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Multidimensional insalubrity analysis in N'Djamena: Capability approach based on fuzzy set

ONSOU KOBOBE

ZOUMAYE ZOUA

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Association Tchadienne pour la Réussite Environnementale
Quartier Amtoukoui . Cel (235) 62 97 72 30 Phone 22 74 28 51
Email: contact@atrenviro.org, Site web: www.atrenviro.org

ANALYSE DE L'INSALUBRITE MULTIDIMENSIONNELLE A N'DJAMENA : APPROCHE PAR LES CAPABILITÉS BASÉE SUR LES ENSEMBLES FLOUS

Kobobé Onsou
ATRENVIRO, OTRT
k.onsou@atrenviro.org

Zoumaye Zoua
ATRENVIRO
contact@atrenviro.org

Résumé

Le caractère multidimensionnel de l'insalubrité de l'environnement est encore de nos jours peu connu. Beaucoup d'études présentent l'insalubrité de l'habitat par l'approche par cotation. Le présent article porte sur l'insalubrité multidimensionnelle de l'environnement. Il présente le cadre théorique pour rendre opérationnel l'approche par les capabilités en se basant sur les ensembles flous. Le modèle est appliqué aux données d'enquête sur l'insalubrité de la ville N'Djamena et aboutit à un indicateur composite d'insalubrité permettant de classer les arrondissements de la ville. Les résultats obtenus montrent une plus grande contribution de l'insuffisance de collecte des ordures, de non-paiement des taxes, de l'intention de commettre l'acte d'insalubrité et du manque d'infrastructures publiques.

Mots clés: Insalubrité, capabilitiés, théorie des ensembles flous, atrenviro, arrondissement, N'Djamena.

MULTIDIMENSIONAL INSALUBRITY ANALYSIS IN N'DJAMENA: CAPABILITY APPROACH BASED ON THE FUZZY SETS

Abstract

The multidimensional nature of unhealthy environments is still little known today. Many studies have developed on unsafe habitat approach by rating. This article focuses on the multidimensional of unhealthy environments. It presents a theoretical framework to operationalize the capability approach based on fuzzy sets. The model is applied to survey data on insalubrity in the City N'Djamena and leads to an unhealthy composite indicator, to classify the districts of the city. The results show a larger contribution of inadequate garbage collection, non-payment of taxes, intent to commit insalubrity act and lack of public infrastructure.

***Key words*:** Insalubrity, capability approach, fuzzy sets theory, atrenviro, district, N'Djamena

Content

1. Introduction

The sanitation problem raises always many debates and work within the international institutions and became today one of the priorities. Since 2000, French Agency of Development (AFD) focuses its actions towards hygiene, sanitation and the availability of drinking water in many sub-Saharan African countries. According to World Health Organization (WHO), «the insalubrity of environment affects all factors which are not physical, chemical and biological exogenous and all non- related factors influencing behaviors. Environmental health aims to prevent environmental diseases and creates a health promoting environment". This definition excludes behaviors related to social and cultural backrounds, genetic factors and behaviors that are not related to the environment. It shows (WHO, 2010) that immediate environment insalubrity causes 13 million deaths in the world and appears to be the second cause of mortality among children below 5. Malaria, cholera and diarrheal diseases, typhoid fever, hepatitis, cancer, etc., are directly or indirectly related to unhealthy environments and now constitute an obstacle to the achievement of the Millennium Development Goals (MDG).

Spread over 1,284,000 km² with two-thirds desert and a population of approximately 11 millions in 2009 (INSEED[1], RGPH2), Chad is a Central African country, without access to the sea. In 2000, the gross domestic product (GDP) of Chad was dominated by agriculture and livestock. The exploitation of oil since 2003 has changed the situation. This country has experienced 30 years of civil wars causing the destruction of homes, property and an increase the number of displaced. The Human Development Index (UNDP, 2009) ranks Chad 175th out of 182 with an educational system in difficulty despite a remarkable growth of gross enrollment ratio. Like many African countries, Chad experiences since time immemorial problems related to the management and disposal of waste and lacks any sewer network. Poverty affects many Chadians. Some are unable to build toilets respecting the standards. General Census of Population and Housing (INSEED, 2009) shows that life expectancy is 52 years. In N'Djamena City, 1.9% of households use surface water as a source of water and only 19.6% have a tap at home. To note that in this city, 28.9% of households discharge their waste on roadsides, 34% in concessions, 51.1% discharge their wastewater in streets and 20.8% in concessions; garbage bins disposal by the municipality 15.5%.

Although insalubrity has been studied by many institutions, questions of measurement and approach used are rarely known in the literature. It is the purpose of this article to present a necessary methodological approach to the study and measurement of multidimensional insalubrity, thanks to the capability approach of Amartiya Sen, based on fuzzy sets. This article also reveals the behavior of the people of N'Djamena as regards insalubrity, reveals the factors largest contributors to insalubrity and ranks the districts of N'Djamena by insalubrity. In other words, we seek to implement the techniques commonly used for measuring poverty to measure insalubrity. The indicator that we seek to construct is still very little used in the research on insalubrity.

This document is based on the investigation of the unhealthiness of the city of N'Djamena directed by the Chadian Association for Environmental Achievement (ATRENVIRO, 2011) and is structured as follows. The next section presents the background study and literature review. In this section, we will review the different types of indicators to measure insalubrity. Section 3 is devoted to the methodology of a capability approach and its application on insalubrity. We will conclude and make recommendations in section 4.

[1] INSEED : Institut National de la Statistique, des Etudes Economiques et Démographiques.
RGPH : Recensement Général de la Population et de l'Habitat

2. Background Study

2.1. Motivation

Everyone knows today the impact of the survivals environment on the health of the population. N'Djamena experiences since time immemorial problems related to the place of deposit and collection of domestic garbage, the use of ponds and undeveloped spaces as places of defecation. Each year, many cases of cholera, typhoid fever, malaria, sinusitis, chronic cold, etc. are detected which are directly or indirectly related to the insalubrity of environment. Much of N'Djamena is flooded during the rainy season because of the inadequacy of drains pipe or pipes are closed. This flood causes in its turn the proliferation of mosquitoes which increase cases of malaria and mortality rate significantly. WHO shows that each year, 13 millions deaths could be prevented by improving the safety of the immediate environment.

