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Urban wastewater treatment technologies and the implementation of discharge standards in developing countries

Marcos von Sperling *, Carlos Augusto de Lemos Chernicharo

Department of Sanitary and Environmental Engineering, Federal University of Minas Gerais, Av. do Contorno, 842-7 andar, 30110-060 Belo Horizonte, Brazil

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Abstract

The paper analyses the practical implementation of standards for treated urban wastewater and receiving water bodies with a special focus on the following points of concern for developing countries: (a) typical problems with setting up and implementing standards in developing countries; (b) the need for a stepwise implementation of the measures necessary to achieve the standards; (c) the need for institutional development; and (d) the availability of wastewater treatment technologies. The treatment technologies are presented in a simple and practical way (tabular form), showing their expected effluent quality in terms of important parameters such as BOD, COD, suspended solids, ammonia, total nitrogen, total phosphorus, faecal coliforms and helminth eggs. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Developing countries; Discharge standards; Institutional development; Wastewater treatment; Water quality legislation

1. Introduction

The impact of the discharge of urban wastewater into rivers, lakes, estuaries and the sea is a matter of great concern in most countries. An important point in this scenario is the establishment of an adequate legislation for the protection of the quality of water resources; this being a crucial point in the environmental and public health development of all countries. Developed nations have already surpassed the basic stages of water pollution problems, and are currently fine-tuning the control of micro-pollutants, the impact of pollutants in sensitive areas or the pollution caused by the drainage of storm water. However, developing nations are under constant pressure, from one side observing or attempting to follow the international trends of frequently lowering the limit concentrations of the standards, and from the other side of being unable to reverse the continuous trend of environmental degradation. The increase in the sanitary infrastructure can barely cope with the net population growth in many countries. The implementation of sanitation and sewage treatment depends largely on the political will and, even when this is present, financial constraints are the final barriers to undermine the necessary steps towards environmental restoration and public health maintenance. Time passes, and the distance between desirable and achievable, between laws and reality, continues to enlarge.

Fig. 1 presents a comparison between the current status of developed and developing countries in terms of the actual effluent concentrations of a particular pollutant and its associated discharge standard. In most of the developed countries, compliance occurs for most of the time, and the main concern relates to occasional episodes of non-compliance, at which most of the current effort is concentrated. However, in most developing nations the concentrations of pollutants discharged into the water bodies are still very high, and the efforts are directed towards reducing the distance to the discharge standards and eventually achieving compliance.

One of the main stages in the implementation of standards is the conversion and adaptation of the philosophy, guidance and numeric values of general guidelines, such as those set by international agencies such as WHO, World Bank and others into quality standards, defined by each country individually. *Guidelines* are usually generic by nature, aiming at protecting public health or environment on a large scale or

* Corresponding author. Tel.: +55-31-3238-1935, fax: +55-31-3238-1879.

E-mail address: marcos@desa.ufmg.br (M. von Sperling).

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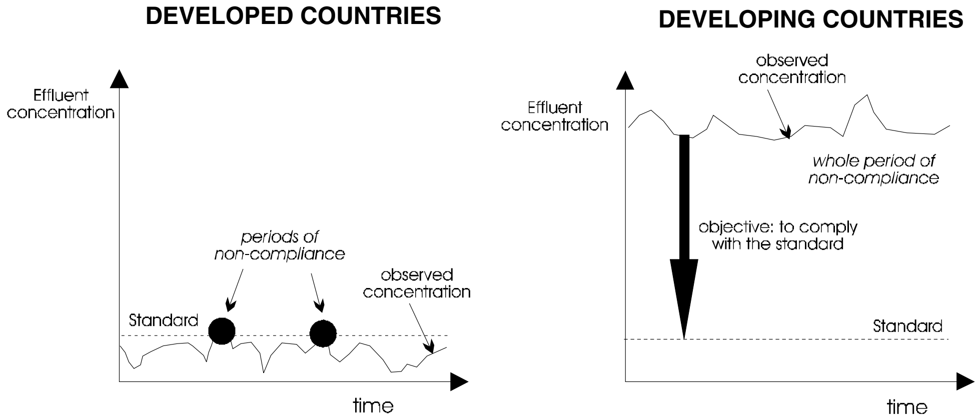

