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# Municipal Environmental Management Indicators: A Bottom-Up Approach Applied to the Colombian Context

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**Abstract** The participation of local governments is one of the determining factors for achieving the objectives of sustainable development, whereby municipalities must have planning, assessment, control instruments, and indicators which will lead to proper environmental management and sustainable development. In this respect the existing models of sustainability indicators reflect, mainly, the state of the environment. However, these indicators do not allow the identification of the state of the environment's direct responsible actors and do not contribute towards the formulation of specific objectives and goals for each of the responsible actors. Furthermore, the sustainable development indicators are elaborated and measured by higher level entities, and are aimed towards a regional and national level, using a top-down approach. In this context, this paper proposes a model of environmental management indicators that lets us observe the state of the environment and identifies those responsible for that state. The set of indicators was developed in the municipalities of the department of Nariño, Colombia, through a participatory bottom-up approach which includes: the vision and needs of the stakeholders, who are responsible for the information, and the vision of the regional control organisms. Thus, a set of 40 environmental management indicators was formulated, and a framework to assess the strengths and weaknesses of the local environmental management was proposed. Their application indicates that a majority of the municipalities are in a weak environmental management

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situation and it lets the stakeholders critically analyze their performance through the set of indicators and also identify areas for improvement.

**Keywords** Municipal environmental management · Environmental management indicators · Nariño—Colombia · Participatory approaches

## 1 Introduction

In recent decades, the emergence of the need to effectively implement sustainable development has increased the need to address the serious effects of human activities on the environment and the imminence of climate change. With this in mind, the debate on sustainability and the necessity of finding better measures of progress in that direction have taken on a new urgency (Dahl 2012; Hak et al. 2012). In order to meet the challenge of sustainability, participation of local governments gained importance as one of the determining factors for achieving the objectives of sustainable socio-economic development (SD) (United Nations 1992), which include ensuring healthy lives, promoting well-being for everyone at all ages (goal 3), ensuring the availability of water and its sustainable management, sanitation for all (Goal 6), sustainable management of forests, protecting, restoring and promoting sustainable use of terrestrial ecosystems, combating desertification, halting and reversing land degradation, stopping loss of biodiversity (Goal 15), promoting inclusive societies for sustainable development, and commitment to cooperation and partnership to achieve the Sustainable Development Goals. In this sense, accessible, timely and reliable disaggregated data of quality is needed in order to help with the measuring of progress and are key to decision-making (United Nations 2015). To achieve this, the municipalities require indicators that make formulating strategies with an integral approach and vision of the future possible. The available indicators mostly succeed at measuring unsustainable trends that can be targeted by management action, but fall short of defining or ensuring sustainability (Dahl 2012).

On the other hand, existing environmental indicators, indexes or systems such as the Key Environmental Indicators of the Organisation for Economic Co-Operation and Development or the European Environment Agency core set of indicators (EEA-CSI), for instance, help provide insight into the state of the environment; such a state is the result of complex processes of development (Dahl 2012). These indicators also let us evaluate the effectiveness of policies and facilitate the communication of complex phenomena to non-technical audiences (European Environment Agency 2014). However, they are applicable at a national level mainly and, in order to be measured, they require resources that small size municipalities do not have. In addition, most of the small size municipalities in Colombia do not have the institutional capacity to promote autonomous policies that improve the quality of life of their inhabitants (Gutiérrez et al. 2010) or to formulate their own management instruments. This situation is aggravated by the lack of coordination between central and territorial levels (Criollo 2014). Therefore, this paper proposes an evaluation of the fulfillment of the municipal administrations' functions in the environmental area by means of a model of indicators of environmental management, made simpler and more viable, as a first step to later implement a system of information that allows the evaluation of the progress that is being made towards sustainable development.

Additionally, most of the systems of indicators have been formulated using a top-down approach, which reduces their legitimacy with respect to stakeholders (Sotelo et al.

2011). Moreover, the topic of monitoring and assessing sustainable development is frequently addressed in scientific publications, on a national, regional or international scale as well as in the sector and company related scale (Bluszcz 2016). In fact, there are still gaps in the definition and application of local Sustainability Indicators, especially for rural areas (Sotelo et al. 2011). Therefore, this paper presents a framework development in a bottom-up approach and proposes a set of 40 indicators for a case study region: the Department of Nariño in Colombia. The framework includes stakeholders in the identification of environmental indicators for the Municipal Environmental Management (MEM). This bottom-up approach allows the inclusion of the vision and needs of those responsible for the information as well as their users. The framework makes the indicators consistent with the indicator systems used at national and regional levels by being formulated, based on the databases from the Contraloría Departamental de Nariño (CDN) and the Corporación Autónoma Regional de Nariño (CORPONARIÑO). The municipalities in the department of Nariño in Colombia, under the jurisdiction of the CDN and CORPONARIÑO, comprise the case study. The CDN and CORPONARIÑO are the entities in charge of local governments' fiscal environmental control and managing the environment and renewable natural resources, respectively.

The online publication of the indicators will provide information to the public and institutions about environmental problems and their severity. This can provide support for policy development and priority setting by identifying key factors that cause pressure on the environment, and to monitor the effects of policy responses. Moreover, the model will contribute to increasing public awareness of environmental issues and can be a common strategy to strengthen public support for policy measures.

It is important to note that the model does not pretend to evaluate a municipality's sustainability, but rather the local authority's management with respect to their constitutional obligation to protect people's right to a healthy environment, as a first step to evaluate the commitment of municipal administrations to sustainability.

## 2 Colombian Context

In the Colombian National Environmental System's structure (SINA for its Spanish acronym), the Ministry of the Environment (ME) is responsible for the formulation of national public policy relating to the environment and renewable natural resources, as well as setting the rules and criteria for land use and environmental regulation. Similarly, the Regional Autonomous Corporations (CAR for its Spanish acronym) are responsible of managing the environment and renewable natural resources in areas that, given their characteristics, geographically constitute an integrated ecosystem or a geopolitical, bio-geographic or hydro-geographic unit. Meanwhile, municipalities are in charge of promoting and executing national, regional and sector-specific policies relating to the environment and renewable natural resources. Additionally, municipalities must elaborate plans, programs and municipal environmental projects in line with those defined at a regional and national level (Colombia 1993b). To sum up, environmental policy is formulated and regulated at the national level by the ME, and is implemented and executed at a regional and local level by the CAR and the municipalities.