RGPH (2009) shows that life expectancy is lower in N'Djamena than in other regions. This low life expectancy can be explained by the unhealthiness of the city. One can also see that between January and April, dust containing substance from garbage already decomposed, human waste, dried animal and other unhealthy substances blow into N'Djamena. The prohibition of the use of plastic bags by the Town Hall has not solved the problem of insalubrity of N'Djamena because some are visible at the places of deposit of garbage. In addition, few researchers are interested in the measurement of insalubrity compared to poverty.

2.2. Literature review

We distinguish in the literature two types of insalubrity: insalubrity of habitat that has been the subject of many studies, particularly in developed countries and insalubrity of environment that affects many developing countries. The insalubrity of the habitat refers to a certain number of parameters which can impact negatively on the health of inhabitants, for example the presence of moulds, the humidity of housing, the risk of exposure to lead, asbestos, risk related to the presence of radon, risk of contamination by carbon monoxide, the risk of falling, the risk of electrocution, etc. Measurement of the insalubrity of housing is performed by evaluating the risks after inspect the localites. This measurement is obtained through a score called dimension of insalubrity, which is obtained by calculating the relationship between the sum of the notes obtained and the maximum that this sum could reach (DGS/DGUHC/SD7c/IUH4 n°293, 2003). The value of this indicator lies between 0 and 1 and is an increasing function of the states of insalubrity of housing. The situation of insalubrity of housing differs according to whether one deals with slums, old houses, nonregulatory houses, etc. According to FIJALKOW (2010), one estimates at more than three million, the people inhabitants the over-populated residences, without comfort, dwellings of fortunes, etc So that this definition of measurement of the insalubrity of the habitat is bracket to the context of the countries in the process of development, it must entirely be to be revised, to be able to take into account the standard of living of the population, local, cultural realities (dignity, will, habit, etc).

The insalubrity of the environment as that of housing have negative impacts on the health of the man. According to the Guide of competences of the Mayor insalubrity disorder of vicinity (the Low-Rhine, 2007), insalubrity refers to the production of waste. According to the code of the environment, L541-1 Article, is defined like waste, “any residue of a production process, of transformation or of use, any substance, material, produced or more generally any given up personal property or than its holder intend for the abandonment”. Article L541-2, “Any person, who produces or holds waste under conditions likely to attack the health of the man and to the environment, is held to ensure some or to make some ensure elimination”. This code distinguishes two types of waste: comparable household wastes and the waste other than domestic and assimilated like the industrial waste, waste of activities of care, etc.

The question of measurement of insalubrity remains very little approached by the great institutions like the World Bank, Unicef, the UNDP, etc the definition of concept and of measurement of insalubrity can be delicate like that of poverty. Most of these institutions do not appreciate it in terms of insalubrity but rather in terms of access to cleansing. According to WHO (2009), more than 2 billions people do not

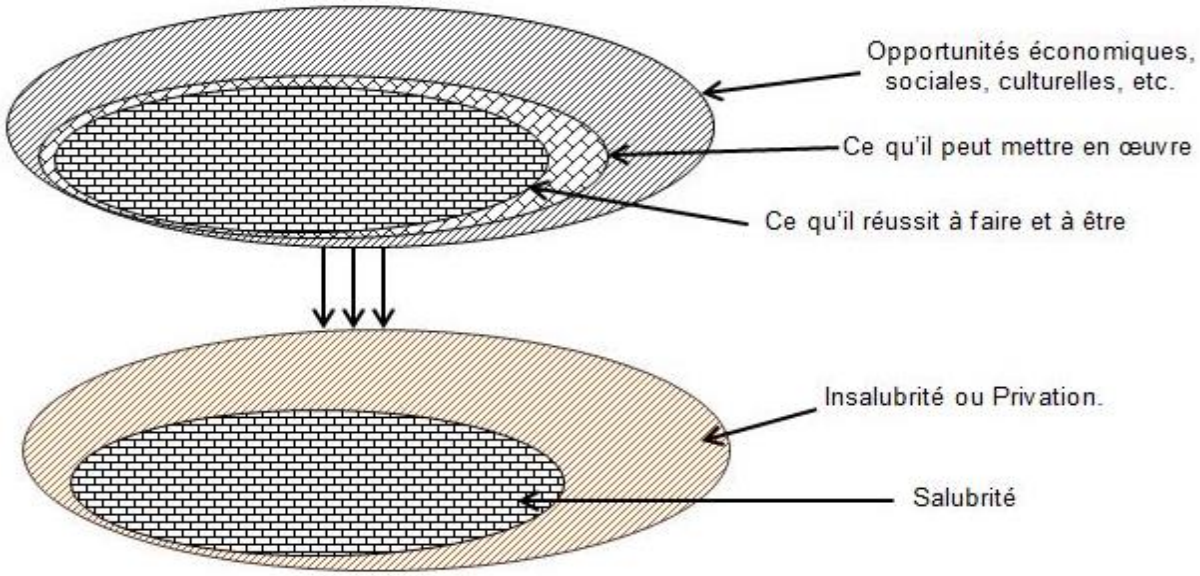
have access to an improved cleansing and nearly a billion people are still without access to an improved water supply, of which half live in African and in western Pacific unities. According to WHO, the fast population growth an obstacle to the improvement of the cleansing in many countries constitutes. In Chad, the access to cleansing evolves very slowly. Indeed, the rate of access to a cleansing improved was 5% in 1990 in Chad, 19% in urban environment compared with 1% in rural environment. In 2000, this rate is 7% for the worldwide with 21% for urban environment and 4% for rural environment, are an increase of 4 points for the nationwide in 16 years.

