Wastewater technologies in Latin American and the Caribbean countries

J.M. Morgan-Sagastume*, A.J. Padilla, L. Romero-Casallas, L.P Güereca, M. Cisneros-Ortìz, A. Musharrafie, F. Hernández, A. Noyola.

Instituto de Ingeniería, Universidad Nacional Autónoma de México, Ciudad Universitaria, Distrito Federal CP 04510, México.

*Corresponding author: Juan Manuel Morgan Sagastume (jmms@pumas.iingen.unam.mx)

Abstract

This paper presents a technology review in six countries of Latin America and the Caribbean (LAC) which are the result of the analysis taking into account a large number of flow ranges and types of treatment technologies. Additionally, the legislations of the countries of the region are analyzed. The most representative technologies according to the sample analyzed for LAC countries are stabilization ponds, activated sludge processes, upflow anaerobic sludge blanket reactors (UASB) and trickling filters, with an average flow capacity of; 13 l/s, 70 l/s, 618 l/s and 5,800 l/s, for the following arbitrary flow classification: 0-25 l/s, 25-250 l/s, 250- 2,500 l/s and >2,500 l/s respectively.

Keywords

Wastewater, treatment technologies, Latin America.

Introduction

In the countries of Latin America and the Caribbean (LAC) region, growing population pressure on water supply has exceeded, in most cases, the ability of governments to achieve planned urban growth. As a result, priority has been given to water services and sewage, so that the treatment of wastewater and solid waste disposal has lagged (Moscoso and Egocheaga, 2002).

This is confirmed by Fernandez (2006), who established that LAC has a coverage of 85% of potable water supply, while PHAO (2001) notes that only 15% of collected wastewater is treated. On the other hand, Pardon (2005) mentions that in LAC, 77.7% of the population have sanitation services, considering sewage services or *in situ* treatment and disposal).

In order to improve this situation, there have been several international initiatives, among which the one presented in September 2000 at the Assembly of the United Nations (UN): the Millennium Development Goals (MDGs) (UN, 2000) whose goal number 7 seeks to ensure environmental sustainability, and thus establishes various targets, of which number 10 raises the commitment to "Halve the proportion of people without sustainable access to safe drinking water and sanitation by 2015 "and number 11 " Achieve by 2020 a significant increase in quality of life of at least 100 million people in marginalized areas ".

According to the above, the indicator of the Joint Monitoring Program of the UN establish that LAC should increase coverage of sanitation services from 77% for 2004 to 85% for the year 2015, which in turn implies increased demand on infrastructure systems (sewage). Even if wastewater treatment facilities are not explicitly mentioned, it is a necessary part of the sanitation system and should be considered in the sector planning and investments.

Based on the foregoing, it is imperative to develop and implement new solutions, fill the gaps of existing infrastructure for wastewater management, with new administrative and technological systems that should consider the limitations and conditions of the region, offering innovation and adaptation over conventional solutions (Noyola, 2003).

Existing water systems were initially designed for hygiene and sanitation reasons; however, given the need to achieve long-term sustainability, the objectives of urban water systems need to go beyond the protection of public health and receiving bodies. It is necessary to reduce the impacts to natural resources, to optimize the use of energy and water, reduce waste generation and allow nutrients recycling in plants (Lundin *et al*., 2000). Selection of a particular wastewater treatment technology should not be based primarily on technical insight (Helen, 2008) , but should also be the result of the integration of technological, economic, social and environmental activities that surround it, seeking as far as possible, the potential reuse of treated wastewater (Bernal, 2003).

This paper presents the first stage of a research project which consists of identifying the most used wastewater treatment technologies tbased on a sample of LAC countries, as well as the definition of the most representative flow rates and a comparative analysis of the legislation of selected countries in the region.

Methodology

Selection of treatment technologies and wastewater capacities

The selection of countries representing LAC was based on comparative analysis according to the sanitation coverage. A sample of six countries were selected to represent the entire LAC, the methodology followed was based on “Regional Report on the Evaluation 2000 in the Region of the Americas” (PAHO, 2001), water supply and sanitation status and perspectives.

