ON THE PERFORMANCE OF 78 WASTE STABILIZATION PONDS SERIES IN NOTHEAST OF BRAZIL

P. A. Silva Filho*, A. L. C. Araújo, F. B. B. Medeiros***, C. O. Andrade Neto****, M. A. C. Duarte*****

* National Health Foundation (FUNASA), Rio Grande do Norte Branch, Natal-RN, Brazil. pedroasfilho@yahoo.com.br
**Department of Natural Resources, Technological Education Federal Centre of Rio Grande do Norte. Post-Graduation Program of Sanitary Engineering, Federal University of Rio Grande do Norte. Avenida Senador Salgado Filho, 1559, Tirol, 59000-015, Natal-RN, Brazil. acalado@cefetrn.br
***Rio Grande do Norte Water and Wastewater Company. Natal-RN, Brazil
**** Post-Graduation Program of Sanitary Engineering, Federal University of Rio Grande do Norte. Natal-RN, Brazil. Cicero@ct.ufrn.br
***** Department of Natural Resources, Technological Education Federal Centre of Rio Grande do Norte. Rio Grande do Norte Water and Wastewater Company. Natal-RN, Brazil. Avenida Senador Salgado Filho, 1559, Tirol, 59000-015, Natal-RN, Brazil.

ABSTRACT
This study aims to evaluate the performance of all 78 waste stabilization ponds systems, in the State of Rio Grande do Norte, Northeast of Brazil. Maintenance and operational practices of all systems were locally evaluated and samples of raw sewages and pond effluents were taken in order to verify their efficiencies on the removal of BOD and faecal coliform. Results showed that only 9% of the evaluated systems obtained a maximum concept on BOD and Coliforms removal, whilst 41%, had the worst concepts in terms of efficiency. The affluent raw sewage in the State presented mean values of BOD and Coliforms of 458 mg/L and 2.54 x10^7 UFC/100 ml, respectively. BOD value was found 30% higher than 350 mg/L, the common values adopted in projects, and BOD/COD relation attested high degradability of sewage. The predominant configuration was a primary facultative, followed by two ponds maturation and almost 50% of all systems did not present a preliminary treatment. The lack of maintenance and operation as well as the use of inadequate project parameters were found to be the main factors to bring the performances of ponds bellow the expected.
KEYWORDS: Maintenance and operation practices, Performance, Sewage characteristics, Waste stabilization ponds,

INTRODUCTION

The use of the waste stabilization ponds (WSP) began in the United States a century ago. They used then to receive domestic sewage from small communities, and, incidentally, they observed these systems improved the effluent quality due to biodegradation processes. Many authors define stabilization ponds as large tanks of small depth, designed to treat wastewater, by means of natural processes (SILVA and MARA, 1979; UEHARA and VIDAL, 1989).

Today, that concept is more comprehensive. These lakes are mainly inland basins of lentic waters, relatively shallow, built to store specific waste such as domestic or industrial, in which the stabilization of organic matter occurs only through biological processes. The biological treatment can occur under anaerobic, facultative or aerobic conditions, according to the availability of dissolved oxygen, led by affluent organic loadings and the physical characteristics of the plant.

WSP systems when well designed, operated and maintained, may produce high quality effluents. In the Rio Grande do Norte State, Northeast Brazil, raw sewage and effluents is, in many places, the only available water resource for irrigation, and its use for this practice is very common. However, WSP are often designed based on under estimated parameters, they are not properly operated and maintained and their configurations normally are not proper to produce good quality effluents. As a

consequence, these effluents still have a large concentration of DOB and pathogenic microorganisms, which put at risk the health of the workers and consumers.

The State of Rio Grande do Norte has under operation 78 WSP systems, however, there are no guidelines for operation and maintenances practices, even by the Water and Wastewater State Company (CAERN). So, this study aimed to realize a general diagnosis of construction, operation and maintenance for all 78 WSP in the State in order to establish a correlation with their performances. The specific objective was to develop a geographical Information System - GIS, compiling all information about sewage treatment in the State by means of WSP.

MATERIAL AND METHODS

Rio Grande do Norte State

The study area comprises the state of Rio Grande do Norte, whose geographical coordinates are: North: 4° 49'53"S and 37 ° 15'11"W; South: 6°58'57"S and 36 43'01"W; East: 6° 29'18"S and 35 ° 58'03"W and West: 6° 23'23"S and 38 ° 36'12" W. This area is located in the Northeast Region of Brazil, covering an area of 53,306 km^2, equivalent to 0.62% of national territory and 3.41% in the Northeast Region. The state has 167 municipalities with a total population of 2,771,538 inhabitants (ATLAS, 2004). The research covers 51 counties that treat their sewage through the waste stabilization ponds (a total of 78 WSP systems). The work was based on the identification of all WSP, and monitoring their performances, as well as observe the routine operational and maintenance practices.