3. Insalubrity in the capability approach

3.1. Functionings and capabilities

SEN, in his works, was activated towards the economics of welfare, the theory of human development, famine and poverty and estimated that basic needs is not able to apprehend wellness. For him, wellness is to be well nourished, to be well placed, to be in good health, to be educated, to be housed adequately, etc. According to SEN, the type of life an individual aspirate to is a function of his capacities to combine all his physical assets, his opportunities social and economical, in other words, it is the freedom which a human being has to choose in the whole set of his functionings those which will enable him to satisfy what he awaits from his life. The capacities are the whole set of functionings which the population are able to implement. Functionings are the achievements of a person, i.e. what he succeeds in doing and being. They partly reflect the state of a person because it is the whole of the possibilities of states and actions of the people which enable them to benefit from the assets they have. The achievements are all functionings processes that a person succeeds in realising.

Graphic 1 : Relationship Functioning-Capability



The capability approach, inspired by the work of Sen, is defined by the capacity to reach functionings (Duclos and Araar , 2006), the capacity to function well (to be salubrious) within a society. This approach is difficult to make operational owing to the fact that certain concepts used are neither directly observable nor directly measurable (for example mental health). What could constitute the limit of this approach. It is one of the reasons which we chose the fuzzy sets. Other researchers on the

other hand, choose measurements of Alkire and Foster (2009) to operationalize the capability approach of SEN.

Within the framework of this study relating to the insalubrity of the town of N'Djamena, we will say that to be salubrious is to have a WC, to have the means of having a WC, of having a vat with refuse, to have the means of getting a waste vat, of not throwing the waste anywhere, of not defecating outside, etc. The situation of insalubrity is thus estimated as a function of these elementary acts. Within the space of functionings, insalubrity is perceived like a lack of realization of certain basic capacities, which guarantees to the individuals a salubrious immediate environment and making it possible to be in good health, and live without concern.

3.2. Methodology

3.2.1. Choice of fuzzy set approach

One often finds in the literature on insalubrity (in particular that of housing) an approach by quotation which is a linear combination of the various risks related to the dwelling of the housing and which can be called in other words score of insalubrity. The shortcomings of this approach are due to the fact that this indicator of measurement of insalubrity does not satisfy the property of decomposability into sub-dimensions and does not allow to know which dimension contributes more to insalubrity. While speaking about poverty, the insufficiencies of monetary approach (exclusively based on the income or consumption) to measure poverty led to new approaches, in particular the capability approach of SEN based on fuzzy sets, whose innovative character widens the concept of poverty to nonmonetary dimensions in order to know the multiple facets of poverty.

During the last thirty years, various methods of measurement were applied to different subjects. We can quote the methods resulting from the fuzzy set theory (Cérioli and Zani, 1990; Cheli and Lemmi, 1995), Analysis of the productive effectiveness (Lovell et al., 1994), axiomatic approach (Chakravarty, Mukherjee and Renade, 1998), information theory (Maassoumi, 1986 and 1999), as well as the methods of factor analysis whose application rests on the use of individual data coming from a census or an investigation into the living conditions of households.

The choice of the approach of fuzzy sets would be justified by its multidimensional character. This approach operationalizes the capability approach of Amartya SEN and enriches it. We point out that the objective of this paper is to classify the districts of N'Djamena by cleanliness. Thus, we will seek to draw up the profile of the insalubrity of N'Djamena by using the capability approach developed by SEN (1985, 1987). The advantage of this latter approach is to allow us to determine the ratio of insalubrity without a threshold and to decompose the indicator into sub dimensions making it possible to know which factors contribute more to insalubrity.

3.2.2. Fuzzy sets and membership function

3.2.2.1. Definition of a fuzzy set

Let X be a set, x of an element X and μ_A application to the X set in the closed interval [0,1]. A subset of X defined by $A = \{ x, \mu_A(x) \}$ is called membership function of x in the fuzzy set A. So each subset A of X is characterized by a membership function which maps μ_A from each point x of X a real number in the interval [0, 1]. The value of $\mu_A(x)$ represents the degree of belonging of the element x to set A. Formally, if A is a regular set, the membership function associated with it can take only the values 0 and 1. So we have:

$$(1) \qquad \mu_A(x) = \begin{cases} 1, & if\ x \in A \\ 0, & otherwise \end{cases}$$

In this case, the membership of an element to an ordinary set is well-known because it can take values 0 or 1. An intermediate value $\mu_A(x)$ between 0 and 1 denotes a certain non-membership of x to A. More the value of $\mu_A(x)$ is close to 1, more the degree of membership of x to A is raised.

We apply the same procedure to define a fuzzy subset of unhealthy. If N is the total number of households (or individuals), a fuzzy subset I of N is defined by the pair $I = \{i, \mu_A(i)\}, i = 1, \ldots, n$, where $\mu_I(i)$ the degree of membership for each household i in the fuzzy set unhealthy.

According to the definition of $\mu_I(i)$, three cases arise:

- $\mu_I(i) = 0$ if household i is absolutely not unhealthy .
- $\mu_I(i) = 1$ if household i belongs unequivocally to the subset unhealthy .
- $0 < \mu_I(i) < 1$ if household i may not belong to the subset unhealthy .

The definition of μ_I membership function is the subject of the following section.

3.2.2.2. Membership function

To analyze the conditions of households insalubrity, it is necessary to proceed to a wise choice of indicators. It is a question of evaluating the degree of membership of each individual or househould into the fuzzy subset of the unhealthy ones. These indicators can be made as well of quantitative variables as of qualitative variables.

- **Discrete Variables**

In the case of discrete variables, we have two situations: dichotomic variables and polytomic variables. For dichotomic variables, the set I is an ordinary set and the definition of function of membership is specified in the previous section. Polytomic variables present several modalities, each one of them corresponding to a certain state of insalubrity. These modalities can be ordered by decreasing or increasing risk of insalubrity. Among these variables (for example, lack of waste vats, the non-payment of taxes on waste, the fact of pouring waste water on the roads, etc.) one can take for example the variable showing subjective perception that the households have of their own situation. Let us suppose that these modalities can be arranged by increasing risk of insalubrity. The possible values can be then, *Very salubrious*, *Rather salubrious*, *Salubrious*, *Rather unhealthy* and V*ery unhealthy*.