Fig. 1. Comparison between developed and developing countries in terms of compliance with discharge standards.

world-wide basis. *National standards* are defined by each country, have legal status and are based on the specific conditions of the country itself. Depending on the political structure of the country, *regional standards* may also be developed for each state, county or other political subdivision. Usually, regional standards are equal to or more stringent or complete than national standards. Economic, social and cultural aspects, prevailing diseases, acceptable risks and technological development are issues which are particular to each country or region, and are better taken into account by the country or region itself, when converting general guidelines into national/regional standards. This conversion is crucial: an adequate consideration or conversion of the guidelines may be an invaluable tool in the health and environmental development of a country, whereas an inadequate conversion may lead to discredit, frustration, unnecessary money expenditure, unsustainable systems and other problems dealt with further in this paper.

The paper analyses the practical implementation of standards, with a special focus on the following points of concern for developing countries:

- Typical problems with setting up and implementing standards in developing countries.
- The need for a stepwise implementation of the measures necessary to achieve the standards.
- The need for institutional development.

In order to give a practical orientation for the derivation of discharge standards, the paper also investigates the capability of wastewater treatment technologies in order to achieve different levels of effluent quality. The main objective is to present in a simplified way the capabilities of the various technologies applied for domestic sewage treatment in terms of important effluent parameters such as BOD, COD, suspended solids, ammonia, total nitrogen, total phosphorus, faecal coliforms and helminth eggs. The technologies investigated comprise single and combined anaerobic and aerobic processes, covering a wide range of systems currently in use. Attention is given to recent process combinations such as those involving anaerobic treatment and a suitable form of post-treatment of the effluent. Although the technologies listed are used world-wide, the main emphasis of the paper is on developing countries, the majority of them having warm climates, concentrated wastewater and more operational and maintenance difficulty, compared to developed nations.

2. Typical problems with setting up and implementing standards in developing countries

The inadequacies and difficulties in the setting up of standards for receiving water body and for discharges in developing countries have been already discussed by several researchers. Johnstone and Horan (1994, 1996) presented very interesting papers, analysing institutional aspects of standards and river quality and comparing different scenarios for the UK and other developed and developing countries. Von Sperling and Nascimento have analysed in detail the Brazilian legislation (von Sperling, 1998), covering aspects such as comparisons between the limit concentrations in the standards with quality criteria for different water uses (Nascimento & von Sperling, 1998), sensitivity of laboratory techniques (Nascimento & von Sperling, 1999) and requirements for dilution ratios (river flow/effluent flow) in order to match compliance of water and discharge standards (von Sperling, 2000).

Table 1 presents a list of common problems associated with setting up and implementing standards, especially in developing countries. Some of the points are discussed in the above-mentioned references.

3. Stepwise implementation of standards

Usually the stepwise implementation of a wastewater treatment plant is through the *physical expansion* of the size or number of units. A plant can have, for instance, two tanks built in the first stage, and another tank built in the second stage, after it has been verified that the influent load has increased, frequently due to the population growth. This stepwise implementation is essential, in order to allow reduction in present value construction costs.

However, another concept of stepwise implementation, which should be put in practice, especially in developing countries, is the *gradual improvement of the treated wastewater quality*. It should be possible, in a large number of situations, to implement in the first stage a less efficient process, or a process that removes fewer pollutants, transferring to a second stage the improvement towards a system more efficient or more wide-reaching in terms of pollutants. If the planning is well structured, the environmental agency could make allowances in the sense of permitting a temporary small violation in the standards in the first stage. Naturally a great deal of care must be exercised in not allowing that a temporary situation becomes permanent, which is a very common occurrence in developing countries. This alternative of stepwise development of wastewater quality is undoubtedly much more desirable than a large violation of the standards, whose solution is often unpredictable over time.