Based on the above it was found that within LAC, Brazil and Mexico are countries in intermediate stage of development, with intermediate coverage (PAHO, 2001), that by their dimension it is advisable to analyze independently of smaller countries. For the Andean Countries (Bolivia, Colombia, Ecuador, Peru and Venezuela) Colombia was selected to represent this area, due to it is the country with higher sanitation coverage (83%), while for the southern cone region (Paraguay, Chile, Argentina y Uruguay), Chile was selected because it has the highest sanitation coverage in that area (93%).

Finally, for the Central America and the Caribbean islands (Hispanic Caribbean and Haiti) (considered in several studies as a sub-region of the Pan-American Health Organization) Guatemala and Dominican Republic were selected in this case as the most representatives in the region,. Additionally, Guatemala was selected for its high vulnerability to climate change (Maplecroft, 2009).

It should be mentioned that there is no direct relationship between the population size served and the size of wastewater treatment plants (WWTP), i.e. many small WWTP may be in place to serve a big population.

The sample information of WWTP was obtained by considering the place of location (county, state, according to the country's political division), name of the WWTP, population, flow capacity of the WWTP (l/s), type of treatment and final destination of treated water in the six countries. According to the information, it was established the three most representative types of treatment processes based on four predominant flow ranges (Q1, Q2, Q3 and Q4). In principle, the analysis was performed individually for each country and then it was considering all the six countries. The flow rates were estimated according to the type (size) of city, as shown in Table 1.

Table 1. Installed capacity ranges according to the type of city

Type of city	Population size (hab)	Range of installed capacity (l/s)
Small	1 to 9,999	0 to 25: Q1
Medium	10,000 to 99,999	25.1 to 250: Q2
Big	100,000 to 999,999	251 to 2,500: Q3
Huge	>1 million	> 2,501: Q4

In order to relate the type of city with the potentially installed capacity of the WWTP, the population size of each type of city was multiply by the per capita wastewater discharge, assuming a water supply of 235 l/day per capita with 85% of wastewater generation. The flow rate values were statistically determined for each range reported in Table 1.

Comparison of the existing regulations for wastewater treatment in each country

Existing regulations were compared in the six countries studied, according to the final use, either water body discharge or water reuse. General parameters were selected for comparison purposes (Table 2). In order to generate characteristic intervals of each selected country, minimum and maximum values established by each regulation were taken from.

Table 2 Parameters compared for each standard

Discharged into water bodies	Reuse of treated wastewater
Biochemical Oxygen Demand BOD_5 (mg/l)	Fecal Coliform (MPN/ 100 ml)
Settleable solids (ml/l)	Helminth eggs (ova/l)
Oil and grease (mg/l)	Oil and grease (mg/l)
Floating matter (mg/l)	Biochemical Oxygen Demand BOD_5 (mg/l)
Nitrogen (mg/l)	Total Suspended Solids TSS (mg/l)
Phosphorus (mg/l)	

Results and discussion

Selection of technologies and installed wastewater treatment capacity

The WWTP sample included 2,169 facilities, which has 23 different types of technologies, in combined and individual processes. It should be noted that in case of combined processes (i.e. UASB reactor followed by activated sludge process) each of those technologies were considered separately, resulting a total number of 2,242.

An analysis of the distribution of the technologies used in the six samples of LAC countries was performed considering the number of technologies as a function of the type of process (Figure 1). Figure 2 shows each type of technology by a range of flow rate as was specified in table 1.

Regardless of the flow range considered for this analysis, the two technologies most used for the sample of LAC countries analyzed are activated sludge processes and stabilization ponds. While for the third technology it was taken into account the distribution of technology in different flow ranges, i.e. for the range of Q1 shows the UASB process, while for Q2 and Q3 is presented trickling filter technology and Q4 anaerobic reactor technology. Based on these findings, for the third and fourth position it is possible identify the UASB reactor and trickling filters.

