Integral restoration of river basins using sustainable technologies: The Moravia Hill, Medellín - Colombia

Restauration intégrale des bassins hydrographiques en utilisant des technologies durables : la colline Moravie, Medellín (Colombie)

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RÉSUMÉ

Medellin est la deuxième ville de Colombie (2 223 078 habitants) et la capitale du département d'Antioquia, située dans la partie nord-ouest de la Colombie. Au cours des trois dernières décennies, Medellin a souffert d'une violence élevée et des activités liées au trafic de drogue. Cette situation a provoqué l'exode rural en direction des villes et l'implantation de populations dans des lieux insalubres, tels que la colline de la Moravia, une ancienne décharge.
La colline de la Moravia était utilisée comme décharge entre 1972 et 1984. Avec le temps, la quantité de déchets a augmenté et les activités de recyclage dans ce secteur ont déterminé l'arrivée massive et l'installation en toute illégalité de personnes travaillant dans le recyclage des matériaux. La proximité de la station locale de transport public a également constitué un facteur non négligeable dans l'augmentation de la population fuyant la violence dans les zones rurales.
Plusieurs études faites sur la colline de la Moravia ont identifié un haut risque géotechnique, une forte pollution chimique (gaz toxiques et lixiviats), et l'insalubrité environnementale et hygiénique de la zone. Au vu de la situation sur la colline de la Moravia, il est prévu d'utiliser des technologies durables pour le traitement des lixiviats et la gestion des eaux de ruissellement.
La situation dans la Colline de la Moravia a motivé la participation active de plusieurs institutions nationales et internationales, publiques et privées, notamment des agences espagnoles de coopération internationale. Ainsi, ce projet fait partie d'un plus grand projet appelé «macro-projet Moravia», visant un seul et même objectif : réussir l'intégration de la Moravia au sein de la société de Medellin dans le nouveau siècle.

ABSTRACT

Medellin is the second most populated city in Colombia (2223,078 inhabitants) and is the capital of the Antioquia department, located in the northwest part of the country. During the last three decades, Medellin has suffered from elevated rates of violence and drug trafficking activities. This situation caused people's migration from the rural areas to the city and their establishment in places not suitable for living like the Moravia Hill, an old garbage dump.
The Moravia Hill was used as a landfill between 1972 and 1984. With time, the amount of waste was growing up, and recycling activities in the area caused the invasion and the illegal settlement of people dedicated to the materials recycling. The proximity to the interurban bus station was also a key point to increase the settlement of people who had been displaced by violence from the rural areas.
Several studies made in the Moravia Hill determined that there were high geotechnical risks, chemical pollution (by toxic gases and leachate), and non-compliance with minimum environmental and health conditions to live in. Due to the conditions in the Moravia Hill, sustainable technologies are going to be used to treat leachate and to manage the run-off water.
The situation in the Morro Hill has motivated the active participation of several national and international public and private institutions, especially from the Spanish International Cooperation Agency. So, this project is part of a bigger one called "The Moravia Macro Project", sharing a common goal: to succeed in the integration of Moravia into the social and urban transformation of Medellin that has taken place within recent years.

KEYWORDS

Buffer strip, constructed wetland, developing countries, leachate, sustainable technologies.

1. Introduction

Medellin is the second most populated city in Colombia with 2214,494 inhabitants (DANE, 2005) and is the capital of the Antioquia department, an administrative regional unit located in the Northwest part of the country. Historically, Medellin has suffered from elevated rates of violence and drug trafficking activities. This situation caused people's migration from the rural areas to the city and their establishment in places not suitable for living, like the Moravia Hill o "Morro de Moravia", an old landfill.

The Moravia Hill is an alluvial area located in the north-eastern slope of Medellin (*see* Figure 1). Between 1972 and 1984 it was used as a landfill where around 100 tons of wastes were dumped each day. With time, informal recycling activities allowed the illegal establishment of recyclers. The proximity to the local bus station contributed to increase the settlement of people who had been displaced by violence from the rural areas.

