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Urban Sustainability in Arid Climates: Challenges for Antofagasta, Chile

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Abstract: Urban sustainability is one of the most important challenges for the new century. In arid climates urban development is even more sensitive to resources use and environmental pollution. In northern regions of Chile, mining industry influences urban development policies, resulting in many cases in a lack of legacy on environmental issues. In this paper the case of Antofagasta is studied, considering the following items: water usage, air and soil pollution, climate change, acoustic and light contamination. A critical revision of Antofagasta master plan shows that environmental challenges have to be considered to address sustainable development towards a family-friendly and healthy city, a place where people would like to live and work.

Keywords: urban sustainability, arid climates, environmental pollution

1. Introduction

Antofagasta is a fast-growing city that leads on the Pacific Ocean in the Northern Atacama Desert of Chile. Inhabitants were 250.000 in 1990, last available data (2012) present 384.000 and future projections estimate 450.000 by 2020. Main economic activity of the zone is mining activity, which means that city has a lot of pollution problems: air, soil and water show high levels of arsenic; noise level doe to construction and cars is often up to 80 dB during all the day; light pollution has also be detected and discussed as first disturbance of sky observation (very close to the city leads one of the most important observatory in the world). In this work a diagnostic of the city is done and a proposal

to assess urban sustainability is briefly presented. Results could be applied to other cities with similar climate (coast desert) and economic activity (mining).

2. State of Antofagasta city

Degradation process of the environment in Antofagasta has been detected many years ago, and many researches have been focused on this topic, like detected in the recently published study of the Organization for Economic Cooperation and Development (OECD) [1]. Social life was also affected by environmental changes and mass-media has largely occupied of related issues (see for example articles of local journal "El Mercurio" [2], [3]).

2.1. Water usage

Antofagasta water supply is in 50% of sea water (desalted) and in other 50% is obtained by rivers from the Bolivian mountains. This part is very highly contaminated by arsenic [4] and has to be treated before to be used as potable water. Mining industry is clearly responsible of the most part of this contamination. Arsenic water contamination has been detected as one of the probable factors in causing cancers in northern Chile [5]. Black and grey water is simply put into the Ocean, 50 meters from the coast. Rain water usage (it rains very infrequently) is not considered at all.

2.2. Soil and air pollution

As water, soil and air show in Antofagasta high levels of pollutants [6]: arsenic is the most dangerous, but levels of CO_2 generated by transportation and energy production (thermoelectric) are also to be considered. The national system of public health describes Antofagasta as one of the cities with the highest levels of metal particles that could combine with CO_2 in generating cancers and other illnesses [7].

2.3. Climate change and heat island effect

Antofagasta climate is nowadays very temperate, with averages temperatures of 20 degrees and low variability due to the sea thermal inertia. However, climate change will affect this situation drastically: temperatures are expected to rise up to 6 degrees to the end of the century [8]. Thermal comfort will also be affected, both in the street and inside of buildings. Phenomenon is self-increasing: the more the cooling demand, the more the electricity consumption, the more the global warming. Heat island effect could be other problem in near future, especially considering the business as usual scenario for real estate sector [9].

2.4 Acoustic and light pollution

Light pollution of Antofagasta is other relevant problem. It has been detected that night lightening of the city streets is disturbing the sky observation of the Cerro Paranal observatory, one of the most important of the world [10], [11]. Urban noise is also an important factor to be considered in assessing quality of life. In Antofagasta, no regulation is present and noise level are many time higher than recommended. Main cause of noise pollution is the building construction, but also traffic noise is intense.

3. Towards sustainability challenge

Antofagasta is a city that is suffering environmental pollution under all possible points of view. This is a direct consequence of industrial development and urban transformation without planning and considerations about sustainability and public health. OECD reports as strategies to improve the environmental performance of the city the following:

- to recover the waterfront of the city
- to promote compact urban development
- to guarantee economical founding to local development
- to socialize environmental problems with large public of inhabitants
- to implement an efficient public transportation system
- to generate a recover system for solid waste
- to generate water treatments in order to guarantee recommended levels of pollutants
- to reduce drastically levels of pollutants

Other recommendation of OECD is the creation of an Institute of Urban Study, which would be responsible of controlling and regulating urban development under interdisciplinary statements. Local Institutions, Universities, Government, Foundations, etc. should be united in the effort to improve life condition in one of the richer cities of the entire country. However, it appears difficult to decide which action should be undertaken first, because of a lack in evaluation processes of sustainable development. One of the first challenges for this Institute should be the assessment of Antofagasta urban metabolism, vulnerability and resilience. All mentioned above factors, could be related to an indicator of efficiency suitable for policy developers, city planners and in general for the community. In order to compose the indicator, a fuzzy logic calculation is required, as proposed by Acebillo et al. [12]. Construction of an indicator that could be used in sustainability challenge means that each considered aspect has to be parameterized with these characteristics:

- each parameter has to be dimensionless
- each parameter could assume values between 0 and 1 (0 = no pollution, 1 = high pollution)
- each parameter has to be weighted by experts respect to its influence on final result

Then, indicator have to use a strategy to consider good results in each aspect to be globally good, that is, to incorporate logic operator AND to construct global value. In the case of two parameters: first indicator is I_1 and α_1 is the weight, second indicator is I_2 and α_2 is its weight. Then, 4 cases could appear: either I_1 and I_2 could be medium (between 0.2 and 0.8) or small (less than 0.2), one of them could be medium or small or both could be high (more than 0.8).

