environmental HIAs

We have argued that there is a need for integrating well-being into environmental HIAs, which moves away from a narrowly framed disease-centred approach towards a broader, comprehensive health perspective that encompasses physical, mental, and social well-being. In this section, we first explore potential strategies for integrating positive well-being measures into HIAs with a working example. We then discuss whether we can currently include well-being in environmental HIAs, given the state of knowledge and existing challenges.

6.1. Two strategies for integrating positive well-being concepts into HIAs

The first approach is to include subjective well-being as an additional (health) outcome next to the commonly used mortality or morbidity outcomes in existing integrated health indicators, such as DALYs. This can be used in quantitative HIAs following different methods, such as the comparative risk assessment framework or microsimulations (Mueller et al., 2023). For example, following a standard comparative risk assessment HIA framework, the well-being impact expected from a change in exposure (comparing baseline with an intervention/policy scenario) can be estimated by combining changes in exposure with exposure-response functions (section 4.2) and baseline rates. Distributions of subjective well-being indicators across populations can be obtained for the population at risk, typically from surveys.

The Well-being Adjusted Life Years (WELLBY) methodology has emerged in economics. It treats well-being as an independent outcome and quantifies the burden of interventions on this well-being outcome. WELLBY can potentially be used in HIA as an outcome indicator to quantify the well-being impact following a comparative HIA approach. WELLBY provides a single indicator to measure well-being experienced over a year. In WELLBY, well-being is represented by life satisfaction, a key component of subjective well-being (McGuire et al., 2022). As explained earlier, one commonly used question to measure life satisfaction is: “Overall, how satisfied are you with your life, nowadays?” A straightforward method entails defining a WELLBY as a one-point increase in life satisfaction, measured on a 0 to 10 scale, for one individual over the course of one year. Lifelong well-being can be calculated using average life satisfaction multiplied by length of life, which considers that life-satisfaction improvements can come from increases in average life satisfaction or from increases in length of life. Beyond using a single question, such as happiness or life satisfaction, to represent well-being, other summarized measurements from questionnaires, such as the WHO-5, can also be used to calculate well-being over a specific period. Using this method, the impact of intervention-relevant changes in exposures on well-being, such as WELLBYs, can be presented together with other health impact indicators, such as DALYs.

For this approach, **distributions of well-being indicators** need to be established, which requires valid measurements within the population of interest. Large-scale, representative surveys can effectively derive distributions of well-being outcomes. For outcome indicators for which registries do not exist, researchers have used epidemiological studies of population distributions to estimate baseline health, as demonstrated in projects like the HRAPIE project by the WHO (WHO Regional Office for Europe, 2013). Given the limited evidence base for environment and subjective well-being studies in terms of geography and population size, epidemiological studies not limited to those assessing relationships with environmental exposures should be evaluated, which can also provide baseline rates. Also, if the distribution of well-being outcomes is available in some countries, this information may be extrapolated to similar locations, supported by evidence showing that life satisfaction scales generally capture a unidimensional construct across diverse populations and survey conditions (Swami et al., 2025). There are some situations in which no information on baseline rates is needed, for example exposure-response functions for noise and annoyance and sleep disturbance, that provide the percentage annoyed and sleep disturbed subjects as a function of noise levels.

Additionally, exposure-response functions describing the association between changes in targeted exposures and well-being based on meta-analyses of epidemiological studies are needed. These may become available in the future as the evidence base grows. In the meantime, exposure-response functions that are available in one study may be applied to other settings. However, the extent to which exposure-response functions are generalizable to other settings remains unclear. Therefore, it is important to acknowledge the uncertainty of HIA results due to data extrapolation. Key considerations include the characteristics of the study population (e.g., age, gender), the broader context in which the study was conducted, such as economic, social, and cultural conditions, and whether the setting is rural or urban. These factors can potentially influence both exposure, well-being outcomes, and the association between exposure and well-being, which should be carefully evaluated when applying exposure-response functions across different populations or geographic areas.

The advantage of considering subjective well-being as an additional health outcome beyond the frequently used mortality, and other major individual diseases is that policymakers and the public can assign their own weight to the different outcomes. For instance, improvements in life satisfaction or mental well-being may carry different weights in different cultural or policy contexts. However, this flexibility can also be a disadvantage. First, it introduces subjectivity into the interpretation of results, potentially allowing selective emphasis (“cherry-picking”) of outcomes that align with a particular agenda, leading to inconsistency in how evidence is applied. Some decision-makers may perceive subjective well-being as less objective or valid—a matter of personal perception rather than a tangible health effect—thus risking reduced credibility or uptake in policy.