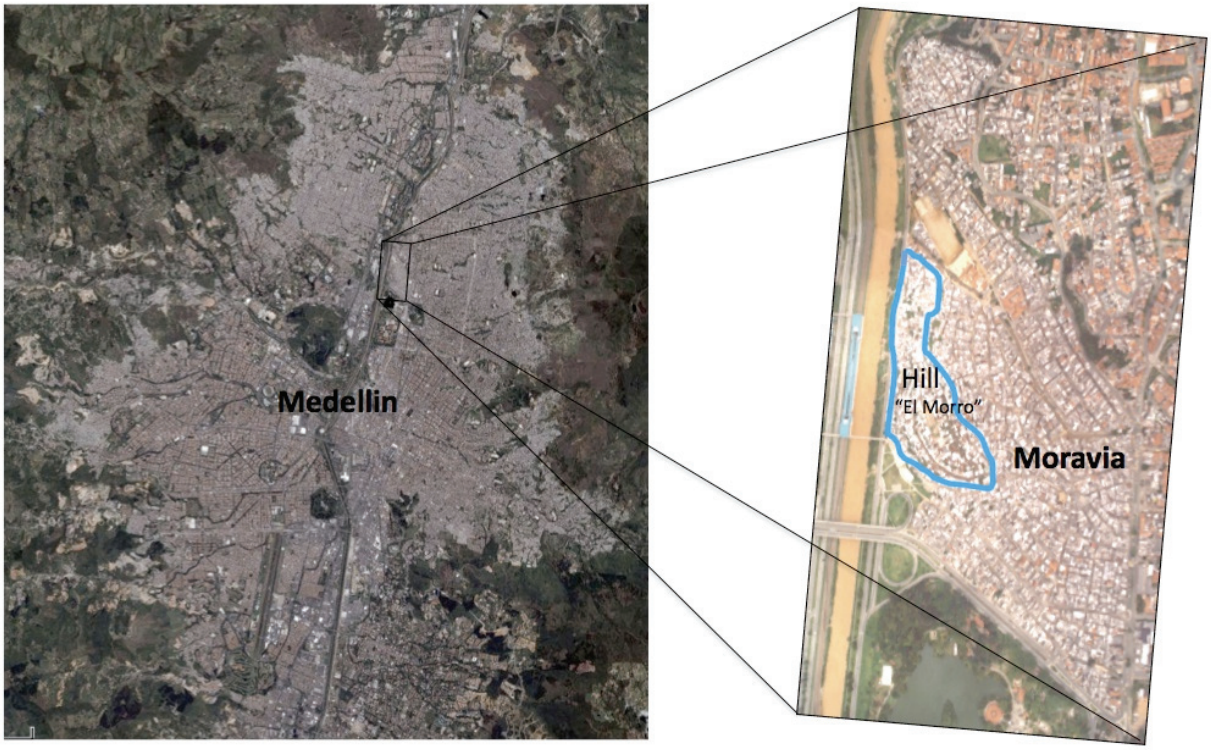

Figure 1. Moravia district and Moravia Hill location.

Between the 80's and the 90's, people occupied all of the empty space in the landfill. In 2004, the Moravia Hill had a population of 10000 inhabitants settled in a 7,6 Ha of land. Over 35 m high garbage hill, 2224 families lived in severe overcrowding conditions (*see* Figure 2).

Several studies made in the Moravia Hill, established that the area does not meet the minimum environmental and health requirements for a residential place. In summary, there were high geotechnical and chemical risks due to the presence of toxic gases such as sulphur, benzene and cyanide, and leachate with chromium and lead.

Figure 2. Unstable housing built with reject materials.

Therefore, an environmental and sanitary management plan to mitigate the existing problem was adopted. It aimed at:

- Restoring polluted areas.
- Decreasing public health risks of chemical and microbiological pollutants.
- Improving the environmental and socio-economic situation of the population, by selecting and applying efficient and effective technologies for pollutants removal.