As a supplement to the Colombian administrative structure, the Republic's General Comptroller, the departmental comptrollers and the municipal comptrollers are responsible of overseeing the State's fiscal management under the principles of efficiency, economy,

efficacy, equity, as well as environmental cost assessment. Therefore, these entities establish whether resource assignment has been the most convenient, in order to maximize results in a timely manner and to achieve the goals and objectives of the Administration.

Comptroller management allows the identification of economic action recipients and the analyzing of the cost–benefit distribution between social and economic sectors, as well as between territories. Likewise, comptrollers seek to quantify the impact of use and deterioration of natural resources and the environment as well as evaluating their protection, conservation, use, and exploitation management strategies (Colombia 1993a). In this sense, comptrollers present annual status reports of the natural resources and the environment under their jurisdiction. This research area of study falls under the jurisdiction of the CDN. Annually, said entity develops a questionnaire on the environmental management performed by the Department of Nariño municipalities and based on the information they compile, the CDN presents their annual report on the state of natural resources and the environment.

On the other hand, evidence presented in the European Environmental Agency (2015) and in Daams and Veneri (2017) shows that human health and well-being are intimately linked to the state of the environment and nature, since good quality natural environments can provide multiple benefits to physical, mental and social well-being. However, environmental degradation can have negative effects on health (European Environment Agency 2015). Furthermore, the unequal distribution of environmental and socio-economic conditions contributes to pervasive health inequalities (World Health Organization 2015). In fact, in the high level policy document of England: *The natural choice: securing the value of nature,* the indicator of environmental quality was presented to illustrate not only the presence of environmental inequality in England, but also to endorse the value of environmental improvement and good stewardship to promote better and healthier lives in England. The indicator of environmental quality has thus been exemplary in helping to set clear policy goals for the government and its partners to improve health and well-being and the environment (Secretary of State for Environment Food and Rural Affairs 2011; World Health Organization 2015). In this sense, the proposed model aims to provide information to raise public awareness on environmental issues so it can be an instrument of municipal policy in order to improve health and well-being.

In this context, the proposed model seeks to support municipalities in the formulation of their management instruments (planning, execution and control) and strengthen their institutional capacity by stimulating the acquisition of a self-evaluation culture using indicators. Likewise, the model will support the evaluation functions for the control entities (CDN and CORPONARIÑO).

## 3 Geographical Location and Social Aspects of the Research Region

Geographically, the research region for this work covers all 64 municipalities in the Department of Nariño, located in Colombia's southwestern region, at the border with Ecuador (Fig. 1). The municipalities of the Department of Nariño are socio-economically articulated with the Andean mountain range, the Pacific coast, the Amazonian piedmont and the humid jungles of the Pacific-Amazon corridor. The entire area is under the environmental jurisdiction of the CORPONARIÑO.


**Fig. 1** Location of the Department of Nariño

## 4 Regional and Local Indicators

This study proposes a set of indicators that aims to evaluate local administrative entities (municipalities) in their environmental management and provides a framework for the determination of those indicators. There are a great number of initiatives for the formulations of regional and local indicators, most of them focusing on analyzing Sustainable Development (SD), and are employed in the presentation of Local Agenda 21 reports. In reference to this, the Universidad Nacional de Colombia (2002b) presents a detailed relation of several local and regional initiatives in different parts of the world. The authors describe, among others, the European Common Indicators (ECIs), which is an initiative developed by the Ambient Italia Research Institute for the European Commission and the SISAL21 Initiative: cross-frontier sustainability indicators system for Local Agenda 21 s, that includes 4 regions in Spain and France (Universidad Nacional de Colombia 2002b).

As for the municipal environmental management (MEM), the literature contains several sector-based initiatives, related primarily to waste management (Bovea et al. 2010; Greene and Tonjes 2014; Herva et al. 2014; Petrosillo et al. 2012). Others are related to municipal energy and environmental management systems (MEEMS) (Kostevšek et al. 2013) or with tourism (Torres-Delgado and López 2014). However, there are no references on the application of indicators for the evaluation of MEM from the functional approach or with a benchmarking approach, specifically. There is also no reference to experiences that incorporate better practices in the construction of sustainability indicators for MEM.

## 5 Methods

A work plan was created in coordination with the CDN and CORPONARIÑO, using a bottom-up participatory approach, structured in three stages as mentioned above: indicator

formulation, indicator adjustment & valuation, and validation (Fig. 2). This is an approach that matches current debates in the field of sustainability evaluation, primarily in the aspect of integrating and creating permanent learning processes (Duarte et al. 2013; Gibson et al. 2005).

Two workshops were included as part of the stakeholder participation. The first workshop was part of the indicator formulation phase, while the second one was part of the indicator adjustment phase. The workshops were implemented procuring participation of indicator users primarily, in an attempt to promote cooperation between local and regional entities.

In order to do this, all the small size municipalities of the department of Nariño, cataloged in category 6, according to the Colombian National Planning Department (Departamento Nacional de Planeación 2015) were invited to participate. In the first event, 17 municipalities responded to the invitation (47 officials). CORPONARIÑO and CDN officials, academic members, as well as representatives from social organizations participated. For the second event, all municipalities were invited once again, but only 17