WELLBYs can also be used as a combined measurement, either using weights from social banks or translating from or into DALYs/ QALYs. If one takes WELLBYs as the apex measure, then one uses weights for QALYs or DALYs to translate their contribution into WELLBYs. Using results from Huang et al. (2018), subsequent WELLBY analyses imply that 1 QALY is roughly equivalent to 2.5 WELLBYs if those QALYs are generated by improved health (the quality of life in QALY) and 6 if those QALYs are generated by reduced mortality (the length of life in QALYs) (Frijters et al., 2020).

Based on this approach, we provide an example of a comparative risk assessment HIA to estimate the well-being impact of aligning PM_{10} levels in Barcelona with the WHO air quality guideline of 15 $\mu g/m^3$ (World Health Organization, 2021b). In 2017, the city-wide mean annual PM_{10} concentration was 21.68 $\mu g/m^3$ in Barcelona (Mueller et al., 2024). We use life satisfaction as a proxy for subjective well-being, based on a 2011 survey completed by 950 Barcelona residents, which reported a mean life satisfaction of 7.20 on a 0–10 scale in response to the question: “Taking all things together, how satisfied do you feel with

your life at present?" (Sekulova and van den Bergh, 2013). The exposure-response function can be derived from a study in Estonia, where a 1 μg/m^3 increase in annual average PM_{10} concentrations was found to be associated with a significant reduction in life satisfaction of 0.017 points on a 10-point life satisfaction scale (Orru et al., 2016). In this calculation, we assume a linear exposure-response function. Applying this function, the exposure contrast of 6.68 μg/m^3 corresponds to a projected increase of 0.114 points in life satisfaction, raising the average from 7.20 to 7.31. For the adult population of Barcelona (aged 20 and over) of 1,349,570 subjects in 2017 (Mueller et al., 2024), this results in a total well-being benefit of 153,311 WELLBYs. Confidence intervals could not be calculated in this analysis, as the original exposure–response function did not report them. These could be included in future assessments when more data become available.

An alternative approach to well-being impacts considered in HIAs is to adopt a different apex measure into which everything is collapsed, which could be DALYs or QALYs. If one adopts DALYs as the apex measure, one assigns weights to subjective well-being measurements as an independent outcome alongside other health outcomes, following the disability weight approach for the calculation of DALYs from mortality and morbidity outcomes. This approach, follows the same steps listed above (baseline rates; ERF); the difference is that we integrate the well-being impacts into a more readily used metric, which requires weights for well-being. Similar to the designs to estimate disability weights, potential methods to get weights for well-being include health state description, panel of judges, valuation methods for health states, time presentation, and surveying techniques (Charalampous et al., 2022). Following this approach, if the weight assigned to well-being is relatively low compared to other outcomes such as mortality or morbidity, the estimated burden in HIAs would likely still be dominated by mortality and morbidity.

Similarly, if one uses QALYs as the apex measure, one could include well-being questions in a quality-of-life measurement questionnaire and then calculate utility weights following the QALYs approach. The Quality of Well-Being Scale (QWB) is one method used to calculate weights in QALYs to consider well-being (Kaplan and Anderson, 1988; Sassi, 2006). However, the QWB does not include positive subjective well-being questions, and to our knowledge, no scales with a focus on positive well-being are currently used in utility weight calculations for QALYs.

However, the EQ Health and Well-being instrument (EQ-HWB) includes three positive well-being questions out of 25 items, making it a potential candidate for calculating weights for QALYs, as it incorporates a positive well-being component (Brazier et al., 2022). While combining well-being indicators with other health outcomes into a grouped indicator in HIA is possible, interpreting the results may be less straightforward or potentially less effective for communication purposes. In addition, there is also a risk of double-counting if the effect of well-being is through indirect paths on physical and mental health (see section 4.1), but this may be mitigated by quantifying and adjusting mediation effects if more epidemiological evidence on these mediation effects becomes available.

Moreover, determining the weight of each health outcome component requires significant effort similar to that in DALYs. For the well-being weights, we should be cautious in applying traditional health utility methods, like time trade-off or standard gamble, to subjective well-being outcomes. These methods are grounded in preferences over imagined health states, which differ significantly from directly measuring experienced well-being. When subjective well-being itself becomes the outcome, asking people to estimate its utility introduces a conceptual circularity since there is no longer uncertainty about the outcome, just variation in experience. This shift challenges the validity of using the same valuation techniques, as preference-based and experience-based approaches may yield different, yet individually justifiable, results (Dolan and White, 2006).