Let us consider moreover than these modalities are ordered in such a way that the ascending values of the superscript indicate a stressing of the state or act of insalubrity. According to the specification of Cerioli and Zani (1990), it is possible to assign scores $\varphi_j^{(l)}$, $l = 1, \ldots, m$ to the various methods. The relation between these various scores perhaps represented by: $\varphi_j^{(1)} < \cdots < \varphi_j^{(l)} < \cdots < \varphi_j^{(m)}$. In most case, these scores are defined using m first integers : $\varphi_j^{(l)} = l$ $(l = 1, \ldots, m)$. Being given the ordinal nature of the qualitative variable, it is possible to choose a method in a sufficiently favorable state to exclude insalubrity or to choose a method indicating a situation of insalubrity clearly. If $\varphi_j^{(min)}$ and $\varphi_j^{(max)}$ are the scores corresponding to the two limits, then the function of membership suggested by Cerioli and Zani (1990) is the following one:

$$(2) \qquad \mu_{I_j}(i) = \begin{cases} 0, & if\ \varphi_{ij} \leq \varphi_j^{(min)} \\ \dfrac{\varphi_{ij} - \varphi_j^{(min)}}{\varphi_j^{(max)} - \varphi_j^{(min)}}, & if\ \varphi_j^{(min)} < \varphi_{ij} < \varphi_j^{(max)} \\ 1, & if\ \varphi_{ij} \geq \varphi_j^{(max)} \end{cases}$$

- **Continuous variables**

Among the indicators of insalubrity represented by continuous variables, one finds expenditures on purchase of refuse vats, expenditures of purchase of equipment of cleaning, taxes, etc. But the problem of the specification of threshold arises. It led certain authors to propose alternative methods with the problem of specification of the threshold. For example, in analysis of poverty, Kakwani (1995) focuses on uncertainty related to the specification of the threshold and proposes to use the coefficient of deprivation to measure this one. This approach leads to the definition of a new class of measurements. In the line, Atkinson (1987) and Foster and Shorrocks (1988) underline the impossibility of determining a single poverty line and propose an ordinal approach related to stochastic predominance. These methods establish a supposed interval to contain the poverty line. By adopting a similar approach, Cerioli and Zani (1990) propose to establish two thresholds; the first x_{min} corresponds to the value of continuous variables selected like indicator of insalubrity below which any individual or household may be considered without hesitation as unhealthy; the second noted x_{max}, corresponds to the value of the variable chosen above which an individual or a household is judged incontestably nonunhealthy. For the values of the variable ranging between these two thresholds, the function of membership takes its values in the interval [0, 1]. For variables such as the income or the expenditure for which an increase translates an improvement in the situation of wellness into terms of payment of taxes or purchases of refuse vats, the function of membership is continuous and decreasing. Moreover, by supposing that the risk of insalubrity varies in a linear way between the two thresholds x_{min} and x_{max}, Cerioli and Zani (1990) propose to define the function of membership in the following way:

$$(3) \qquad \mu_{I_j}(i) = \begin{cases} 1, & if \;\; 0 \leq x_{ij} \leq x_j^{(min)} \\ \dfrac{x_j^{(max)} - x_{ij}}{x_j^{(max)} - x_j^{(min)}}, & if \;\; x_j^{(min)} < x_{ij} < x_j^{(max)} \\ 0, & if \;\; x_{ij} \geq x_j^{(max)} \end{cases}$$

It is generally acknowledged the only condition to be satisfied by a function with membership is to take its values in an interval ranging between 0 and 1. The function of membership can thus take several forms other than those presented and depends on the context to which it refers and of the type of indicator that one wishes to describe (Chiappero-Martinetti, 2000). Some authors tried to improve or generalize the functions of membership suggested by Cerioli and Zani (1990). Cheli and Lemmi (1995) qualify their approach of Completely Fuzzy and Relative. This last approach avoids us using a threshold of insalubrity. Moreover, it can be used for an analysis of insalubrity from the multidimensional point of view starting from various types of indicators for states or acts for insalubrity as presented in this document. Thus, for the case of continuous variables for example, Cheli and Lemmi (1995) define the function of membership in two manners. If the risk of insalubrity would increase with an increase in the value taken by the variable continues x_j, the function of membership is written: $\mu_{I_j}(i) = H_j(x_{ij})$. While if the risk of insalubrity increases with a reduction in the value taken by the variable x_j, the function of membership is written: $\mu_{I_j}(i) = 1 - H_j(x_{ij})$.

These functions are defined by taking into account of the relative position of each individual compared to the whole of the individuals. This specification of Cheli and Lemmi (1995), contrary to that of Cerioli and Zani (1990), is based according to the two authors on a theoretical basis (because of its coherence with the concept of relative insalubrity) and on an empirical checking (owing to the fact that $H_j(x_{ij})$ is estimated on a basis of the sample).

Further in the document, we choose the formulation of Cheli and Lemmi (1995), which free us from an arbitrary choice. As we announced previously, the latter is not free from reproach. As we had indicated in the part concerning the definition of the function of membership, when it is about a dichotomic

discrete variable (binary), the set D_j is not a fuzzy set because the function of membership makes it possible to know unambiguous if a household i is in situation of insalubrity or not.

3.2.3. Calculating the ratio of insalubrity

The fuzzy set theory appears to provide the capability approach a rigorous empirical support for the application of a multidimensional analysis of poverty in terms of functioning[2]. It is even for the analysis of insalubrity. The construction of fuzzy measures rests on four essential[3] steps. Let $X = (X_1,\ldots, X_m)$ representing a vector of m attributes of economic variables, demographic, social, cultural, political, etc.. and $A = \{a_1, \ldots, a_n\}$ a population of n households.