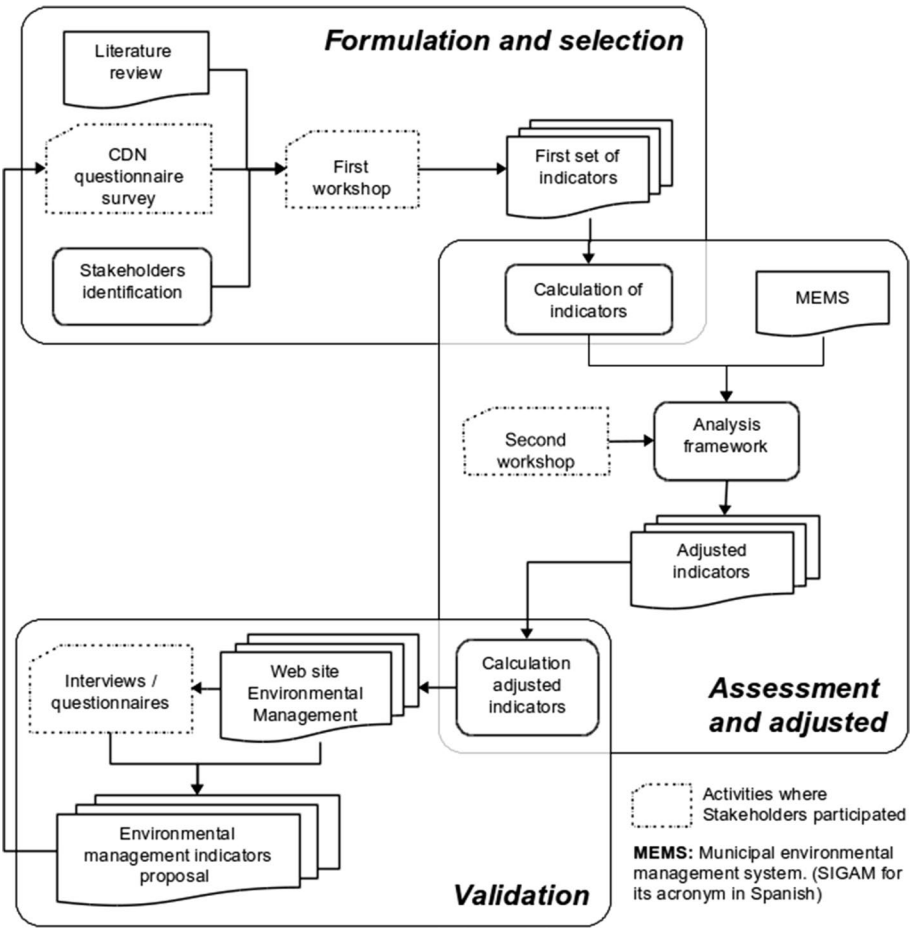


**Fig. 2** Stages in the work plan

representatives from 4 municipalities, as well as officials from CORPONARIÑO, the CDN and academic members participated. A reduction in participation was probably due to two factors: changes in the local government administration and labor instability for municipalities' public officials.

This situation sheds light on a recurring problem faced by research using bottom-up approaches, where, traditionally, it has been difficult to get participation but even more so to maintain it. This situation makes it hard to conceive participation as an objective way of identifying problems, as (Bell et al. 2012) note.

Other bottom-up indicator construction experiences also faced difficulties in mobilizing interested parties; the most critical moments being changes in local administration (Atkinsson 1996; Coutinho and Malheiros 2013; Malheiros et al. 2008; Tayra and Ribeiro 2006). This was the case for this research because on December 31st 2011, local mayors and governors' terms ended in Colombia: 2 months before the second workshop took place.

Even though all the municipalities were invited for the two events, the participation in the first round of research was of 27% of the municipalities in the region of study while participation on the second stage was reduced to 6.3%. Thus the selection criterion was the interests of municipalities and their officials to participate. However, it was considered that the objective of including the vision and needs of those responsible for the information and their users was achieved during the selection of indicators.

Additionally, participation by public officials from CDN and COPONARIÑO, who have more stability in their positions, was permanent. In this way, the work constructed and maintained a team with complementary skills and expertise, both from an institutional point of view as well as regarding their academic background and professional experience. This fact is of vital importance both for the success of the indicator construction process as for the durability of results (Quiroga 2009). In this way, a platform that empowers and educates interested parties was created and also provides a forum where people's concerns can be considered in the planning process (Fraser et al. 2006).

### 5.1 Indicator Formulation

The initial group of potential indicators must reflect the information needs appropriate for the work scope, be it environment or sustainability. Bottom-up systems require some time for group formation, discussion, definition and agreement on rules. Starting with an initial group of indicators facilitates an organized discussion by recognizing the demands of participatory processes (Quiroga 2009).

The first step in the formulation stage consisted in a literature review for selecting the potential indicator list, identifying good indicator formulation criteria and identifying the actors involved with the Municipal Environmental Management Systems (MEMS). Likewise, visits to municipalities and institutional partnerships were performed in cooperation with the School of Engineering of São Carlos from the University of São Paulo.

Taking into account that this work's intention is evaluating environmental management performed in the local Colombian context, the choice of framework is based on the criteria considered in the MEMS organizational guidelines. This work seeks to strengthen the technical and administrative capacity of municipal management, coordination between institutions and citizen participation in the environmental field (Universidad Nacional de Colombia 2002a). Therefore, all possible indicators used were cataloged into four criteria or dimensions: Technical, Resources, Institutional and Normative (Fig. 3).

The Technical dimension includes the formulation, execution and monitoring of plans and projects as well as the function of exercising control and monitoring local

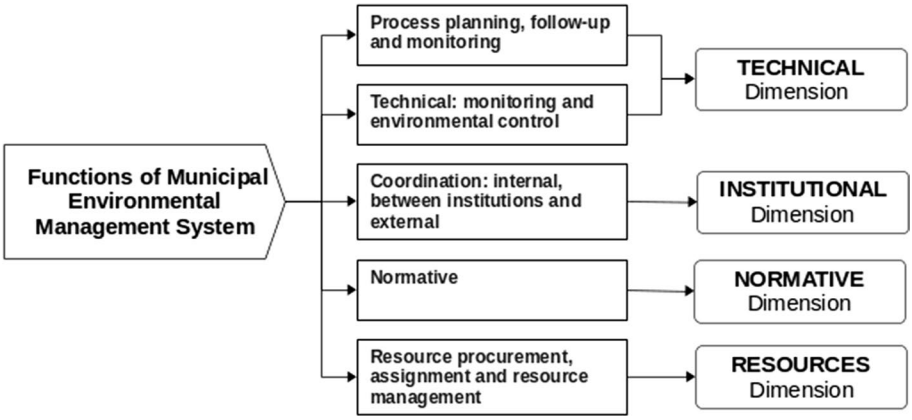


**Fig. 3** Functional dimension categories of the MEM indicators

environmental quality. It is a more proactive and investigative dimension and therefore also includes the operative component. The Institutional dimension is oriented towards the efficient and coordinated operational management between public sector entities related to the MEM. The Normative dimension includes topics related to the definition and application of standards and other regulation and control instruments. The Resource dimension deals with the instruments, means and strategies for the access, generation, management and assignment of resources to support the MEM with a sustainability focus.