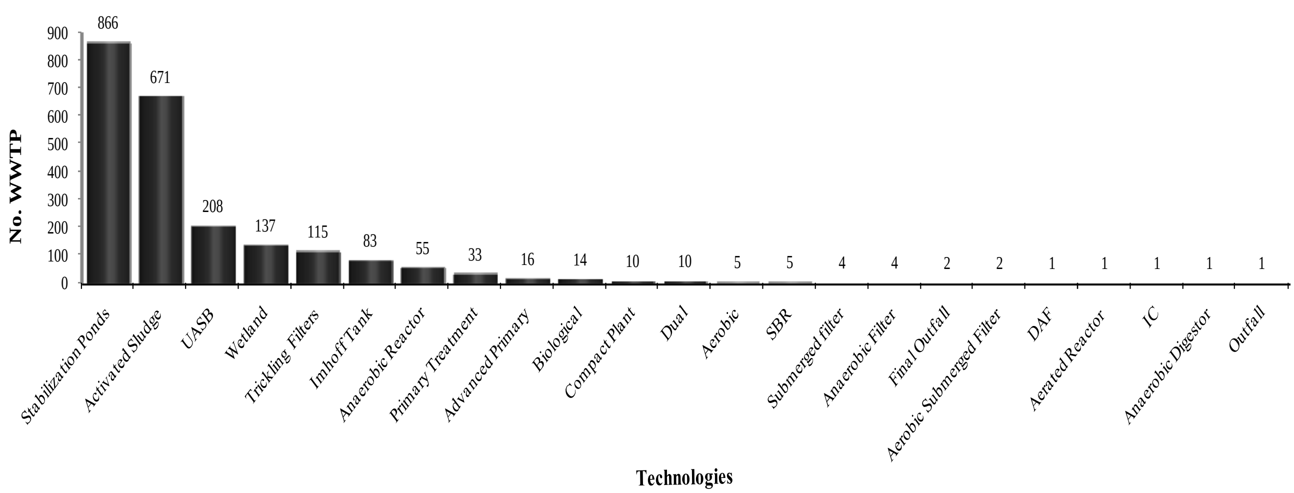

Figure 1 Technologies used in wastewater treatment in LAC

The distribution of technologies according to the flow range criteria indicated: 1,545 units for a flow range from 0 to 25 l/s, 550 units between 25.1 to 250 l/s, 141 units between 251 to 2,500 l/s, while for higher installed capacity only 6 WWTP (≥ 2,501 l/s). were found.