Step 1: Population insalubrity

Costa (2002) defines the set of poor as follows: "The subset of poor Households includes any $a_i \in B$ which presents some degree of poverty in at least one of the m attributes of X." We define the set I of the unhealthy ones as follows: "*The subset of the insalubrity households includes any $a_i \in I$ which presents some degree of insalubrity in at least one of m attributes of X".* In other words, a household is unhealthy, $a_i \in I$, if it is unhealthy in at least one dimension. The second step will allow to calculate the degree of insalubrity per attribute.

Step 2: Degree of membership in the set I

The advantage of the fuzzy theory is to allocate a gradual transition between the situation of poor sanitation and healthiness. It is no required to classify the population by salubrity and insalubrity but consider intermediate situations may be interpreted as a degree of insalubrity or risk of insalubrity. Thus, in an attribute j, the degree of membership of I (the whole of unhealthy) takes values ranging between 0 and 1. As we announced above, we privilege TFR approach (Tottaly Fuzzy and Relative). TFR measurements depend on the whole distribution of the index of insalubrity. Cheli and Lemmi (1995) propose a specification of the function of membership reflecting a nonlinear relation monotonous between X_j and $\mu_i(X_j)$, which means that it depends on the distribution of the indicator X_j and not only of the extreme values.

If $X_j^{(k)}, k = 1, \ldots, K$ represents the variable of order applied to X_j classified by increasing risk of insalubrity ($X_j^{(1)}$ is lowest risk of insalubrity), if $F_j(.)$ is the function of distribution of X_j, if $f_j(.)$ is the function density which associates with each X_j the corresponding relative frequency, specification TFR takes the following shape for a continuous variable X_j: $\mu_i(X_j^{(i)}) = F_j(x_{ij})$ if the risk of deprivation increases with the value taken by the X_j variable. While, if the risk of deprivation increases with a reduction in the value taken by the variable X_j, the function of membership is written $\mu_i(X_j) = 1 - F_j(x_{ij})$.

$$(4) \qquad \mu_i\left(X_j^{(k)}\right) = \begin{cases} 0, & si\ X_{i,j} = X_j^{(1)} \\ \mu_i\left(X_j^{(k-1)}\right) + \dfrac{F_j\left(X_j^{(k)}\right) - F_j\left(X_j^{(k-1)}\right)}{1 - f_j\left(X_j^{(1)}\right)}, & si\ X_{i,j} = X_j^{(k)}; k > 1 \end{cases}$$

Which makes it possible to have

$$(5) \qquad \mu_i\left(X_j^{(k)}\right) = \frac{F_j\left(X_j^{(k)}\right) - f_j\left(X_j^{(1)}\right)}{1 - f_j\left(X_j^{(1)}\right)}, \forall X_{i,j} = X_j^{(k)};\ k = 1, \ldots, K$$

[2] Lardechi (1999) ; Chiappero Martinetti (2000)

[3] Dagum et Costa (2002) ; Costa (2002)

This shows that the TFR measures capture two essential elements in all the analysis of insalubrity. Initially, the influence of the social context is given by the position of the individual in the distribution of the indicator X_j. Then, the significance of insalubrity is deduced through the relative frequency from the unhealthy population in terms from X_j.

Step 3: Ratio of insalubrity household

The ratio of insalubrity of a household a_i is expresses like a balanced sum of the relative degrees of membership:

$$(6) \qquad \mu_I(a_i) = \sum_{j=1}^{m} w_j \ \mu_i(X_j)$$

With w_j the weight of attribute j et $w_j = \ln(1/V_j)/\sum_{j=1}^{m} \ln(1/V_j) \ \ with\, V_j = \frac{1}{n}\sum_{i=1}^{n} \mu_i(X_j)$.

According to Lelli (2000), social context and beliefs of the researcher may influence the choice of the weighting. In this study, we choose the following weighting (7) which is a standard weight and allows to take into account the sampling effect:

$$(7) \qquad w_j = \frac{V_j}{\sum_{j=1}^{m} V_j}, \ \ with \ V_i = \frac{1}{n}\sum_{i=1}^{n} \mu_i(X_j^{(i)})$$

Step 4: Aggregation: Insalubrity Ratio

Once the ratios of insalubrity of households a_i $(i = 1, \dots, n)$ is calculated, the measurement of total insalubrity is obtained by aggregation. It is also expressed in the form of a weighted average of unidimensional insalubrities:

$$(8) \qquad I = \frac{1}{n} \sum_{i=1}^{n} \mu_I(a_i) = \frac{1}{n} \sum_{i=1}^{n}\sum_{j=1}^{m} w_j \ \mu_i(X_j)$$

The indicator of insalubrity is a balanced sum of the indicators of the attributes; but the ratio of insalubrity is the simple average of the indicator of insalubrity. This measurement of insalubrity makes it possible to make adequate comparisons in time and between various populations.

3.3. Applications

We apply the capability approach to survey data carried out by ATRENVIRO in N'Djamena in 2011 within the framework of its activities. To operationalize the fuzzy set theory, the choice of the list of relevant dimensions and the elementary indicators, the determination of the state of insalubrity on each indicator and the aggregation of dimensions represent the various stages which raise a certain number of difficulties, which are the object of the following points.

3.3.1. Choice of dimensions

Although the problem of exhaustiveness often arises with the risk of redundant dimensions and the risk of missing important dimensions, several answers to these difficulties were suggested in the literature in other fields that insalubrity. The choice of dimensions of insalubrity has a considerable influence on the indicator of insalubrity which depends more or less on each one of these dimensions. It is therefore necessary to proceed to careful choice to have an indicator whose relevance and validity would not be questioned. We wondered about the factors which can have direct effects on insalubrity

in N'Djamena. While referring to local realities, with the results of the descriptive study of the insalubrity of the town of N'Djamena which we do not present here and while basing ourselves on the literature on insalubrity, we retained six groups of variables which are: point of deposit of waste, collection and the payment of the taxation on waste, the toilets, the visibility and the odors of waste, public infrastructures and the intention to make the act of insalubrity. The variables setting up a group are supposed to apprehend same reality. For example, the variables *deposit of waste in the course*, *deposit of waste to the front*, *deposit of waste in enjoy*, etc are gathered in the discharge points of waste.