During the first workshop mentioned above, the selection of the initial list of indicators took place, based on the indicator list resulting from the literature review. The selection process considered the criteria and best practices for indicator formulation recommended by (Meadows 1998; Programa de las Naciones Unidas para el Medio Ambiente. Consorcio Parceria 21 2008; Quiroga 2009; Veleva and Ellenbecker 2001). Five main criteria were evaluated: importance, comprehension, information availability, measurement, and analytical congruence. For the evaluation, a scale from zero to five (0–5) was used, where five (5) corresponds to full compliance with the analyzed criterion, and zero (0) corresponds to non-compliance with said criterion. Municipal and control agencies' officials were in charge of performing the evaluation.

## 5.2 Indicator Adjustment and Valuation

Initial indicator applicability was verified by calculating values for four municipalities based on 2009 information from the CDN. This was done in order to confirm the availability of information and each indicator's pertinence for the selected analysis model. The results of this procedure were discussed during the second stakeholder workshop mentioned above. This event allowed us to prioritize the municipalities' environmental problems and link them to the indicators by using a main environmental problem relation structure. This analysis allowed for the adjustment of indicators and verified their pertinence.

Additionally, participants' visions and expectations for their municipality were taken into account and, from these perspectives, new indicators were formulated. According to participants, these new indicators are indispensable for the system's integrity. Conclusions from the workshops became a reference to achieve a new adjustment. Resulting indicators

form the second phase were applied to Department of Nariño's municipalities using data from 2012. For this, the CDN asked, using their environmental questionnaire, the information required for new indicator calculation.

### 5.3 Validation

Validation was carried out using participatory mechanisms, namely two online surveys and non-structured stakeholder interviews. The first survey was formulated to qualify the relative importance of dimensions and indicators used, which permitted the establishment of their relative weights according to stakeholder input. In the second survey, the participants' opinion was requested on the pertinence and utility of the proposed indicator set.

Through these non-structured interviews, participants actively improved the indicator set formulation. Likewise, during this stage, a website www.gestionambiental.udenar.edu.co was launched and verified in a preliminary fashion. Results from the model's application were published as a means to establish a dialogue and a communication instrument.

### 5.4 Calculations and Formulas

Based on the participatory process, the final set of proposed indicators was consolidated and the MEM level for each municipality was evaluated. In order to do this, the indicators were normalized to a single value scale, making it possible to calculate a direct aggregation despite the indicators' different scales. A min–max normalization was utilized based on using the minimum (Xmin) and maximum (Xmax) values observed in the considered sample for each indicator and linearly normalizing the values of each element in the sample. Thus, the minimum and maximum values take a normalized value of 0 and 1, respectively; while all other elements take relative values varying within the interval [0,1] (Gómez-Limón and Arriaza 2011).

The normalization functions were defined according to the target value of the indicator: for a maximization indicator (of the "more is better" type) Eq. 1 was applied and for a minimization indicator (of the "less is better" type) Eq. 2 was applied.

$$Y_i = \frac{X_i - a}{b - a} \tag{1}$$

$$Y_i = \frac{b - X_i}{b - a} \tag{2}$$

where $Y_i$ = Normalized value of indicator $X$ for municipality i; $X_i$ = Original value of indicator for municipality i; $a$ = Minimum value for indicator $X$; $b$ = Maximum value for indicator $X$.

With this transformation, indicators become non-dimensional, taking values in the interval [0, 1], where 0 represents the worst possible value of the indicator while 1 indicates the best value of the indicator (Gómez-Limón and Arriaza 2011). Afterwards, indicators were aggregated using a weighted indicator sum. This process consists of a weighted addition of each dimension's normalized indicator set. Both the average weights for each dimension and those of each indicator were selected through a participatory process involving an online questionnaire. The questionnaire and results can be seen in the supplementary information.

Likewise, the weighted addition across dimensions determined a value of the MEM for each municipality in the scale of 0–1.0 (Eq. 3).

$$INGAm = \sum P_d * \sum P_i * Y_i \tag{3}$$

where *INGAm* Level of municipal environmental management; *Pd* Relative weight of each MEM dimension; *Pi* Relative weight of indicators; *Yi* Normalized indicator value for municipality *i*.

These elements constitute the final indicator set proposal, which is published at the website: www.gestionambiental.udenar.edu.co. This website shares the results and provides accessibility to them, both for actors related to this research and for the general public.

## 6 Results

The final indicator set consists of a group of 40 indicators, 60% of them correspond to the Technical dimension, 10% to the Institutional dimension, 23% to the Resource dimension and 7% to the Normative dimension (Table 1).

Individual results from the indicator aggregation procedure are presented in radar graphs (Fig. 4a). These graphs express the distance between real and ideal indicator values, which permits evaluating the municipality's performance qualitatively with respect to defined standards. Indicator aggregation by dimension and total aggregation are presented with speedometer charts that classify the aggregate value qualitatively in four levels of MEM: Weak (0–0.4), Medium (0.41–0.65), Good (0.6–0.90) and Superior (0.91–1.0).

As an example, Fig. 4a presents the results for the Ancuya municipality, which obtained the highest score in MEM. One can observe that this municipality has strengths in the Institutional and Normative dimensions, while the Technical dimension is in an intermediate level and the Resource dimension is weak according to the proposed scale.

Ancuya's technical dimension has strengths in the solid residue area and some drinking water topics. They show low indicators in the waste water and deforestation areas (both particularly relevant for the environment). Nevertheless, they scored a good management level. This is due to the fact that dimension weights consider that all dimensions have a similar relative weight (even though they hold a different number of indicators). Therefore, by obtaining good scores in the institutional and normative dimensions (corresponding to six (6) indicators) they obtain good scores in the final computation, even if the technical and resources dimensions (corresponding to 22 indicators) do not score the best results.

Finally, the aggregation across all dimensions is shown in a speedometer chart, indicating that the municipality's MEM level is *Good* (Fig. 4b).

The results of the aggregation procedure for all municipalities are presented in Fig. 5. It can be observed that 36.2% of municipalities have a weak MEM (range from 0 to 0.4), 56.9% are at an intermediate level (0.41–0.65) and only one municipality (1.7%) falls into the range categorized as good. The best results in terms of MEM level were found in the Southern, Central and South-Western regions, while the most critical condition can be found in the Pacific Coast region.