A comparison between the two approaches is shown in Table 4.

6.2. Can we currently include well-being in HIAs?

In this section, we address the challenges of integrating well-being into the HIAs of the environment. A significant challenge is determining whether plausible pathways exist between environmental exposures and the various dimensions of subjective well-being. The initial step to address this is synthesizing existing mechanistic and epidemiological studies on the environment and well-being. In section 4.1, we summarized the potential pathways linking environmental exposures, physical health, and mental health with subjective well-being. We found that there is plausible mechanistic and epidemiologic evidence linking green spaces, air pollution, noise, and well-being. For extreme temperatures, these pathways are less well-defined.

We noted the limited availability of epidemiological studies to quantify exposure-response functions. Exposure-response functions from meta-analyses summarizing multiple high-quality prospective epidemiological studies are preferred for HIAs. However, this is currently not feasible due to the limited number of epidemiological studies. To fill the gap in epidemiological evidence, more studies should

Table 4
Comparison between two approaches.

	Approach 1: Separate well-Being outcomes and present as WELLBYs	Approach 2: Integrated into DALYs/QALYs
Health impact indicators	• Estimates well-being impact based on changes in exposure levels	• Calculate impacts on morbidity, mortality, and well-being separately and then combine them into a single indicator to calculate the overall health impact
Data requirements	• Exposure levels for baseline and scenario • Baseline rate of well-being • Exposure-response function	• Exposure levels for baseline and scenario • Baseline rate of well-being • Exposure-response function • Disability weight/ Utility weight for subjective well-being
Strengths	• Provides a clear, distinct focus on subjective well-being, which may help raise its importance in policymaking and support communication to the general public and other stakeholders. • Allows integration with WELLBYs of other health outcomes using weights from social value banks and the cost-benefit units in governments.	• Offers a comprehensive health measure by integrating SWB with mortality and morbidity, simplifying the interpretation of overall health and well-being impact.
Limitations	• This may result in well-being being viewed separately from overall health impacts, making it less influential in final policy decisions.	• Well-being may be over- or underestimated compared to other health outcomes, such as mortality and morbidity, because of the weighting system. • Generating weight • Potential double-counting of impacts due to the interconnection between health and well-being
Complexity	• Lower complexity: straightforward estimation of well-being impact based on direct outcomes.	• Higher complexity due to the need for calculating weights, assigning appropriate values, and combining well-being with other health outcomes.

be conducted, preferably incorporating multiple environmental exposures and using prospective cohort designs. Individual-level modelled or objectively measured exposures should be used to allow for comparability of results between studies. Given the importance of socioeconomic factors affecting well-being, careful adjustment for individual and area-level socioeconomic status is needed in these studies. We consider that ecological studies will not contribute useful information because of the lack of crucial individual-level covariates and the risk of ecological fallacy. Existing datasets, such as large surveys and smaller cohorts in the psychology domain, offer possibilities for addressing these gaps.

To advance the inclusion of well-being in HIAs, standardized and harmonized well-being measures, such as the WHO-5 or other validated scales, should be used across studies to enable comparability and meta-analyses, potentially next to other metrics and scales. Without consistent measures of well-being, using exposure-response functions from various studies and applying them to baseline rates of different measures of subjective well-being using a comparative risk assessment framework will remain challenging and increase uncertainty.

Despite the challenges associated with integrating well-being into HIAs, opportunities remain for preliminary exploration in this area. Exposure levels need to be assigned to allow for epidemiological analyses and produce exposure-response functions. For HIAs, preliminary analyses can be done using national or international surveys, such as the European Social Survey, which can provide a baseline rate of subjective well-being.

The challenges and uncertainty in accurately quantifying well-being impacts should not hinder the exploratory attempt of including well-being into HIAs. If well-being is excluded, it is essentially assumed to have no impact, which is inaccurate and undervalues its significance. The suggestive evidence for associations of noise, air pollution, and green spaces with well-being suggests that exploratory HIAs are possible. We recognize that the evidence base is not sufficient to draw conclusions on a causal or likely causal relationship between external exposures and well-being. Inclusion in HIAs will currently show the potential impact, with more uncertainty than for more established exposure-outcome pairs. We note that the suggestion to perform exploratory analyses based on a few epidemiological studies is consistent with the practice of HIA of air pollution and mortality, which for a long period has been based upon a single study (Pope et al., 2002). The evidence for air pollution and mortality at the time was supported by other lines of evidence, similar to environment and well-being, albeit at a much less established level for the latter.