3.3.2. Validity of dimensions

In the literature, several tests of validity exist. Mention may be made, for example, of factor analysis techniques in order to eliminate variables that are poorly represented on the first factorial axis, control mechanisms such as frequency, social consensus... that justify the inclusion or exclusion of a sub attribute. Before carrying out the construction of the indicator we sought to know if selected dimensions are valid. With this intention, we carried out a test of validity within each group of under-dimensions. This internal validity was evaluated by the means as of frequencies of the variables, the correlations (linear simple) between these variables and the calculation of the **Cronbach's** coefficients[4]. Variables low frequency or zero frequency, as those which are not correlated with the others within the same group were removed. After having validated the variables, we allotted values to some of them and recoded others, in order to express clearly the states of insalubrity. This stage is followed of that of the determination of the degree of membership of the individuals to the fuzzy set and the aggregation of the fuzzy sets. Within the framework of this study, we use the dichotomic method to express the membership or not in a state of insalubrity. The use of this method is justified by the fact that the polytomic variables are not ordinal. Table 1 presents dimensions selected and the values taken by these dimensions.

Table 2 shows the relationship between the different dimensions of insalubrity. A low correlation between attributes proves that each dimension measures another significant aspect of the unhealthiness. On the other hand there is a slightly higher correlation between μ_2 and μ_5 : the collection and disposal of waste is actually related to the presence of public infrastructure. The weak correlation between μ and μ_3 highlights the omission of important sub-dimensions related to lavatories. Alpha control stata software easy to obtain Cronbach worth 0.67 for dimensions.

[4] The Cronbach used to assess the consistency or internal consistency of an evaluation instrument composed by a set of items which should help to understand the same reality. For example, as regards the place of deposit of waste, we have the variables deposit of waste in the yard, deposit of waste in ponds, deposit of waste front, and deposit of waste in the gutters... Whether these variables actually measure the same thing, we used Cronbach . This is an index that reflects the degree of internal consistency within an even more its value is close to unity group. In practice, a coefficient greater than or equal to 0.6 is satisfactory. This coefficient is calculated using the following formula : $\alpha = \frac{k}{k-1}\left[1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_T^2}\right]$, with k the total number of items in the instrument group, σ_T^2 the variance of the instrument as a whole, σ_i^2 the variance of item i. It is shown that the Cronbach is: $\alpha = \frac{k * \rho_m}{1+(k-1) * \rho_m}$, où ρ_m is where the average coefficient of correlation between all the pairs of items . For k items , then $\frac{k(k-1)}{2}$ correlation coefficients.

Table 1 : Functioning and associated indicators

Dimensions	Components	Types	Conditions of insalubrity
Point of deposit of waste	Existence of public dustbins built in the district	Binary 0/1	No = 1
	Deposit of waste in the courtyard	-	Yes = 1
	Deposit of waste in the front of the house	-	-
	Deposit of waste in ponds	-	-
	Deposit of waste in the gutters	-	-
	Deposit of waste in non-made-up spaces	-	-
	Deposit of waste at the edge of the road	-	-
Collection and payment of taxes	Service of collection of waste in the district	Binary 0/1	No = 1
	Possession of the waste vats	-	-
	Payment of taxation waste	-	-
	Collection of the waste is well organized in the district	-	-
Toilets	Provision of a WC	Binary 0/1	No = 1
Visibility and odors of waste	Scattering of waste everywhere in the district	Binary 0/1	Yes = 1
	Deposit of refuse in the vats	-	No = 1
	Standar nauseous odor	-	Yes = 1
	Prickly nauseous odor	-	-
	Gutters of the district are stopped by the waste	-	-
	Gutters of the district are stopped by soil	-	-
Public infrastructures	Gutters are built in the district	Binary 0/1	No = 1
	Gutters are closed in the district	-	-
	Existence of roads bituminized in the district	-	-
	Existence of ponds in the district	-	Yes = 1
	Existence of spaces non made-up in the district	-	-
	Enclavement of the district during the rain season	-	-
The intent to make an act of insalubrity	Throw the waste anywhere	Binary 0/1	Yes = 1

Table 2 : Index of linear correlation between measurements of dimensions

	μ_1[5]	μ_2	μ_3	μ_4	μ_5	μ_6	μ
μ_1	1						
μ_2	0,249	1					
μ_3	-0,018	0,0478	1				
μ_4	0,2403	0,1318	-0,0004	1			
μ_5	0,2144	0,5421	-0,0033	0,0771	1		
μ_6	0,1451	0,2212	-0,0248	0,2101	0,2499	1	
μ	0,4536	0,6875	0,0118	0,4379	0,6665	0,7478	1

[5] μ_1 : Measuring the dimension Places deposit of waste; μ_2 : Measure of *Collection and Payment of the taxation of the refuse;* μ_3 : *Toilets;* μ_4 : *Visibility and odors of waste;* μ_5 : *Public Infrastructure;* μ_6 : *Intent to commit the insalubrity act ;* μ_6 : Measure all dimensions unhealthy