Figure 5 also shows the administrative entities in charge of the MEM. It is observed that in most municipalities (59%), the Secretary of Agriculture is responsible for the MEM, particularly of the Technical Assistance Municipal Units (UMATA for its acronym in Spanish). Five (6) municipalities (9%) develop MEM through an exclusive unit from an entity such as Secretary of the Environment or similar. This fact did not imply that they

**Table 1** Municipal environmental management indicators

| Function | Code | Indicator | Source | Unit |
|---|---|---|---|---|
| *Technical dimension (24)* | | | | |
| Basic sanitation | ARD01 | Existence of sanitation plans and wastewater dumping approved and/or in force | CORPONARIÑO, municipality, CDN | Qualitative |
| | ARD02 | Sewage system coverage | Municipality | % |
| | AP01 | Urban aqueduct coverage | IDSN, municipality | % |
| | AP02* | Per capita water consumption | Municipality | Lt/per/day |
| | AP03* | Municipal risk index for drinking water supply | IDSN, IDEAM | Qualitative |
| | AP05 | Risk index for drinking water quality | IDSN | Qualitative |
| | AP06 | Existence of an approved and/or in force | CORPONARIÑO, Municipality | Qualitative |
| | RS01* | Coverage of solid residue pick up service | CORPONARIÑO, Municipality | % |
| | RS02 | Integral solid residue management plan approved and/or in force | CORPONARIÑO, municipality | Qualitative |
| | RS03 | Per capita residue production | CORPONARIÑO, municipality | kg/per/day |
| | RS04 | Adequate final disposal of solid residues | CORPONARIÑO, Municipality | % |
| Healthy environment | ARD03* | Total volume of non-treated domestic waste water (DWW) | CORPONARIÑO, municipality | $m^3$/day |
| | ARD04 | Percentage of treated DWW with respect to total DWW volume produced | CORPONARIÑO, municipality | % |
| | ARD05* | Annual contaminated load dumped into water bodies | CORPONARIÑO, Municipality | ton/year |
| | AP04 | Hydrological vulnerability index (dry climate conditions) | IDEAM—ENA-2010. | Qualitative |
| | DEF01* | Urban vegetation coverage | Municipality | $m^2$/per |
| | DEF02 | Deforested areas with respect to municipality's total area | CORPONARIÑO | % |
| | DEF03 | Reforested or revegetated area for the protection of watersheds in maintenance for every 1000 people | Municipality | Ha/1000 per |
| | DEF04* | Strategic Ecosystems (moors, wetlands, mangroves, dry zones, etc.) management and regulation plans in effect | CORPONARIÑO | Qualitative |
| | BIO01* | Threatened flora and fauna species | CORPONARIÑO | Unit |
| | BIO02* | Threatened flora and fauna species with Conservation Plans in effect | CORPONARIÑO | Unit |
| | RP01* | Percentage of hazardous waste or residue generators under monitoring | CORPONARIÑO, Municipality | % |
| Quality for life | ARD06 | Rate of specific morbidity by EDA | IDSN | Rate/1000per |
| | RS06 | Rate of specific morbidity by IRA | IDSN | Rate/1000per |

**Table 1** (continued)

| Function | Code | Indicator | Source | Unit |
|---|---|---|---|---|
| *Resources dimension (9)* | | | | |
| Basic sanitation | ARD07 | Investment on water supply and sewage systems (law 715 from 2001) | Municipality | % |
| | RS05 | Investment in residue management (law 715 from 2001) | Municipality | % |
| | AP07* | Annual per capita cost of operation and maintenance of drinking water treatment plants | Municipality | $/per |
| Healthy environment | DEF05 | Investment in degraded area recovery and watershed protection | Municipality | % |
| | CI07 | Investment in the environment (Not including AC. nor AL.) | Municipality | % |
| | ARD08 | Payment of waste water tax with respect to population | Municipality, CORPONARIÑO | $/per |
| | AP08 | Payment of water use rate, per capita | Municipality, CORPONARIÑO | $/per |
| Quality of life | DEF06 | Per capita investment in urban green areas | Municipality | $/per |
| | RP02 | Investment in hospital solid residue management, per capita | Municipality | $/per |
| *Normative dimension (3)* | | | | |
| Healthy environ-ment | DEF07* | Protected areas declared under municipal jurisdiction | CORPONARIÑO | Ha |
| | CI02 | Sanctions received for non-compliance with norms and regulations | CORPONARIÑO, municipality, CDN | Number |
| | CI01 | Production and enforcement of norms and instruments for regulation and control | Municipality | Number of actions |
| *Institutional dimension (4)* | | | | |
| Healthy environment | CI03 | Inclusion of environmental and risk dimensions into the territory management plan | CORPONARIÑO, municipality | Qualitative |
| | CI04 | Number of public officials in charge of environmental management and their level of preparation | Municipality | Adimensional |
| | CI05 | Exclusive jurisdiction for MEM and public officials hiring scheme | Municipality | Adimensional |
| | CI06 | Participation in inter-institutional environmental projects | Municipality | Number of projects |

*Indicators without data for calculations done with municipal data for 2012, 2013, 2014 and 2015

*IDSN* Instituto Departamental de Salud de Nariño (Institute for Health of the Nariño Department), *PUEAA* plan de uso eficiente y ahorro de agua (plan for efficient water use), *EDA* enfermedad diarreica aguda (acute diarrheal diseases), *IRA* Infeccion respiratória aguda (acute respiratory infection), *AC, AL* Acueducto, Alcantarillado (Storm and waste water sewer)

presented a better level of MEM than other municipalities that manage their MEM through non-exclusive units.

Likewise, proposed indicators may relate to others that are frequently used at a national level, such as the Unsatisfied Basic Needs (UBN) index. This index seeks to determine if a population's basic needs are covered. Groups that do not reach a fixed minimum threshold are classified as poor (Departamento Administrativo Nacional de Estadística 2015). In this way, the UBN measures the percentage of population that lives in poverty. Therefore, one can verify the relation between the UBN and the MEM level in the Nariño Department, verifying that municipalities that have a high population percentage with high UBN have weak or intermediate MEM levels (Fig. 6).

The application of the model is presented in a ranking that gives prestige and credibility to the leaders and decision makers of municipalities with better indicators. This opportunity encourages municipal administrators to improve the municipality's environmental performance, which translates into credibility and political benefits. Furthermore, the development of local indicator systems will contribute to the monitoring and control of administrative instruments such as strategies, sectoral plans, territorial ordering plans of rural areas, etc. (Sotelo et al. 2011).