Fig. 2 presents a typical situation concerning the implementation of wastewater treatment. If a country decides to implement treatment plants that can potentially lead to an immediate compliance with the standards, this will require a large and concentrated effort, since the current water quality is probably very poor, especially in developing countries. This large effort is naturally associated with a large cost. In most instances, the country cannot afford this large cost, and the plant construction is postponed and eventually never put into effect. On the other hand, if the country decides to implement only a partial treatment, financial resources may be available. A certain improvement in the water quality is obtained and health and environmental risks are reduced, even though the standards have not been satisfied. In this case, the standards are treated as target values, to be achieved whenever possible. The environmental agency is a partner in the solution of the problem, and establishes a programme of future improvements. After some time, there will probably be additional funds for expanding the efficiency of the treatment plant, and the standards will finally be satisfied. In this case, compliance with the standards will probably occur in a shorter time compared with the alternative without stepwise implementation (concentrated, late step).

Not only wastewater systems should expand on a stepwise basis on developing countries but also the standards for water quality. There should be a knowledge about the targets which are desired to be achieved over time, and these targets could eventually be the same as the general guidelines. However, with the standards the approach should be different, and the numeric values of the limit concentrations should progress in a stepwise manner towards stringency. The standards should be adapted periodically, eventually reaching the same values as those in the guidelines.

The advantages of a stepwise implementation of standards and sanitary infrastructure are discussed in Table 2.

An important issue in the stepwise approach is how to guarantee that the second and subsequent stages of improvement will be implemented, and not be terminated at the first stage. Due to financial restrictions, there is always the risk that the subsequent stages will be indefinitely postponed, under the argument that the priority has now shifted to systems which have not yet implemented the first stage. Even though this might well be a justifiable argument, it cannot be converted into a commonly used excuse. The environmental agency must set up scenarios of intervention targets with the entity responsible for the sanitary system. The scenarios should include the minimum intervention, associated with the first stage, and subsequent prospective scenarios, including required measures, benefits, costs and timetable. The formalisation of the commitment also helps in ensuring the continuation of the water quality improvement.

4. Treatment technologies and effluent quality

Tables 3–5 present a list of commonly used urban wastewater treatment technologies, together with their capability of achieving different levels of effluent quality. Industrial wastewater is not covered in the tables. The parameters investigated are: BOD, COD, suspended solids, ammonia, total nitrogen, total phosphorus, faecal coliforms and helminth eggs. Although most countries do not adopt discharge standards for all these parameters, they are included here only for the sake of comparison with the treatment technologies' capabilities. The tables represent an effort in consolidating existing experiences, but naturally the indications are not universal, and even within one country, regional diversities can be responsible for deviations in the listed capabilities. The main objective of the tables is to serve as a practical orientation for setting up discharge standards, especially in developing countries. Whereas receiving water quality standards should be based on quality criteria for the intended uses of the water, the discharge standards have to be also associated with existing capable and affordable technologies. Otherwise, the discharge standards will remain confined to official papers, without reaching reality and without helping the country in its path towards environmental protection.

Table 1
Common problems associated with setting up and implementing standards, especially in developing countries