- IF I_1 is not high AND I_2 is not high, then pollution value should be $\alpha_1 I_1 + \alpha_2 I_2$
- IF I_1 is not high AND I_2 is high, then pollution value should be I_2
- IF I_1 is high AND I_2 is not high, then pollution value should be I_1
- IF I_1 is high AND I_2 is high, then pollution value should be 1

4. Pollution indicator construction

An example of how indicator could work is done for 6 aspects: metal particulate pollution in the air (2.5 μ and 10 μ), NO_X and SO_X pollution in the air, As pollution in water, waste production. Weight assigned to each indicator results from bibliographical analysis that indicates PM_{10}, As and residuals as most important aspects to be considered because of their impact on human health. Table 1 resumes detected values for Antofagasta by the National System of Air Quality Information (SIMCA) and by OECD. Maximum values are obtained by WHO recommendation (PM and As) [13] or are the maximum value for Chileans cities (SO_X and NO_X). Residuals production was compared with average production for many world countries estimated by OECD.

Table 1. Parameter values, indicator and weight for considered aspects

Parameter	Antofagasta value	Maximum value	Indicator value	Weight
$PM_{2.5}$ air pollution ($\mu g/m^3$)	13	35	0.40	0.1
PM_{10} air pollution ($\mu g/m^3$)	42	70	0.65	0.2
SO_X air pollution (ton/year)	1200	164380	0.02	0.1
NO_X air pollution (ton/year)	300	10528	0.08	0.1
Arsenic in drinking water (g/dm^3)	30	10	1	0.3
Residuals (kg/person year)	341	720	0.48	0.2

Calculation of the indicator shows that the presence of the value “1” for As water pollution leads immediately to a global pollution evaluation “1”. This fact indicates to policymakers that first aspect to be approached is As in water reduction. If As in water indicator is reduced to 0.8 (that is, As concentration in drinking water under 8 g/dm^3), indicator calculation starts using the weighted average and final indicator decreases to 0.52. Then, actuations on other aspects start to influence the final result.

5. Conclusion and future work

This indicator could be used to test the relevance of future interventions: if one strategy reduces only one parameter value, its impact on global pollution indicator will be low, whilst if one strategy (or a combination of strategies conforming a scenario) reduces many parameters, then its impact on global indicator will be high.

The example of a "general pollution" indicator could be improved considering more general indicators, like "metabolic efficiency", "quality of life" or "global sustainability" indicator. Then, global strategies could be defined to help urban planning in life quality assessment and proposal.

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. OECD Territorial Reviews: Antofagasta: Chile 2013
2. El Mercurio de Antofagasta, http://www.mercurioantofagasta.cl/impresa/2014/08/27/full/4/
3. El Mercurio de Antofagasta, http://www.mercurioantofagasta.cl/impresa/2014/07/28/full/2/
4. Smedley, P., Kinniburgh, D. "A review of the source, behaviour and distribution of arsenic in natural waters." *Applied Geochemistry* **2002,** 17 (5), pp. 517-568
5. Ferreccio, C. *et al.* "Lung Cancer and Arsenic Concentrations in Drinking Water in Chile." *Epidemiology* **2010** 11 (6), pp. 673-679
6. Flynn, H. "Assessment of bioavailable arsenic and copper in soils and sediments from the Antofagasta region of northern Chile" *Science of the Total Environment* **2002**, 283 (1-3), pp. 51-59
7. Valdés J. *et al*. "Metal contents in coastal waters of San Jorge Bay, Antofagasta, northern Chile: a base line for establishing seawater quality guidelines." *Environmental Monitoring and Assessment* **2011**, 183 (1-4), pp. 231-242
8. Chilean Government "Plan Nacional de Adaptación al Cambio Climático." Available on line (in spanish): http://www.mma.gob.cl/1304/articles-55412_PlanNacionalAdaptacionCClimatico.pdf (Accessed on august 2014)
9. Palme, M., Guerra, J. "A Critical Assessment and Projection of Urban Vertical Growth in Antofagasta, Chile." *Sustainability* **2013**, 5 (7), pp. 2840-2855
10. Jacques M. Beckers. "Estimating the effects of nitrate mining activities on the astronomical site quality of the Cerro Paranal Observatory", Proc. SPIE 2199, Advanced Technology Optical Telescopes V, 817 (June 1, 1994); doi:10.1117/12.176253
11. Riddle, R. *et al.* "An analysis of light pollution at the Thirty Meter Telescope candidate sites." Proc. SPIE 7012, Ground-based and Airborne Telescopes II, 08/2008
12. Acebillo, J. "*A new urban metabolism*". iCUP ed., Mendrisio, CH., 2012.
13. World Health Organization. "*Air Quality Guidelines".* Available on line: http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/
14. Antofagasta Region. National System of Quality Air Information (SINCA) http://sinca.mma.gob.cl/index.php/region/index/id/II