Field work

Initially, a survey was conducted, in the Archives Division and Laboratories of CAERN, of all projects of WSP in the State. With these data a scale of *in loco* visiting was planned. Afterwards, all 78 WSP systems were visited. All visits were carried out by the transport support of the Regional Coordination of National Health Foundation (FUNASA/CORE/RN) from December 2005 to July 2006.

Each field team was composed by a driver, a biologist and an engineer. During the visits, a Daily Operational Control Schedule (DOCS), developed particularly for this research, was applied. This spreadsheet was a model questionnaire used for understanding of operational practices and makes a diagnosis of these procedures. The procedures for the implementation of DOCS are described below:

- General data of the WSP: the GPS coordinates; the name of ETE's and date of visiting. There was also done a croqui, identifying the kinds of ponds with their actual dimensions (length, width and depth).
- Field Survey: the behaviour of the WSP in terms of operation and functionality of the system. It was also possible to detect the destination of the final effluent, the frequency of operation and maintenance, the use of personal protection equipment by the operator, the knowledge by the operator of the operational practices. It was also investigated and measured the distance of WSP in relation to the nearest residence.
- In situ Physical-chemical parameters: flow rate, temperature, pH, dissolved oxygen, and settling solids. Samples were collected and taken to laboratory for posterior analysis.

Laboratory work

Collected samples during field work were analyzed for BOD, COD and faecal coliform following the APHA et al. (1998) recommendations. It is important to point that from 78 WSP's in operation,

only 32% have been frequently monitored by CAERN, so, this stage was directed to the others 68%.

Operational survey

In possession of all operational data obtained in the previous steps, it was possible to evaluate the effectiveness of each WSP. For the development of efficiency diagnostic of WSP, the following concepts were defined, within the range established, as presented in Table 1.

The limit (1000 CF/100 ml) refers to the standard for faecal coliforms, for rivers of Class 3 (CONAMA 357/2005). For animal drinking, irrigation and other uses, the limit is $\leq 10^4$ CF/100 ml According to Ceballos (2005), there are bacteriological standards 10 times less restrictive, used for irrigation in most rivers and lakes in the world, with values ranging from 10^3 to 10^4 CF/100ml. To BOD, the limit of 50 mg/L, refers to the maximum efficiency that stabilization ponds can reach, which, according Von Sperling (2005), and Jordão e Pessoa (2005), is around 80 to 85%. As they treat predominantly domestic sewage, it is commonly based in a range of BOD affluent of 300 - 350 mg/L.

Table 1. Ranges used to attribute concepts for the WSP systems.

Concept		Ranges	Efficiency (%)
GOOD	BOD	BOD $\leq$ 50mg/L	$\geq$ 80%
	Faecal coliform	FC $\leq 10^3$ FC/100ml	$\geq$ 3 log
MEDIUM	BOD	50 mg/L $\leq$ BOD <180mg/L	60% to 79%
	Faecal coliform	10^3 FC/100ml $\leq$ FC < 10^4 FC/100ml	1 – 2 log
POOR	BOD	BOD> 180mg/L	< 60%
	Faecal coliform	FC > 10^4 FC/100ml	< 1 log

The final stage includes the statistical treatment. The results were structured in a Microsoft Excel spreadsheet and subjected to statistical treatment through the program Statistic 6.0 for Windows, version 2002, in order to verify the correlation of values. Descriptive statistics was performed to give central tendency values (arithmetic and geometric means, median) and dispersion values (standard deviation, quartiles, range).

RESULTS

Use of WSP in Rio Grande do Norte

The use of WSP started in the beginning of 1980 with the construction of 12 systems. In 1990 the State had 43 WSP and nowadays it has 78 WSP systems in operation in 52 municipalities, being the principal technology for sewage treatment in the State. This fact is related to the advantages of ponds such as low cost of construction, operation and maintenance, besides the high performance they can achieve, particularly in regions with a high mean temperature and solar radiation, such as the northeast of Brazil (Araújo at al., 2003).

Design configuration

From 78 WSP, 15% are a single primary facultative pond and 22% are a single primary facultative pond followed by a maturation pond. The predominant series configuration is a single facultative pond, followed by two maturation ponds with a total 36 WSP, which represents 46% of all systems. The remaining 15% are series of septic tanks followed by a secondary facultative pond and aerated ponds and series with anaerobic pond. It is important to point that, due to operational problems

associated with production and final destination of sludge and generation of odors, the designers have avoid the use of an anaerobic phase on WSP series (Andrade Neto, 1997).

The presence of the preliminary treatment composed by screening, grit removal and Parshall flume, was observed only in 38 WSP's. The absence of this phase obviously had a negative impact on the performance of these series and, on the aesthetic point of view, due to the accumulation of sludge, sand, floatable solids and vegetation.