2. METHODOLOGY

Solutions and technologies description. Currently there is an unfit management of wastewater and rainwater in the Moravia Hill, by the inadequate sewer systems to dispose wastes. The different discharges and pollutants from different sources present in the garbage dump and the infiltration of precipitation and the migration of water through the water distribution system produced a leachate containing a high concentration of organic material, nutrients, pathogens and heavy metals.

There are several physical, chemical and biological processes that can be employed to treat landfill leachate, but for developing countries they can be expensive to construct and to operate (Sawaittayothin & Polprasert, 2006). Therefore, low-cost alternatives like constructed wetlands and buffer strips, known as natural systems, are better suited to deal with pollutant removal in such conditions. Technologies to treat contaminated sites through planting trees are emerging worldwide (USEPA, 1998; Westphal & Isebrands, 2001), and are designed to take advantage of the physical, chemical and biological processes that occur in the natural environment when water, soil, plants, microorganisms and the atmosphere interact (Metcalf & Eddy, 2003).

Due to the scarcity of wastewater collecting systems, the rainwater infiltrations raise the volume of generated leachate. The leachate analysis showed that this fluid has the typical organoleptic characteristics of a leachate coming from a mature landfill, with high organic mass, heavy metals, dark colour and penetrating smell.

In the Moravia Hill, these sustainable technologies are being used to treat leachate, buffer strips for on-site phytoremediation and constructed wetlands for final treatment of surface water runoff. The buffer strip in the Moravia Hill is constituted by a strip of planted trees, shrubs and grasses along its hillside, between the contaminant source and constructed wetlands. In such situation, the vegetated

buffer would act as a green filter in order to improve the water quality through the biodegradation, trapping and filtration of nutrients and other pollutants, and by slowing down runoff. Moreover, the buffer strip help reducing the speed of runoff, stabilizing the slope and, as a consequence of high evapotranspiration and rainwater interception, reducing the amount of leachate generated.

One demonstration treatment plant of 300 square meters is being built since late 2009, in the lower part of the slope (Figure 3). Previously, an experiment trial was conducted in a subsurface flow constructed wetland pilot plant (2x1 m.) at the University of Antioquia (UdeA). Total heterotrophic bacteria, COD, and the other usual physic-chemical control parameters were determined.

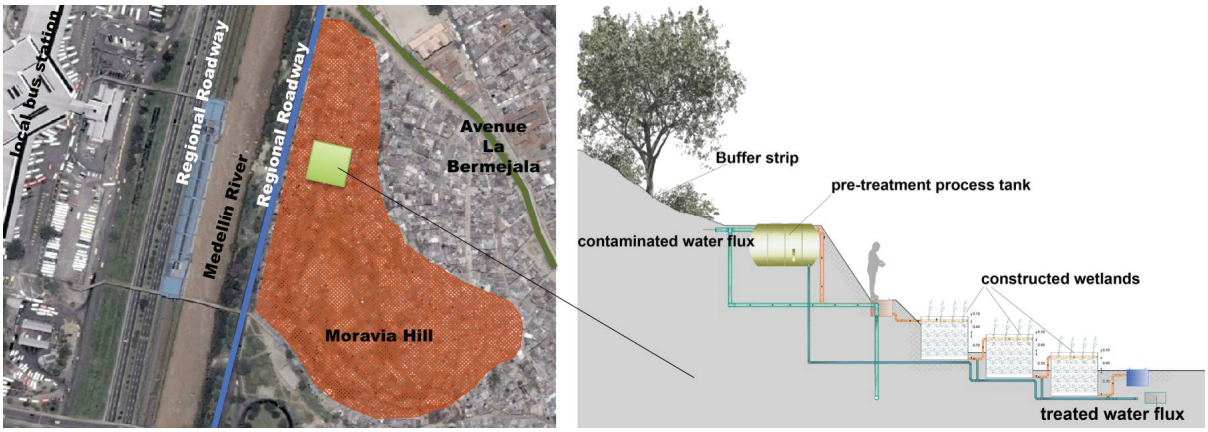

Figure 3. Buffer strips and constructed wetland localization.