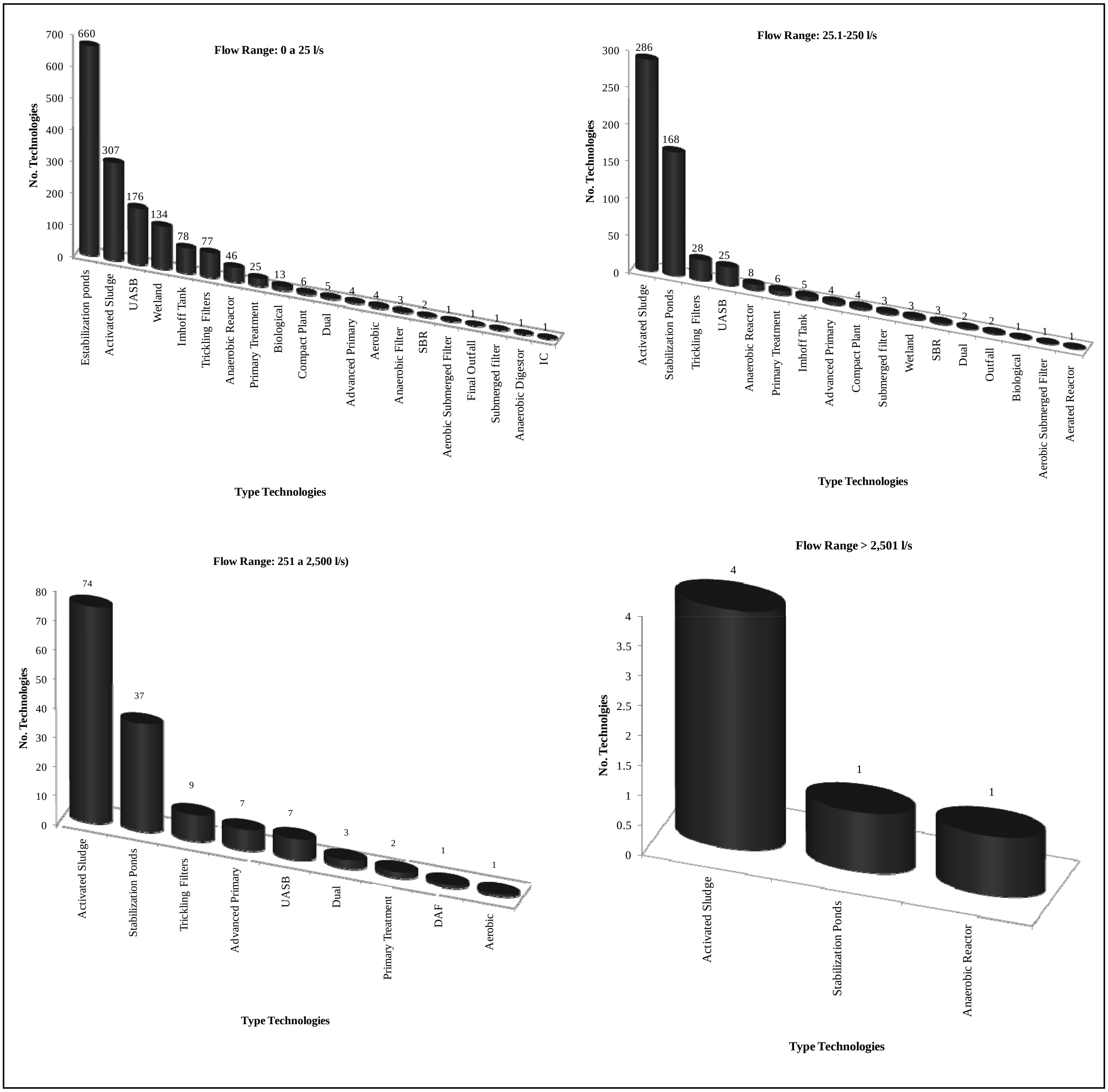

Figure 2 Distribution of the technologies used in flow rate interval in LAC

The use of small WWTP is a very common practice in LAC wastewater treatment, i.e. the tendency to place a large wastewater treatment plant with high flow rate is not very common in the region. However, the environmental impacts which together generate many small WWTP could be greater than building a big properly operated wastewater treatment plant which serves to a big population.

In order to determine the average installed capacities of the technologies used in each flow range and to establish a representative flow value, a statistical analysis was performed (data not shown).

The most used technologies have a representative installed capacity of 13 l/s, 70 l/s, 618 l/s and 5,800 l/s for flow ranges between 0-25 l/s, 25.1 -250 l/s, 250.1-2,500 l/s and > 2.501 l/s respectively.

It should be noted that this same exercise was performed individually for each of the countries studied, obtaining for each country the most representative flow rates, the results obtained in these cases are similar to those obtained considering all the countries together.

Comparison of the existing regulations on wastewater treatment

The regulations of the countries studied can be classified into three types: the standards that set maximum limits to be met by wastewater discharges into receiving bodies (applicable to Mexico, Guatemala and Chile), the regulations which are focused on the receiver body in order to preserve its water quality (Brazil), and those that requires a removal percentage of the organic load rate discharged (Colombia, Dominican Republic). Table 3 shows the parameter limits for each country in relation to the discharge of wastewater into water bodies.