Problem	How it should be	How it frequently is
Guidelines are directly taken as national standards	Guidelines are general world-wide values. Each country should adapt the guidelines, based on local conditions, and derive the corresponding national standards	In many cases the adaptation is not done in developing countries, and the world-wide guidelines are directly taken as national standards, without recognising the country's singularities
Guideline values are treated as absolute values, and not as target values	Guideline values should be treated as target values, to be attained on a short, medium or long term, depending on the country's technological, institutional or financial conditions	Guideline values are treated as absolute rigid values, leading to simple "pass" or "fail" interpretations, without recognising the current difficulty of many countries to comply with them
Protection measures that do not lead to immediate compliance with the standards do not obtain licensing or financing	Environmental agencies should license and banks should fund control measures (e.g. wastewater treatment plants) which allow for a stepwise improvement of water quality, even though standards are not immediately achieved. However, measures should be taken to effectively guarantee that all steps will be effectively implemented	The environmental agencies or financial institutions do not support control measures which, based on their design, do not prove to lead to compliance with the standards. Without licensing or financing, intermediate measures are not implemented. The ideal solution, even though approved, is also not implemented, because of lack of funds. As a result, no control measures are implemented
Standards are frequently copied from developed countries	National standards should be based on the country's specific economical, institutional, technological and climatic conditions	National standards are frequently directly copied from developed countries' standards, either because of lack of confidence on their own capacity, desirability to achieve developed countries' status, lack of knowledge or poor knowledge transfer from international consulting companies. Cost implications are not taken into account. The standards become purely theoretical and are not implemented or enforced
Developed countries sometimes attempt to reach developed countries' status too quickly	If the guidelines and even the standards are treated as target values, time would be necessary to lead to compliance. Each country, based on the economic and technological capacity, should take the time which is reasonably necessary to achieve compliance. Developing countries are naturally likely to take more time than developed countries. Developing countries should understand that current standards in developed countries result from a long period of investment in infrastructure, during which standards progressively improved	The desire to achieve developed countries' status too quickly can lead to the use of inappropriate technology, thus creating unsustainable systems
Some standards are excessively stringent or excessively relaxed	Standards should reflect water quality criteria and objectives, based on the intended water uses	In most cases, standards are excessively stringent, more than would be necessary to guarantee the safe use of water. In this case, they are frequently not achieved. Designers may also want to use additional safety factors in the design, thus increasing the costs. In other cases, standards are too relaxed, and do not guarantee the safe intended uses of the water
There is no affordable technology to lead to compliance of standards	Control technologies should be within the countries, financial conditions. The use of appropriate technology should always be pursued	Existing technologies are in many cases too expensive for developing countries. Either because the technology is inappropriate or because there is no political will or the countries' priorities are different, control measures are not implemented

Compliance with standards is at a lower level of priority compared to other basic environmental sanitation needs	Each country, based on the knowledge of its basic conditions and needs, should set priorities to be achieved. If standards are well set up, they will naturally be integrated with the environmental control measures	Basic water supply and sanitation needs are so acute in some countries that standards are seen as an unnecessary sophistication
Standards are not actually enforced	Standards should be enforceable and actually enforced. Standard values should be achievable and allow for enforcement, based on existing and affordable control measures. Environmental agencies should be institutionally well developed in order to enforce standards	Standards are not enforced, leading to a discredit in their usefulness and application, and creating the culture that standards are to remain on paper only
Discharge standards are not compatible with water quality standards	In terms of pollution control, the true objective is the preservation of the quality of the water bodies. Discharge standards exist only by practical (and justifiable) reasons. However, discharge standards should be compatible with water quality standards, assuming a certain dilution or assimilation capacity of the water bodies	Even if water quality standards are well set up, based on water quality objectives, discharge standards may not be compatible with them. Some parameters in the discharge standards may be too stringent and others too relaxed. In this case, different assimilation capacities of the water bodies are implicit. The aim of protecting the water bodies is thus not guaranteed
Number of parameters are frequently inadequate (too many or too few)	The list of parameters covered by the national standards should reflect the desired protection of the intended water uses, without excesses or limitations	In some countries, the standards include an excessively large list of parameters, many of which have no actual regional importance, are very costly to monitor or are not supported by satisfactory laboratory capabilities. In other situations, standards cover only a limited list of parameters, which are not sufficient to safeguard the intended water uses
Monitoring requirements are undefined or inadequate	Monitoring requirements and frequency of sampling should be defined, in order to allow proper statistical interpretation of results. The cost implications for monitoring need to be taken into account in the overall regulatory framework	In many cases, monitoring requirements are not specified, leading to difficulty in the interpretation of the results. In other cases, monitoring requirements are excessive and thus unnecessarily costly. Still in other cases, monitoring requirements are very relaxed, not allowing interpretation of results with confidence
Required percentage of compliance is not defined	It should be clear how to interpret the monitoring results and the related compliance with the standards (e.g. mean values, maximum values, absolute values, percentiles or other criteria)	The non specification of how to treat the monitoring results may lead to different interpretations, which may result in diverging positions as to whether compliance has been achieved or not
Low standard values are sometimes below laboratory detection limits	If standards are treated as target values and are well linked with the water quality objectives, they should not be limited by current laboratory detection limits. In due time, laboratory techniques will improve and be consistent with the standard values	Standards which are below the detection limit are sometimes seen as unjustifiable, which may be true in some cases, but not in many other cases
There is no institutional development which could support and regulate the implementation of standards	The efficient implementation of standards requires an adequate infrastructure and institutional capacity to license, guide and control polluting activities and enforce standards	In many countries the health and environmental agencies are not adequately structured or sufficiently equipped, leading to a poor control of the various activities associated with the implementation of standards
Reduction of health or environmental risks due to compliance with the standards is not immediately perceived by decision-makers or the population	Decision-makers and the population at large should be well informed about the benefits and costs associated with the maintenance of good water quality, as specified by the standards	Decision-makers are frequently more sensitive to costs than to benefits resulting from the implementation of control measures. The population is not well informed, and does not drive politicians and decision-makers in order to invest in health and environmental protection