## 7 Discussion

The proposed model allowed us to identify municipalities facing significant weaknesses in their MEM as well as the most relevant aspects that determine it. Likewise, it was possible to identify the specific environmental problems of these municipalities and their regions. In the Nariño Department, these problems are related to wastewater management, quality and availability of drinking water, deforestation, solid residue management and loss of biodiversity.

### 7.1 Model Application for Evaluating MEM

During the model's application phase we were able to establish that most of the necessary data required to calculate indicators is available. However, in some cases, this information is not public or is unavailable at a regional scale. This is the case for the *Threatened flora and fauna species* indicators, whose data is published by CORPONARIÑO only at a Department level and it is necessary to discern data by municipality.

Another example is the *Total untreated domestic wastewater volume* and the *Annual contaminant load poured into bodies of water*. This data is available for all companies providing sanitation services and information can be used to calculate the wastewater tax rate. However, the data is not published. So, it would be beneficial that CDN request this information for their annual report. Likewise, it is necessary that national and regional level institutions place the largest amount of information possible, disaggregated by municipality, at the general public's disposal.

In spite of the lack of part of the information, it was possible to calculate 70% of selected indicators, allowing for the evaluation of the MEM in Nariño's municipalities. This evaluation constitutes a bench-marking instrument because municipal authorities can observe the best management results and learn from that interaction. In fact, the first application of the model was done with data from 2012. At that time, only one municipality out of 63 reached a good level of management ($> 0.65$). In 2013, two municipalities reached

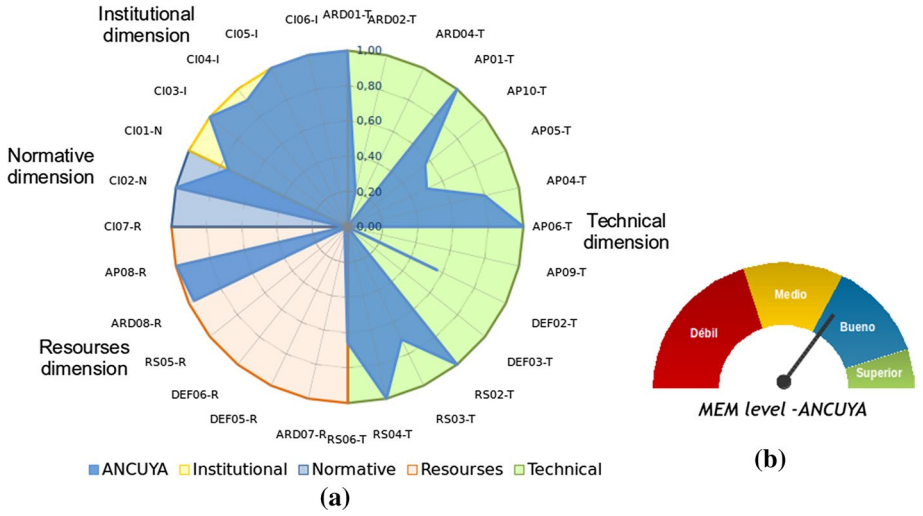


**Fig. 4** Ancuya's municipal indicators for environmental management

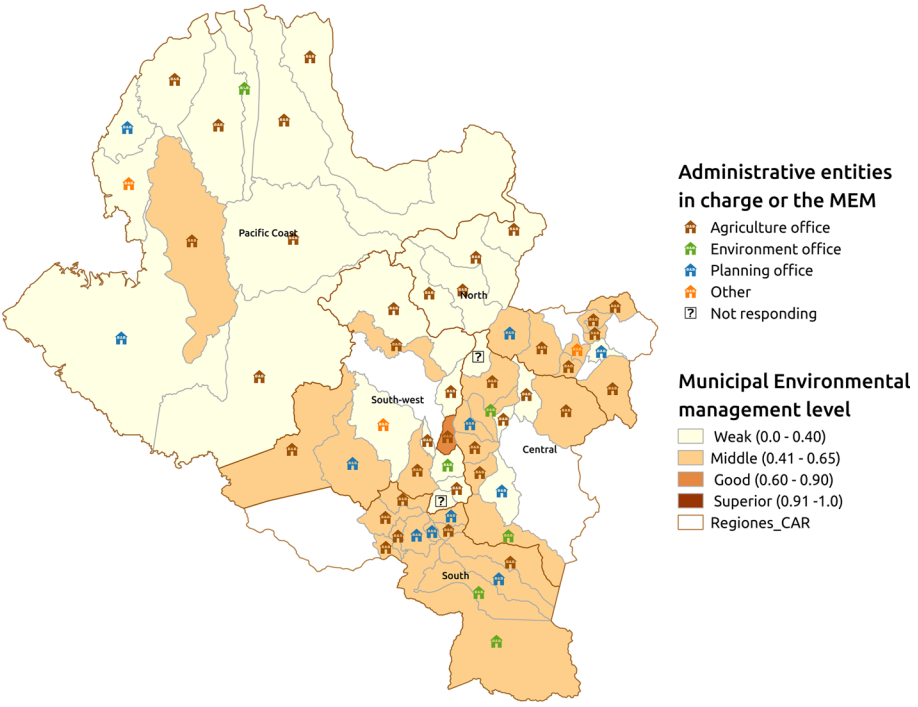


**Fig. 5** MEM level for Nariño municipalities—Colombia

the same level and in 2014 three municipalities presented a good level of management. This indicates that the model encourages decision makers to improve their performance in MEM, at least incipiently.

### 7.2 Structure of the Proposed Model

There is an apparent unbalance between the number of indicators within each dimension: Twenty-four (24) for the Technical, four (4) for the Institutional, nine (9) for the Resource and three (3) for the Normative dimension. This is explained by the fact that the SINA established that municipalities must have an executive function as well as coordinating regional and national policies and programs (Colombia 1993b). Therefore, the management of a municipality has a big technical component whose results are reflected in the state of the local environment.

Likewise, the reduced number of indicators in the *Normative* dimension is explained by the fact that legislative functions are under the jurisdiction of the central national level. Additionally, most control and monitoring functions are performed by the CAR, reducing the normative competence of municipalities.

In this sense, it is possible that a municipality obtain good results in the *Normative* and *Institutional* dimensions (adding up to 6 indicators), present a high level of MEM and yet have weaknesses in their *Technical* and *Resources* management. Said situation could be resolved by using weights that grant a more pertinent relative weight to the most relevant dimensions. Due to the participatory nature of the process, this step was not conducted. Further workshops would be necessary to introduce this change.