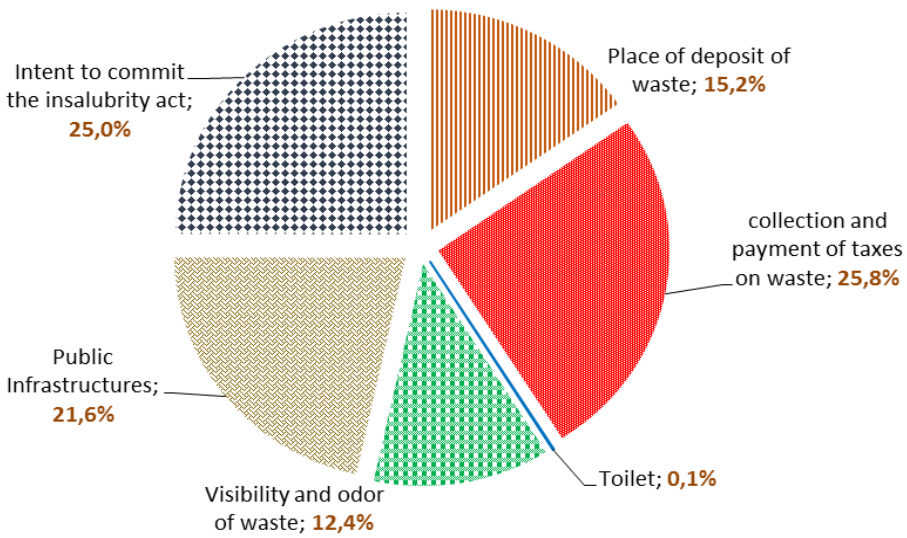
3.3.3. Insalubrity ratio

The number and types of attributes are based on the information contained in the database and literature review. Each attribute is allowed to measure a certain degree of insalubrity different from the others. Table 3 presents the ratios of insalubrity by attribute in N'Djamena. These indicators are obtained from the formula (7) and (8). The analysis of this table shows that the degree of insalubrity of N'Djamena is 63.6%. It is observed that deprivation (unhealthy) in terms of the collection and payment of taxes on waste and intent to commit the insalubrity act are the most factor in the city of N'Djamena (respectively 72,3% and 71.2%) . The lack of infrastructure is in third place with a rate of deprivation of 66%. Deprivation in the less importante is the disposition of toilet (Only 4% of the population is private). This low proportion is justified that in N'Djamena over 95 % of the population have toilets.

Table 3 : Insalubrity by dimension

Dimensions Xj	weighting	Insalubrity
X_j	W_j %	P_j %
Point of deposit of waste	17,4	55,7
Collection and payment of taxes	22,6	72,3
Toilets	1,3	4,0
Visibility and odors of waste	15,7	50,1
Public Infrastructure	20,7	66,2
Intent to commit an insalubrity act	22,3	71,2
Total	100,0	63,6

Graphic 2 : Contribution of dimensions to the total insalubrity



The fuzzy set theory is used to calculate the contribution of each attribute to the overall unhealthiness. The contribution of attribute j is given by the formula:

$$(9) \qquad CTR_j = \frac{w_j I_j}{\sum_{j=1}^{J} w_j I_j}$$

The graph 2 shows that the dominant attribute in N'Djamena attribute is the collection and payment of taxes on waste with a contribution of 26% to the total insalubrity, followed by the intent to commit an insalubrity act (25%) and the absence of public infrastructure (22%).

The analysis of the indicator of insalubrity according to the districts allows us to know the situation of insalubrity of each district compared to the others. In view of these results, it is seen that the most unhealthy district of N'Djamena is the 10th district, followed by 7th district, 9th district (Graphic 3). It will be noticed that these are the districts which hold the highest rates of insalubrity in collection and payment of the taxes and also in intention to make an act of insalubrity.

Graphic 3 : Insalubrity and districts

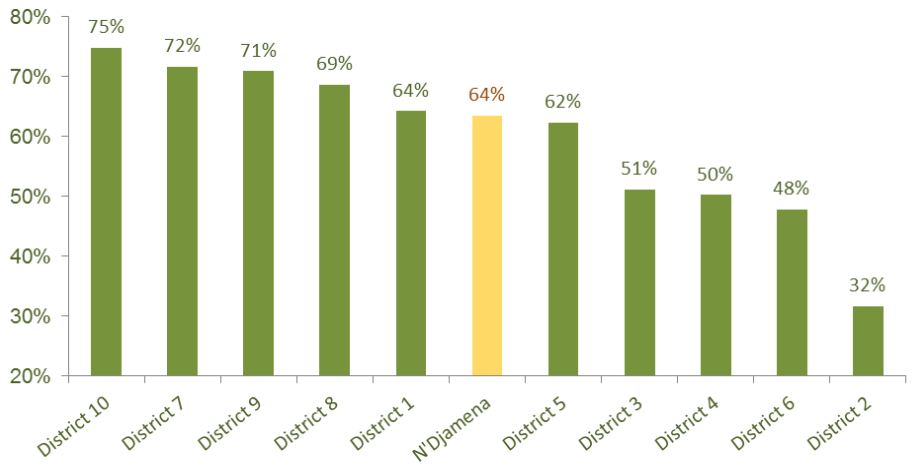


Table 4 : Quintile of insalubrity per districts

Districts (en %)	Higher healthiness	High healthiness	Standard healthiness	Low healthiness	poor healthiness	Total
Districts 1	14,7	21,2	28,8	26,3	9,0	100
Districts 2	83,2	16,0	0,8	0,0	0,0	100
Districts 3	41,9	20,9	26,7	9,3	1,2	100
Districts 4	41,2	36,0	14,9	6,1	1,8	100
Districts 5	21,2	18,9	24,5	22,6	12,7	100
Districts 6	45,8	29,2	21,9	3,1	0,0	100
Districts 7	4,3	14,9	26,2	30,2	24,5	100
Districts 8	13,5	19,0	17,6	16,3	33,6	100
Districts 9	5,7	24,5	14,5	25,2	30,2	100
Districts 10	2,6	15,5	12,9	29,0	40,0	100

The analysis of insalubrity following quintiles allows us to refine the analysis and to know in which district there is the most salubrious individuals and those with poor healthiness. The five quintiles of insalubrity form a partition of all households (or concessions) in five equal proportions (20%) while going form the lowest scale (poor health) to the top of the scale (health). Population's greater safety is more likely in the second district (83%), followed by the 6th district (46%) and the 3rd and 4th districts (respectively 42 and 41%). The proportion of households with poor health is less than 15 % from the 1st to the 6th districts. The proportion of individuals experiencing higher safety is well below 10% in districts 7, 9 and 10. The rate of poor health is less than 2 % in districts 2, 6 and 4.