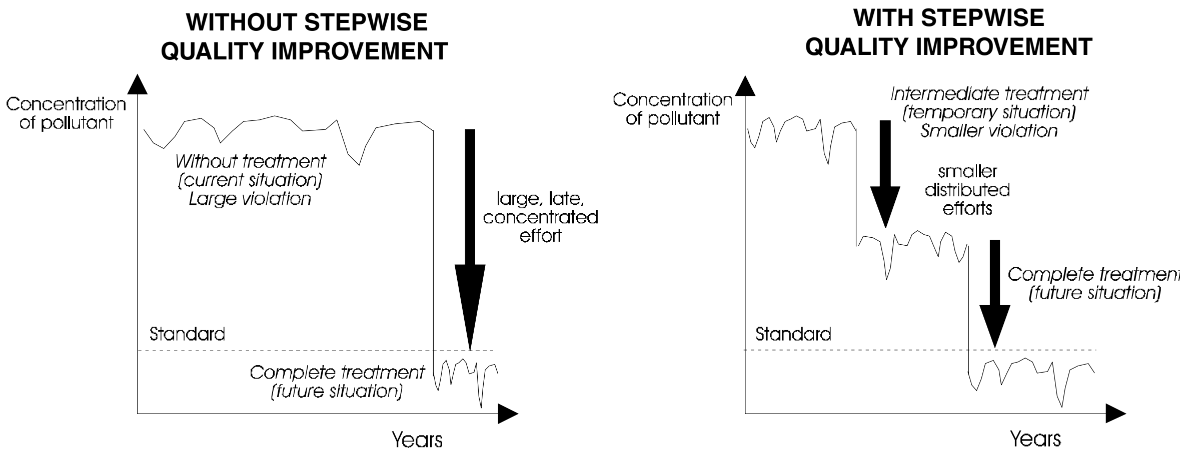

Fig. 2. Concept of the stepwise improvement of water quality.

Table 2
Advantages of stepwise implementation of standards and sanitary infrastructure