Operational practices

According to von Sperling (2002), it is necessary at least 3 workers in WSP systems attending a population higher than 10,000 to carry out all the daily operation and maintenance activities. However, in 52 out of 78 WSP systems, which represent 67%, there is only one operator, while in the remaining systems, operation and maintenance procedures are not performed. The presence of an operator in the system does not represent that series are correctly operated: they generally have no knowledge about operational procedures, they do not use individual protection equipments (IPE), and besides they have activities in others sectors of the Company. Figure 1 resumes the operator's profiles in the WSP.

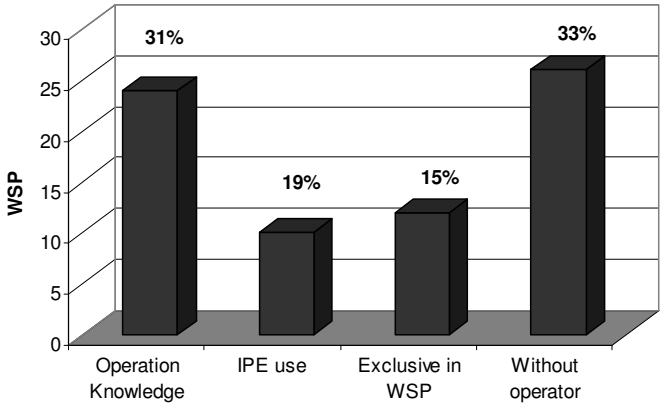

Figure 1. Operator's characteristic is WSP systems in Rio Grande do Norte – Brazil.

Table 2 shows the results about the removal of solids from preliminary treatment and ponds. In most cases, removals occur due to complaints by the surrounding population, or by the intimation of the Environmental Attorney. The systems with daily and weekly frequency of cleaning are just the ones which have exclusive operators. None of the systems has a proper place for the disposal of the material removed, being this, generally disposed aside the ponds.

Table 2. Frequency of solids removal in WSP systems.

Frequency of cleaning	38 WPS Solids Removal (Screening)	%	78 WSP Sludge Removal	%	38 WSP Grit Removal (Grit chamber)	%
Daily	8	21	8	10	8	21
Weekly	17	45	14	18	18	47
Biweekly	-	-	2	3	-	-
Monthly	5	13	4	5	5	13
Bimonthly	6	16	4	5	4	11
Casual*	2	5	46	59	3	8

* Semester or by intimation.

Performance evaluation

Only 9% of the WSP achieved a good performance while the majority (41%) had a performance considered as poor, as shown in Figure 2. Figure 3 depicts all 78 WSP systems of Rio Grande do Norte with their performance evaluation. It is important to point that these poor quality effluents may cause environmental impacts on the receiving water bodies as well as health risks when used for irrigation. The term "other", set in Figure 2, refers to WSP's in the final stages of construction or in the process of commissioning. The final effluent is discharged in river from 47 WSP (59%), being half perennial and half occasional rivers. In 22 WSP (29%) effluent is directly disposed on soil and in 9 WSP (12%), effluent is reused for irrigation.

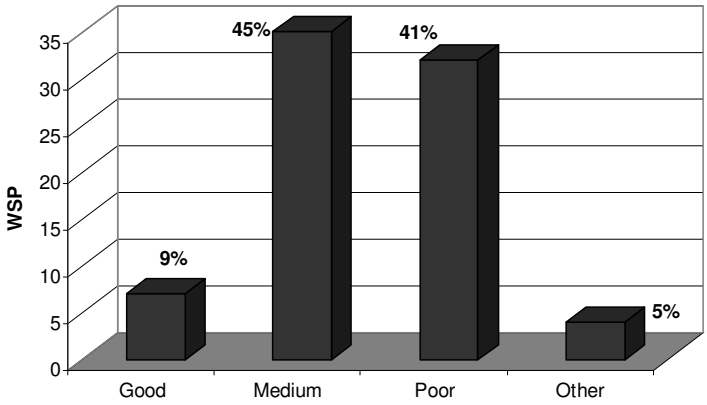

Figure 2. Performances on the removal of BOD and Coliform in WSP systems.