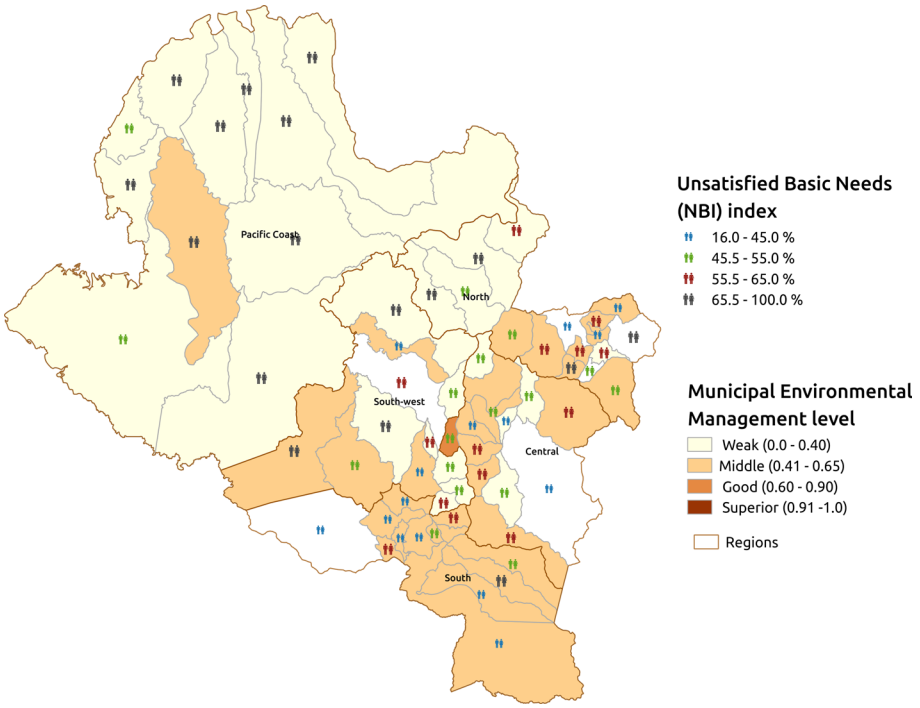


**Fig. 6** Relation between MEM level and unsatisfied basic needs index—UBN

## 8 Conclusions

This work describes the methods used for selecting MEM indicators based on a bottom-up participatory approach and in collaboration with several institutions. This methodology allowed to take the interested parties' vision into consideration and contributed to considering all important topics. 40 indicators were selected in order to permit the evaluation of the local entities' environmental management.

Selected indicators delve on topics related to waste water, drinking water, deforestation, solid residues, hazardous waste, loss of biodiversity and institutional capacity. These topics were considered the most important for the region of study, which has particular environmental and socio-economic characteristics and a specific problematic. However, the procedures used may be adapted for other localities with similar characteristics, adjusting the indicators to the environmental problems and local needs or even selecting new indicators.

The proposed indicator model presents the MEM evaluation through graphs and offers a panoramic view of relevant progress being made as well as highlighting problematic areas. This turns the model into a useful data analysis and presentation instrument for the State of the Natural Resources Annual Reports elaborated for CDN for the Department of Nariño. Additionally, it can contribute to solving dispersion, weakness, lack of available and comparable information problems identified by the Republic's General Comptroller (Contraloría General de la República 2010).

Likewise, local entities can utilize the model as an instrument for formulating and executing environmental management strategies. The model is also useful for knowing a municipality's environmental status, evaluate its own performance with concrete data points and monitor environmental goals and adverse tendencies.

Given the fact that the state of the environment is reflected on the MEM results, many of the formulated indicators are environmental indicators. These may form part of a larger system that permits the evaluation of the municipalities' sustainable development, which makes it necessary to complement the study with social and economic indicators.

Based on the adoption of the model by the CDN and the alliance between institutions and NGOs, they could move forward with the creation of an environmental management monitor and even one of sustainability that broadens participation and diffusion of results.

**Supplementary Information** Online participatory questionnaire available at: https://es.surveymonkey.com/r/MPQTF3F Last accessed July 31st 2015.

Results for the questionnaire are available at: https://es.surveymonkey.com/results/SM-DK6R6MYY/ Last accessed July 31st 2015.

Results of the application of indicators years 2012, 2013, 2014 and 2015 in: www.gestionambiental.udenar.edu.co.

## References

Atkinsson, A. (1996). Developing indicators of sustainable community: Lessons from sustainable Seatle. *Enviromental Impact Assessment Review, 16*(4–6), 337–350.

Bell, S., Morse, S., & Shah, R. (2012). Understanding stakeholder participation in research as part of sustainable development. *Journal of Environmental Management, 101,* 13–22.

Bluszcz, A. (2016). A comparative analysis of selected synthetic indicators of sustainability. *Procedia—Social and Behavioral Sciences, 220,* 40–50. https://doi.org/10.1016/j.sbspro.2016.05.467.

Bovea, M., Ibáñez-Forés, V., & Colomer-Mendoza, F. (2010). Environmental assessment of alternative municipal solid waste management strategies. *Waste Management, 30,* 2383–2395.

Colombia. (1993a). Ley 42 de 1993. Organización del sistema de control financiero, Colombia.