Advantage	Comment
The present value of construction costs is reduced	The division of construction costs into different stages leads to a lower present value than a single, large, initial cost. This aspect is more relevant in countries in which, due to inflation problems, interest rates are high
Polluters are more likely to afford gradual investment for control measures	Polluters and/or water authorities will find it much more feasible to divide investments in different steps than to make a large and in many cases unaffordable investment
The cost-benefit of the first stage is likely to be more favourable than in the subsequent stages	In the first stage, when environmental conditions are poor, usually a large benefit is achieved with a comparatively low cost. This means that already in the first stage a significant benefit is likely to be achieved, with only a fraction of the overall costs. In the subsequent stages, the increase of the benefit is not so substantial, but the associated costs are high. The cost-benefit is then less favourable
There is the opportunity to optimise operation, without necessarily making physical expansion	The experience in the operation of the system will lead to a good knowledge of its behaviour. This will allow, in some cases, the optimisation of the process (improvement of efficiency or capacity), without necessarily requiring the physical expansion of the system. The first stage will be analogous to a pilot plant
There is more time and better conditions to know the water or wastewater characteristics	The operation of the system will involve monitoring, which, on its course, will allow a good knowledge of the water or wastewater characteristics. The design of the second or subsequent stages will be based on the actual characteristics, and not on generic values taken from the literature
There is time and opportunity to implement, in the second stage, new techniques or better developed processes	The availability of new or more efficient processes for water and wastewater treatment is always increasing with time. Process development is continuous and fast. The second or subsequent steps can make use of better and/or cheaper technologies than it would be possible with a single step
The country has more time to develop its own standards	As time passes, the experience in operating the system and evaluating its positive and negative implications in terms of water quality, health status and environmental conditions will lead to the establishment of standards which are really appropriate for the local conditions
The country has more time and better conditions to develop a suitable regulatory framework and institutional capacity	Experience obtained in the operation of the system and in setting up the required infrastructure and institutional capacity for regulation and enforcement will also improve progressively, as the system expands on the second and subsequent stages

The tables are based on a review which included international references (Arceivala, 1981; Metcalf & Eddy, 1991; Qasim, 1985; WEF/ASCE, 1992), Brazilian references (Chernicharo, 1997; von Sperling, 1996), plus a consolidation of the results from the Brazilian Research Programme on Basic Sanitation – PROSAB (Alem Sobrinho & Kato, 1999; Coraucci Filho et al., 1999; Marques, 1999), which unifies the research efforts of various universities and water authorities located in many different states of the country.

Table 3
Capacity of sewage treatment technologies, in terms of consistently achieving the indicated effluent quality for BOD, COD and SS

System	BOD					COD			SS		
	100 (mg/l)	80 (mg/l)	60 (mg/l)	40 (mg/l)	20 (mg/l)	200 (mg/l)	150 (mg/l)	100 (mg/l)	90 (mg/l)	60 (mg/l)	30 (mg/l)
Facultative pond	■	■				■			■		
Anaerobic pond + facultative pond	■	■				■			■		
Facultative aerated lagoon	■	■	■			■			■		
Completely mixed aerated lagoon + sedimentation lagoon	■	■	■			■			■		
Stabilisation ponds + maturation ponds	■	■	■			■			■		
Stabilisation ponds + high rate pond	■	■	■			■			■		
Stabilisation ponds + algae removal	■	■	■	■		■	■		■	■	
Low rate infiltration	■	■	■	■	■	■	■	■	■	■	■
Rapid infiltration	■	■	■	■	■	■	■	■	■	■	■
Overland flow	■	■	■			■			■	■	
Constructed wetlands	■	■	■			■			■		
Septic tank + anaerobic filter	■	■	■			■			■	■	
Septic tank + infiltration	■	■	■	■	■	■	■	■	■	■	■
UASB reactor	■					■			■		
UASB reactor + activated sludge	■	■	■	■		■	■	■	■	■	■
UASB reactor + submerged aerated biofilter	■	■	■	■		■	■	■	■	■	■
UASB reactor + anaerobic filter	■	■	■			■			■	■	
UASB reactor + trickling filter (high rate)	■	■	■	■		■	■	■	■	■	■
UASB reactor + maturation ponds	■	■	■			■			■		
UASB reactor + overland flow	■	■	■			■			■	■	
Conventional activated sludge	■	■	■	■	■	■	■	■	■	■	■
Extended aeration	■	■	■	■	■	■	■	■	■	■	■
Sequencing batch reactor	■	■	■	■		■	■	■	■	■	■
Activated sludge with biological N removal	■	■	■	■		■	■	■	■	■	■
Activated sludge with biological N/P removal	■	■	■	■		■	■	■	■	■	■
Activated sludge + tertiary filtration	■	■	■	■	■	■	■	■	■	■	■
Low rate trickling filter	■	■	■	■		■	■	■	■	■	■
High rate trickling filter	■	■	■			■			■	■	■
Submerged aerated biofilter	■	■	■	■	■	■	■	■	■	■	■
Submerged aerated biofilter with biological N removal	■	■	■	■	■	■	■	■	■	■	■
Rotating biological contactor	■	■	■	■		■	■	■	■	■	■