4. Conclusion

The purpose of this research was to provide a multidimensional analysis of insalubrity. This work is a continuation of the work of SEN and provides a simpler methodological approach as for the application of the set theory to make operational the capability approach. These last are the whole of opportunities which an individual lays out. Insalubrity is perceived here as the lack of realization of necessary functionings. Non- collection and non-payment of taxes on waste, intent to commit an insalubrity act and the absence of public infrastructures are factors that influence significantly the insalubrity of N'Djamena City. Districts N° 10, 7, 9, and 8 are those most unhealthy and are peripheral districts. Thus, the Mayor should focus on garbage collection, encourage households to pay taxes on garbage, educate people for a radical change of mentality, develop roads, ponds, undeveloped areas… This will reduce flooding, incidence of malaria, typhoid and garbage collection will be done easily in any season.

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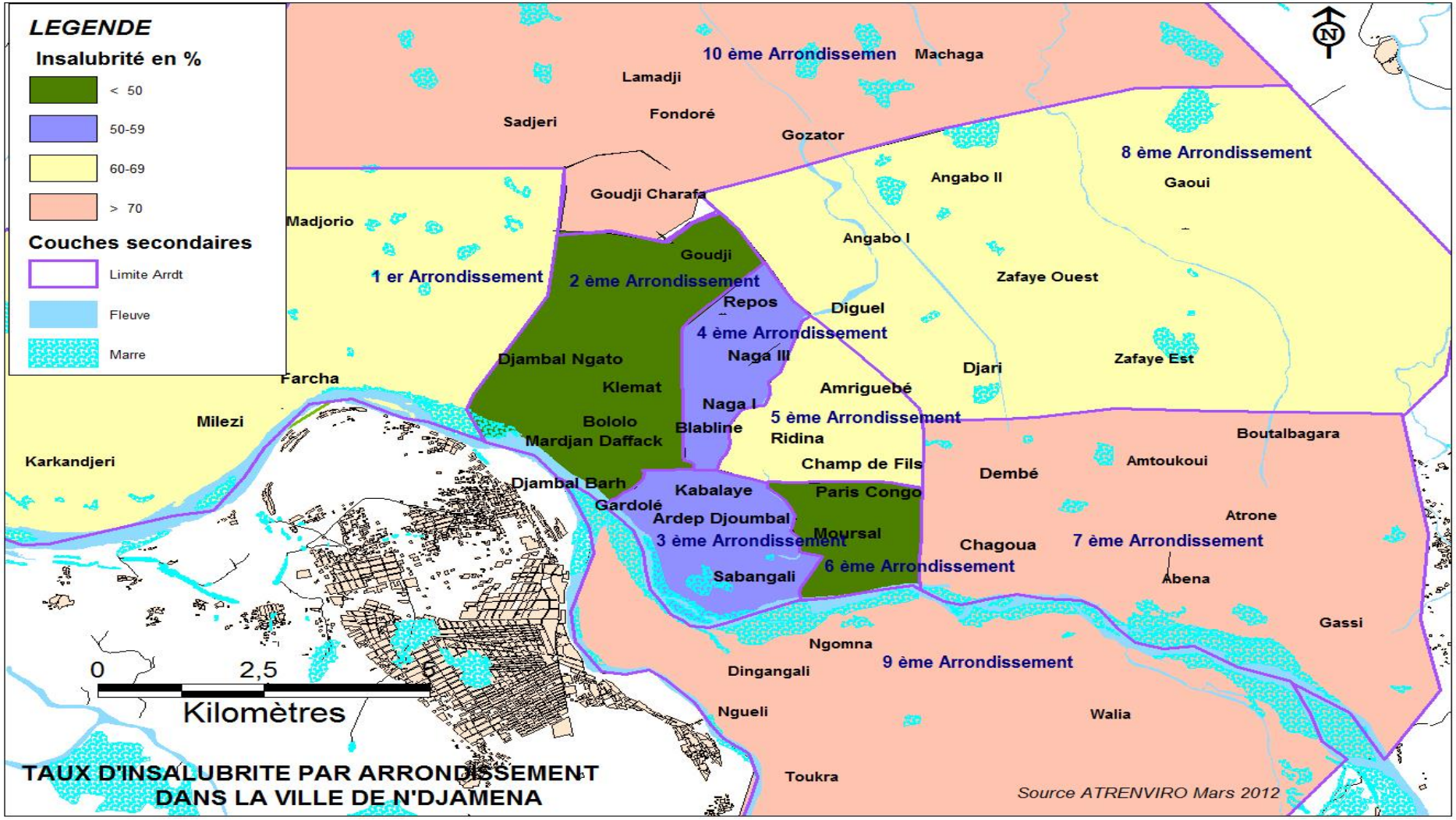
Annexe

Table 5: Population of N'Djamena City

N'Djamena	RGPH 2009			Estimation				
	Homme	Femme	Total	2 010	2 011	2 012	2 013	2 014
1er Arrondissement	39 665	35 538	75 203	77 760	80 404	83 137	85 964	88 887
2ème Arrondissement	32 518	26 742	59 260	61 275	63 358	65 512	67 740	70 043
3ème Arrondissement	22 713	18 215	40 928	42 320	43 758	45 246	46 785	48 375
4ème Arrondissement	40 086	31 981	72 067	74 517	77 051	79 671	82 379	85 180
5ème Arrondissement	54 313	46 635	100 948	104 380	107 929	111 599	115 393	119 316
6ème Arrondissement	23 464	22 036	45 500	47 047	48 647	50 301	52 011	53 779
7ème Arrondissement	116 218	107 013	223 231	230 821	238 669	246 784	255 174	263 850
8ème Arrondissement	98 804	85 837	184 641	190 919	197 410	204 122	211 062	218 238
9ème Arrondissement	39 302	36 291	75 593	78 163	80 821	83 569	86 410	89 348
10ème Arrondissement	39 135	34 912	74 047	76 565	79 168	81 859	84 643	87 521
Total	506 218	445 200	951 418	983 766	1 017 214	1 051 800	1 087 561	1 124 538

Graphic 4 : Map of insalubrity of N'Djamena



Association Tchadienne pour la Réussite Environnementale
Quartier Amtoukoui . Cel (235) 62 97 72 30 Phone 22 74 28 51
Email: contact@atrenviro.org, Site web: www.atrenviro.org