Colombia. (1993b). Ley 99 de1993. Ley Ambiental Colombiana, Colombia.
Contraloría General de la República. (2010). *Estado de los Recursos Naturales y del Ambiente 2009–2010. La sostenibilidad ambiental urbana: un reto para Colombia*, Bogotá, DC.
Coutinho, S. M. V., & Malheiros, T. F. (2013). Indicadores de sustentabilidade local: Caso de Ribeirão Pires—SP. In A. Philippi Jr. & T. F. Malheiros (Eds.), *Indicadores de sustentabilidade e gestão ambiental* (1st ed., pp. 189–222). Barueri: Manole.
Criollo, R. (2014). *Gestión Ambiental Municipal: Una propuesta de indicadores*. Universiadade de São Paulo. Retrieved October 17, 2016, from http://www.teses.usp.br/teses/disponiveis/18/18139/tde-08092015-150634/es.php.
Daams, M. N., & Veneri, P. (2017). Living near to attractive nature? A well-being indicator for ranking Dutch, Danish, and German functional urban areas. *Social Indicators Research*, *133*(2), 501–526. https://doi.org/10.1007/s11205-016-1375-5.
Dahl, A. L. (2012). Achievements and gaps in indicators for sustainability. *Ecological Indicators, 17,* 14–19. https://doi.org/10.1016/j.ecolind.2011.04.032.
Departamento Administrativo Nacional de Estadística. (2015). *Necesidades básicas insatisfechas*. Retrieved January 1, 2015, from http://www.dane.gov.co/index.php/estadisticas-sociales/necesidadesbasicas-insatisfechas-nbi.
Departamento Nacional de Planeación. (2015). *Tipologías Departamentales y Municipales: Una propuesta para comprender las entidades territoriales colombianas*. Bogota, DC. Retrieved February 1, 2016, from https://colaboracion.dnp.gov.co/CDT/DesarrolloTerritorial/Tip-FormatoPublicacion.pdf.
Duarte, C. G., Gaudreau, K., Gibson, R. B., & Malheiros, T. F. (2013). Sustainability assessment of sugarcane-ethanol production in Brazil: A case of sugarcane mill in São Paulo state. *Ecological Indicators, 30,* 119–129.
European Environment Agency. (2014). *Digest of EEA indicators 2014—EEA Technical report No 8/2014*. Retrieved December 17, 2017, from https://www.eea.europa.eu/publications/digest-of-eea-indicators-2014.
European Environment Agency. (2015). *The European environment—State and outlook 2015: Synthesis report*. Copenhagen.
Fraser, E., Dougill, A., Mabee, W., Reed, M., & McAlpine, P. (2006). Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management, 78,* 114–127.
Gibson, R., Hassan, S., Holtz, S., Tansey, J., & Whitelaw, G. (2005). *Sustainability assessment—Criteria and process* (Earthscan, Ed.), London.
Gómez-Limón, J., & Arriaza, M. (2011). La construcción de indicadores sintéticos de sostenibilidad agraria. In J. Gómez-Limón & M. Arriaza (Eds.), *Evaluación de la sostenibilidad de las explotaciones de olivar en Andalucía* (pp. 111–133). Málaga: Analistas Económicos de Andalucía.
Greene, K., & Tonjes, D. (2014). Quantitative assessments of municipal waste management systems: Using different indicators to compare and rank programs in New York State. *Waste Management, 34,* 825–836.
Gutiérrez, F., Barberena, V., Garay, L., & Ospina, J. (2010). In Fundación Konrad Adenauer en Colombia (Ed.), *25 años de la descentralización en Colombia*. Colombia. Retrieved June 12, 2014, from http://www.kas.de/wf/doc/23110-1442-4-30.pdf.
Hak, T., Kovanda, J., & Weinzettel, J. (2012). A method to assess the relevance of sustainability indicators: Application to the indicator set of the Czech Republic's Sustainable Development Strategy. *Ecological Indicators, 17,* 46–57. https://doi.org/10.1016/j.ecolind.2011.04.034.
Herva, M., Neto, B., & Roca, E. (2014). Environmental assessment of the integrated municipal solid waste management system in Porto. *Journal of Cleaner Production, 70,* 183–193.
Kostevšek, A., Petek, J., Čuček, L., & Pivec, A. (2013). Conceptual design of a municipal energy and environmental system as an efficient basis for advanced energy planning. *Energy, 60,* 148–158.
Malheiros, T. F., Philippi, A., Jr., & Coutinho, S. M. (2008). Agenda 21 nacional e indicadores de desenvolvimento sustentável: contexto brasileiro. *Saúde E Sociedade, 17*(1), 07–20.
Meadows, D. (1998). In T. S. Institute (Ed.), *Indicators and information systems for sustainable development: A report to the Balaton Group*. Hartland: The Sustainability Institute. Retrieved May 18, 2012, from http://donellameadows.org/archives/indicators-and-information-systems-for-sustainable-development/.
Petrosillo, I., De Marco, A., Botta, S., & Comoglio, C. (2012). EMAS in local authorities: Suitable indicators in adopting environmental management systems. *Ecological Indicators, 13*(1), 263–274.

Programa de las Naciones Unidas para el Medio Ambiente. Consorcio Parceria 21. (2008). *Metodología para la elaboración de informes GEO Ciudades: Manual de aplicación*. In Pnuma (Ed.), Ciudad de Panamá.

Quiroga, R. (2009). *Guía metodológica para desarrollar indicadores ambientales y de desarrollo sostenible. Serie Manuales No. 61*. In CEPAL (Ed.), Santiago de Chile.

Secretary of State for Environment Food and Rural Affairs. (2011). *The natural choice: Securing the value of nature,* United Kingdom.

Sotelo, J. A., Tolón, A., & Lastra, X. (2011). Indicators by and for sustainable development: A case study. *Estudios Geográficos, LXXII*(271), 611–654. https://doi.org/10.3989/estgeogr.201124.

Tayra, F., & Ribeiro, H. (2006). Modelos de indicadores de sustetabilidade: síntese e avaliação crítica das principais experiências. *Saúde E Sociedade, 15*(1), 84–95.

Torres-Delgado, A., & López, F. L. (2014). Measuring sustainable tourism at the municipal level. *Annals of Tourism Research, 49,* 122–137.

United Nations. (1992). *Agenda 21*. Retrieved March 22, 2017, from http://www.un-documents.net/agenda21.htm.

United Nations. (2015). *Objetivos de Desarrollo Sostenible, Colombia Herramientas de aproximación al contexto local*. Bogotá, DC. Retrieved March 22, 2017, from http://www.humanumcolombia.org/wp-content/uploads/2016/01/ODS-Colombia.compressed.pdf.

Universidad Nacional de Colombia. (2002a). *Guia de gestión administrativa para la aplicación del SIGAM*. In O. G. Editores (Ed.). Bogotá, DC: Ministerio de Medio Ambiente.

Universidad Nacional de Colombia. (2002b). *Propuesta organizacional Sistema de Gestión Ambiental Municipal SIGAM*. In O. Gráficas (Ed.). Bogotá, DC: Ministerio de Medio Ambiente.

Veleva, V., & Ellenbecker, M. (2001). Indicators of sustainable production: Framework and methodology. *Journal of Cleaner Production, 9,* 519–549.

World Health Organization. (2015). *Environmental health inequalities in Europe*. Copenhagen: World Health Organization.