The Brazilian experience is relevant in the sense that a large regional, climatic (equatorial, tropical and sub-tropical) and economic diversity exists within Brazil itself, allowing the extrapolation of characteristics applicable to many other developing countries. Additionally, the treatment technologies currently in investigation and practice in Brazil represent an important focus on appropriate technologies, giving special attention to simple and more affordable technologies such as stabilisation ponds and anaerobic reactors followed by various forms of post-treatment processes. The PROSAB experience led to an important knowledge of the behaviour of anaerobic processes followed by several different post-treatment processes. The combination of anaerobic treatment and aerobic or anaerobic post-treatment is very recent for urban wastewater; few international references are available on this subject and many of the results have been obtained through PROSAB.

From the tables, it is seen that:

- Most of the commonly applied treatment technologies are capable of achieving reasonable (not very stringent) values of effluent quality for BOD, COD and, to some extent, SS, compatible with most existing discharge standards in developed and developing countries.
- For ammonia, nitrogen, faecal coliforms and especially phosphorus, only a limited range of treatment technologies can generate an effluent compatible with most existing standards in developed and developing countries.

Developed countries usually have the financial resources which will allow them to adopt the treatment processes which will lead to compliance with most existing discharge standards. A different picture is encountered in developing countries, in which only the cheaper processes have some chance of being implemented. Unfortunately, many of these cheaper technologies will be unsuccessful in meeting most of the currently existing discharge standards for ammonia, nitrogen and phosphorus.

5. Institutional development

An efficient implementation of standards must go in parallel with the development, in the sector of environmental agencies, of the institutional framework

Table 4
Capacity of sewage treatment technologies, in terms of consistently achieving the indicated effluent quality for ammonia – N, total N and total P

System	Ammonia – N			Total N			Total P			
	15 (mg/l)	10 (mg/l)	5 (mg/l)	20 (mg/l)	15 (mg/l)	10 (mg/l)	4, 0 (mg/l)	3, 0 (mg/l)	2, 0 (mg/l)	1,0 (mg/l)
Facultative pond										
Anaerobic pond + facultative pond										
Facultative aerated lagoon										
Completely mixed aerated lagoon + sedimentation lagoon										
Stabilisation ponds + maturation ponds	■			■						
Stabilisation ponds + high rate pond	■	■		■	■		■			
Stabilisation ponds + algae removal										
Low rate infiltration	■	■	■	■	■	■	■	■	■	
Rapid infiltration	■	■	■	■	■		■			
Overland flow	■	■		■						
Constructed wetlands										
Septic tank + anaerobic filter										
Septic tank + infiltration	■	■	■	■	■	■				
UASB reactor										
UASB reactor + activated sludge	■	■								
UASB reactor + submerged aerated biofilter	■	■								
UASB reactor + anaerobic filter										
UASB reactor + trickling filter (high rate)										
UASB reactor + maturation ponds	■			■						
UASB reactor + overland flow	■	■		■						
Conventional activated sludge	■	■	■							
Extended aeration	■	■	■							
Sequencing batch reactor	■	■	■							
Activated sludge with biological N removal	■	■	■	■	■	■				
Activated sludge with biological N/P removal	■	■	■	■	■	■	■	■	■	
Activated sludge + tertiary filtration	■	■	■				■			
Low rate trickling filter	■	■								
High rate trickling filter										
Submerged aerated biofilter	■	■	■							
Submerged aerated biofilter with biological N removal	■	■	■	■	■					
Rotating biological contactor	■	■								
Any of the above technologies + chemical P precipitation							■	■	■	■

necessary for monitoring, controlling, regulating and enforcing the standards. This topic is well discussed by Johnstone and Horan (1996) and some of the points are summarised below.