Integrating well-being into HIAs raises important concerns beyond methodological challenges. First, equity considerations must be central: maximizing aggregate well-being does not guarantee equitable distribution of benefits. Vulnerable groups—often disproportionately affected by environmental hazards—may experience little gain or even face unintended harms if well-being metrics overlook systemic disparities. Second, while well-being offers a more holistic view of health impacts, its inclusion risks introducing uncertainty due to several methodological gaps. This could obscure clear policy signals or delay action on health priorities. Microsimulation modeling in HIAs may offer a promising solution. By simulating individuals rather than population averages, microsimulations can account for heterogeneity in population characteristics and well-being status, and incorporate transition probabilities to model how changes in environmental exposures may lead to improvements (or declines) in well-being over time.

In the case of including well-being into HIAs, exploratory attempts should be made, and public health sectors, citizens, and other policymakers should be involved in this incremental progress. The experience with QALYs demonstrates that even imperfect measures can be useful (Frijters et al., 2020). What matters is that the metrics capture the essential elements of the concept they were designed for —in this case, well-being. Over time, this methodology can improve and ultimately lead to better data and processes for integrating well-being into HIAs. Using QALYs shows that health systems can learn from early attempts at measurement.

Because of the current uncertainty in the HIAs and the complexity of generating weights to include well-being in QALYs or DALYs, we propose to include well-being as a separate indicator in the first instance, whilst making progress on aspects that would enable its integration within QALYs or DALYs, such as methods for assigning weights.

7. Summary and conclusion

Given the critical role of well-being in shaping comprehensive health assessments, this position paper underscores the importance of integrating well-being into environmental HIAs. In this work, we summarized well-being definitions, indicators, and plausible frameworks linking environmental exposures to subjective well-being.

We argue that the inclusion of well-being in HIAs is essential for providing a broader view of health that aligns with the WHO's definition of health, which includes physical, mental, and social well-being.

Although “well-being” is frequently used as an umbrella term, often operationalized through general quality-of-life measures or through the absence of physical or mental illness. The positive aspect of subjective well-being is missing. Neglecting well-being in HIAs implicitly assumes that the health impact of environmental exposures on well-being is zero, which almost certainly leads to an underestimation of the totality of health impacts of environmental exposures.

We followed this train of thought and assessed the epidemiological evidence and found positive relationships between low air pollution, low noise, greenness, and constant temperature with well-being. The implication is thus indeed that integrating direct well-being impacts into HIAs will increase the estimated impact of policies designed to improve environmental exposure. Despite the challenges we identified, including the need for more epidemiological studies, we argue that exploratory attempts should be made to include subjective well-being in HIAs. We proposed two different approaches to integrate well-being in environmental HIAs: reporting well-being as a separate outcome among a set of outcomes, which can be implemented immediately, or picking an apex measure to summarize all other physical health and well-being impacts, which needs further data to implement. Subjective well-being measurements, such as life satisfaction and other tools used like the WHO-5, offer practical means to incorporate well-being into HIAs and can be used in both approaches. Exploratory HIAs can already be conducted based on limited evidence for exposures such as green spaces.

In conclusion, this position paper advocates for the inclusion of well-being in environmental HIAs, emphasizing that doing so is important for creating a more comprehensive assessment of health impacts. Given the current lack of epidemiological studies on environmental risk factors and well-being, a first step for future research is to conduct epidemiological studies—preferably longitudinal—that incorporate well-being measures.

CRediT authorship contribution statement

Xuan Chen: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Gerard Hoek:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Paul Frijters:** Writing – review & editing, Methodology. **Georgia M.C. Dyer:** Writing – review & editing. **Stefan Gössling:** Writing – review & editing, Conceptualization. **Sasha Khomenko:** Writing – review & editing. **Haneen Khreis:** Writing – review & editing. **Eline Kolb:** Writing – review & editing. **Natalie Mueller:** Writing – review & editing, Methodology. **Brigit Staatsen:** Writing – review & editing, Methodology. **Rafael Costa Simões De Vasconcelos:** Writing – review & editing. **Daniel Saldanha Resendes:** Writing – review & editing. **Elise van Kempen:** Writing – review & editing, Methodology. **Mathew P. White:** Writing – review & editing, Methodology. **Roel Vermeulen:** Writing – review & editing,

Supervision. **Mark Nieuwenhuijsen:** Writing – review & editing, Funding acquisition, Conceptualization. **Ulrike Gehring:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Professor Nieuwenhuijsen's is Editor in Chief for Environment International but had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor. No other authors declared that they have known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2026.110067.

Data availability

Data used in this paper have been included in Appendix.

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