With the proposed design, the research group wants to experiment with different conditions, like the effect of the buffer width, the phytoremediation capability of endemic plants and its adaptability to the leachate, in order to improve the key design aspects.

2.1 Sustainable criteria adopted to solve the problem. The main sustainable criteria adopted to solve the Moravia Hill issue are as follows:

- **Maintenance of health.** Stimulates the equality to health access giving the population opportunity to have social and environmental development. The main objective would be the eradication of several diseases (flu, diarrhoea, malnutrition and intoxication, among others).
- **Conservation and maintenance of soil and water resources**. Stimulates and encompass the protection of soil against erosion, leaching, compacting and depletion, and the protection of water against pollution in the Moravia Hill.
- **Maintenance and enhancement socio-economic benefits for the society.** Stimulates and compasses the socio-economic input for employment, recreation activities and tourism, research and development, cultural, social and spiritual values and needs, and the Moravia Hill requirements.
- **Environmental conservation and sustainable management**. Stimulates and evaluates the capacity to carry out research and development aiming at ensuring sustainability, including laws, regulations, guidelines and economic framework support to ensure the conservation and sustainable management of the Moravia Hill.
- **Social reconstruction of the Moravia Hill.** Stimulates the community strengths and provides them with the required elements for pacific coexistence, violence eradication, self-management and development of sports and recreation activities.

3. RESULTS

The studies made in the Moravia Hill area between 1999 and 2005, by consultant companies and government agencies (Environmental and Social Development Departments) concluded that:

- The Moravia Hill has high geotechnical risks **because of the unplanned urbanization process and the own nature of the site**.
- There are elevated risks for public health by chemical pollution **because of the presence of toxic gases as sulphur, benzene and cyanide, and leachate with chromium and lead**.
- The area does not satisfy the minimum environmental and health conditions to live in.

Based on the mentioned studies, in 2006 the Moravia Hill was declared as a **Public Calamity Site** and it was decided to relocate the population who at that time lived in the area. It was also decided to formulate, in short and medium term, an environmental and sanitary management plan to mitigate the existent problem.

The relocation of the population to more suitable areas has improved the quality of life of the Moravia population. Until today, 1414 families have been relocated to new housing. In addition, the mortality rate due to scarce health services, repeating intestinal problems and damages because of soil collapse, has decreased significantly.

The pilot treatment plant at the Universidad de Antioquia was used as an essential tool to find the main aspects for operational function. At the end of the experiment, it was determined that 1/8 to 1/4 in. (fine gravel) were the most appropriate sizes of the gravel for the leachate treatment. The results showed that the best pH level to precipitate the heavy metals in the pre-treatment process is 8,5. With the subsurface flow constructed wetland pilot plant, the objective was to arrive to an 80% removal of the pollutant load of the leachate as COD. The demonstration plant was recently finished, and the first results will be processed to assess the efficiency of the natural treatment.

4. CONCLUSIONS

The restoration of the Moravia Hill is going to be possible through the articulation of the different key stakeholders. Sustainable water management involves the need for a greater participation of the various stakeholders. In the definition of sustainable solutions to environmentally treat the area and to help the population, the leader institutions actively promote participation of the local community.

This represents a huge revolutionary process under the framework of the urban transformation in Medellín, in which local institutions, stakeholders and international cooperation agencies play an important role, working to act as a catalyst to maximize the community benefits and to generate scientific and technologic knowledge between multidisciplinary groups.

The integration of the Moravia Hill as a public space would be a worldwide experience about landfills management and social adaptation. The active participation of the involved institutions is aiming at maximizing the community benefits in terms of social, academic, cultural, economic and environmental benefits. The objective is to integrate them into the society, as well as to generate knowledge through scientific and technologic collaboration between multidisciplinary groups of Spain, Colombia and from other Latin American countries.

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