Institutional development takes time and the models cannot be directly copied from developed countries. Even though lessons should be learned from other countries which have already passed the basic steps of institutional development, an adaptation is also required in order to accommodate the countries' specific economic, cultural and social conditions. However, experience from other countries can help in structuring the organisations, especially when they are introduced for the first time. It must be recognised that institutional development is a continuous process building on the experience of prior organisations.

Another important point is the need to separate the duties and responsibilities of regulating quality with those of achieving standards. This is especially true when private sector operators have to comply with standards.

The main points to be emphasised for developing countries are (Johnstone & Horan, 1996): (a) consider the process of institutional development and technical improvements to be long term; (b) build on past experiences; (c) separate regulatory and operational duties and responsibilities; (d) develop regulatory systems and procedures needed to enforce standards; (e) ensure that sufficient legal powers are in force; (f) recognise the costs of regulation and legal enforcement.

6. Conclusions

- Stepwise implementation of standards and of sanitary systems is an approach which should be adopted by developing countries.
- The concept of targets should be included in developing countries' legislations. Limiting values for water quality concentrations should be considered as targets to be achieved over time, and not as absolute values. Developing countries are likely to take more time to achieve the targets than developed countries.
- Discharge standards should be adapted periodically, eventually allowing targets for receiving water bodies to be achieved.
- Institutional development is also an integral part in the implementation of standards and needs to be pursued by countries.

Table 5
Capacity of sewage treatment technologies, in terms of consistently achieving the indicated effluent quality for faecal coliforms and helminth eggs

System	Faecal coliforms (FC/100 ml)				Helminth eggs
	1 x 10^6	1 x 10^5	1 x 10^4	1 x 10^3	≤ 1 egg/l
Facultative pond	■				■
Anaerobic pond + facultative pond	■	■			■
Facultative aerated lagoon	■				
Completely mixed aerated lagoon + sedimentation lagoon	■				■
Stabilisation ponds + maturation ponds	■	■	■	■	■
Stabilisation ponds + high rate pond	■	■			
Stabilisation ponds + algae removal	■	■			
Low rate infiltration	■	■	■	■	■
Rapid infiltration	■	■	■		■
Overland flow	■				■
Constructed wetlands	■	■			■
Septic tank + anaerobic filter	■				
Septic tank + infiltration	■	■	■	■	■
UASB reactor					
UASB reactor + activated sludge	■				
UASB reactor + submerged aerated biofilter	■				
UASB reactor + anaerobic filter	■				
UASB reactor + trickling filter (high rate)	■				
UASB reactor + maturation ponds	■	■	■	■	■
UASB reactor + overland flow	■	■			■
Conventional activated sludge					
Extended aeration	■				
Sequencing batch reactor					
Activated sludge with biological N removal					
Activated sludge with biological N/P removal					
Activated sludge + tertiary filtration	■	■	■	■	■
Low rate trickling filter					
High rate trickling filter					
Submerged aerated biofilter					
Submerged aerated biofilter with biological N removal					
Rotating biological contactor					
Any of the above technologies + disinfection / barrier (a)	■	■	■	■	Variable

[a] Disinfection: e.g. Chlorination, Ozonation, UV radiation; Barrier: e.g. Membranes (provided disinfection/barrier process is compatible with effluent from preceeding treatment).

- The majority of commonly applied treatment technologies are capable of achieving reasonable (not very stringent) values of effluent quality for BOD, COD and, to some extent, SS, compatible with most existing discharge standards or effluent criteria.
- The reverse applies to ammonia, nitrogen, faecal coliforms and especially to P, for which only a limited range of treatment technologies can generate an effluent compatible with most existing standards or effluent criteria.
- Discharge standards need to be based on existing capable and affordable wastewater treatment technologies, in order to be put into real practice, and play their role as a tool for environmental and public health protection, especially in developing countries.

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