Table 3. Comparison of the regulations for discharge into water bodies for six different countries of LAC

Country	Brazil	Chile	Colombia	Guatemala	Mexico	Dominican Republic
Parameter/ Rule	CONAMA 357 (2005)	Decreto 090	Decreto 1594 de 1984	Acuerdo gubernativo 236-2006	NOM-001-SEMARNAT-1996	AG-CC-01
BOD_5 (mg/l)	3-10	35-60	Removal > 80% laden	100-200**	30-150	35-100
Oil and Grease (mg/l)	NA	20	Removal >80% laden	10***	15	NA
Settleable solids (ml/l)	NA	NA-5*	NA	NA	1	NA

NA- Not Applicable *ml/ 1hr ** Compliance goal by 2024 (current generators), took into account new generators.***
CONAMA- National Environment Council (in Portuguese)
NOM- Mexican Official Standard (in Spanish)
SEMARNAT-Environment and Natural Resources Department (In Spanish)

The parameters of nitrogen and phosphorus are not considered, since none of the selected technologies ensures compliance with the maximum permissible limits for these parameters. It can be see that the only parameter included in the regulations of all countries is the Biochemical Oxygen Demand (BOD), which presents a wide variation between 3 and 150 mg/l.

It is important to note that more stringent BOD is presented by Brazil as it regulates the quality of receiving waters, while other countries regulate the concentration of the effluent on the receiving body. Therefore, it is not possible to compare these regulations. The wide variation in the criteria for standards may be due to the monitoring and control capacity of each country. Also, internal political or commercial interests may play a role for not allowing adequate development of the regulations. In Table 4 it is possible to see a comparison of the national standards concerning the reuse of treated water.

Mexico sets limits for all parameters shown in table 4; the values of fecal coliforms and BOD are likely to be compared with those in Guatemala (one similarity for fecal coliforms and a wide variation for BOD). Chile and Mexico have set a similar value for oil and grease, and fecal coliforms parameters.

Table 4. Comparison of the standards for reuse of treated wastewater from different countries of LAC

Country	Brazil	Chile	Colombia	Guatemala	Mexico	Dominican Republic
Parameter/ Rule	-	NCH-1333	-	Acuerdo gubernativo 236-2006	NOM-003-SEMARNAT-1997	-
Fecal Coliforms (NMP/100 ml)	-	1000	-	NA< $2*10^2$	240-1000	-
Helminth eggs (h/l)	-	NA	-	NA	<5	-
Oil and grease (mg/l)	-	5	-	NA	15	-
BOD5 (mg/l)	-	NA	-	NA-<200	20-30	-
TSS (mg/l)	-	NA	-	NA	20	-

Current research and perspectives

- A process simulator was developed for comparing wastewater treatment full processes for LAC, considering the most representative flow rates and technologies. This tool provides important information, such as mass balances, energy requirements and estimated investment costs, for several process arrangements for a given flow rate and wastewater quality required.

- The most appropriate technologies based on environmental and social aspects will be established, through the development of the methodology of Life Cycle Assessment (LCA), which will identify potential, environmental impacts of the treatment technologies from a global perspective (cradle-to-grave). This approach begins with the extraction of raw materials, continues with product development and manufacturing, and finally ends when all materials are returned to earth and finally disposed.

- In order to promote sustainable development in LAC, the most suitable technologies will be recommended to decision takers in the LAC region.

Summary and conclusions

The most representative technologies in LAC are: stabilization ponds, activated sludge, UASB reactors and trickling filters (which represent 80% of WWTP in LAC).

Based on the foregoing, the municipal wastewater treatment plants in LAC are designed to treat flows below 25 l/s, (which represents 77% of reported cases), There is no direct relationship between the installed capacity of the WWTP and the population size of the city they serve.

Brazil has the strictest regulations in comparison with other countries, since their maximum permissible limits are set in order to maintain the water quality of the receiving bodies, in contrast to countries that regulate the quality of effluent WWTP that discharges into the water body. The approach to preserve the quality of the receiving body represents a step forward in environmental sanitation, which defines the direction for regulatory efforts in treatment of wastewater in LAC.

The overall analysis of various environmental legislations leads to the conclusion that there is no ideal standard to be applied to the entire LAC region.

Acknowledgements

This project research is being developed with financial support of the International Development Research Center (IDRC), Ottawa, Canada. The authors like to thank the IDRC, for supporting this research (project internal number *IDRC – UNAM 105701-001*).

References

Acuerdo Gubernativo Número 236 (2006). Reglamento de descargas y reúso de aguas residuales y de la disposición de lodos. Ministerio del Medio Ambiente y Recursos Naturales Guatemala 5 mayo (in Spanish).

Bernal D.P., Cardona D.A. (2003). Guía de Selección de Tecnología para el Tratamiento de Aguas Residuales Domesticas por Métodos Naturales. Seminario Internacional sobre métodos naturales para el tratamiento de aguas residuales (in Spanish).

CONAMA 357, Conselho Nacional do Meio Ambiente. (2005). Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Resolução No. 357, de 17 de Marco (in Portuguese).

Decreto 090 (2000)- Ministerio Secretaria General de la Presidencia. 07-03-2001. Norma de emisión para la regulación de contaminantes asociados a las descargas de residuos líquidos a aguas marinas y continentales superficiales. Santiago, mayo (in Spanish).

Decreto 1594 (1984). Uso del agua y residuos líquidos. Ministerio de Agricultura. Colombia, Diario Oficial No. 36.700, junio (in Spanish).

Economic Commission for Latin America and the Caribbean (ECLAC) (2009). Anuario Estadístico de América Latina y el Caribe. División de Estadística y Proyecciones Económicas. Publicación de las Naciones Unidas. Nueva York, Estados Unidos. http://www.eclac.org.

Fernandez A., Ojeda, C. (2006). Wastewater management in Greater Buenos Aires, Argentina. *International Journal of Desalination*, (218), 52-61.

Helen E. Muga, James R. Mihelcic (2008). Sustainability of wastewater treatment technologies Journal of Environmental Management 88 437-447.

Lundin M., Bengtsson M., and Molander S. (2000). Life Cycle Assessment of wastewater systems: influence of system boundaries and scale on calculated environmental loads. *Enviromental Science and Technology,* 34, 180-186.

Maplecroft (2009). Climate Change Risk Report. Country by country risk analysis and mapping.

Moscoso Cavallini J. y Egochea Young L. (2002). Sistemas integrados de tratamiento y uso de aguas residuales en América Latina: Realidad y potencial. XXVIII Congreso Interamericano de Ingeniería Sanitaria y Ambiental. Cancún México, 27 al 31 de Octubre del 2002.

NCh 1333 (1978) Norma chilena sobre requisitos de calidad del agua para diferentes usos. Instituto Nacional de Normalización (in Spanish).

NOM-001-SEMARNAT-1996 (1996). Secretaria del Medio Ambiente. Norma que establece los límites máximos permisibles de contaminantes en las descargas de aguas residuales en aguas y bienes nacionales.

NOM-003-SEMARNAT-1997 (1997). Secretaria del Medio Ambiente. Norma que establece los límites máximos permisibles de contaminantes para las aguas residuales tratadas que se reusen en servicios al público (in Spanish).

Noyola, A. (2003). Tendencias en el tratamiento de aguas residuales domesticas en Latinoamérica. Seminario Internacional sobre métodos naturales para el tratamiento de aguas residuales (in Spanish).

PAHO(2001) Regional Report on the Evaluation 2000 in the Region of the Americas", water supply and sanitation status and perspectives, Washington D.C. 81 pp. www.bvsde.ops-oms.org/bvsaas/e/fulltext/infregio/infregio.pdf

Pardon Mauricio, (2005). Situación del Manejo de las Aguas Residuales Domesticas en América Latina Latinoamérica. Taller Sudamericano; Validación de Lineamientos para Mejorar la Gestión del Agua Residual y Hacer más Sostenible la Protección de la Salud, Lima, Perú (in Spanish).

Secretaría del Medio Ambiente Recursos Naturales (2001). AG-CC-01. Norma de Calidad y Control de Descargas. Santo Domingo Republica Dominicana. Junio (in Spanish).

United Nations (2000). Goal 7. Ensure environmental sustainability. United Nations Millennium Goals. http://www.un.org/millenniumgoals/