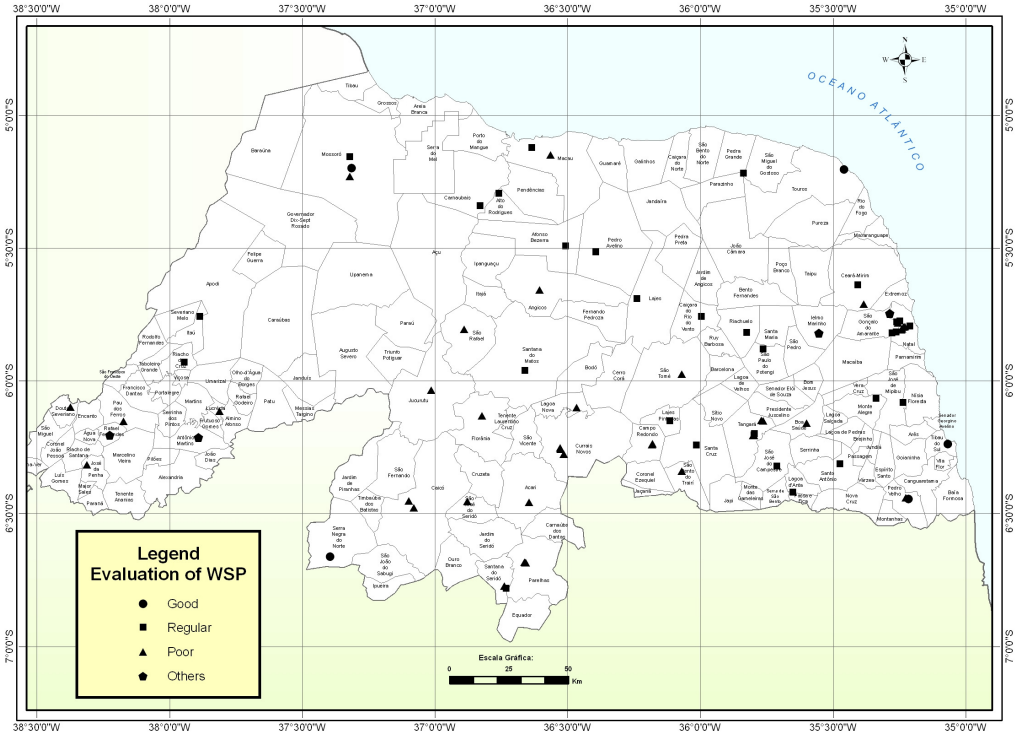

Figure 3. Map with the evaluation of all 78 WSP systems in Rio Grande do Norte State.

Best performances were observed in WSP with some particularities: the presence of an exclusive operator with knowledge of operation and maintenance procedures; systems designed with appropriated parameters according to local reality; and systems constructed as designed. Also it is

important to point that the values depicted in Table 1 do not take in consideration the system configuration.

It was expected, and verified that best results occurred in series of facultative and 2 maturation ponds while higher BOD and faecal coliform concentrations in final effluents were commonly observed in systems with just a primary facultative pond and a septic tank followed by a secondary facultative pond. Besides configuration, poor performances can also be related with lack or wrong operational practices. Also, in some systems it was observed that construction did not followed the project, such as depth and area, which consequently interfere with the hydraulic detention time and organic loadings. Around 95% of WSP are located too near of urban areas and in all systems commissioning was not properly performed.

During project phase, designers rarely know the real characteristics of affluent raw sewage. They generally use typical values expressed by literature which can lead to wrong results. Table 3 compares the affluent characteristics of the WSP's in the State, with their typical range, according to literature.

Table 3. Typical and real characteristics of raw sewage.

Parameter	Usual concentration*		Real Concentration
	Range	Typical	Mean
BOD (mg/L)	250-400	300	**458**
COD (mg/L)	450-800	600	**821**
pH	6.7-8.0	7.0	7.0
Temperature (°C)	22-30	29	29
Faecal coliform (ufc/100ml)	10^6 - 10^9	$5.0x10^7$	$2.54x10^7$

Sources*: Silva e Mara (1979); Uhera e Vidal (1989); Von Sperling (2005).

Data highlight in Table 3 shows that raw sewage in the State have a higher concentration of organic matter than that usually expressed in literature and used on the projects (it is common in the State the adoption of a BOD of 350 mg/L and faecal coliform of $7.5x10^7$). In same cases, these high values are related to industrial wastes contribution, particularly from slaughterhouses, or due to the use of grab samples instead of composite. However, in most cases the main cause may be the linked to low water per-capita consumption rate, as the study area is predominantly in an arid region, with scarce water resources.

Table 4 presents the characteristics of raw sewages, final effluents, and the performances of the series of ponds studied. Among the systems analyzed, the series that presented best performances on the removal of both BOD and COD, and microorganisms, were composed by primary facultative and two maturation ponds. BOD affluent and final mean concentrations were 429 mg/L and 136 mg/L, respectively, reaching a total efficiency of 69%. As for COD, these values were 699 mg/L and 240 mg/L, respectively, with a removal of 65%. Removal of faecal coliform was only 2 log units (99.34%), reaching an average concentration on the final effluent of $1.88x10^5$ ufc/100 ml.

These figures are well below those found literature for WSP with this configuration. Jordão e Pessoa (2005), for example, presents a range of 80% - 85% on BOD removal and of 70% - 80% for COD. According to them faecal coliforms removal in a 3 pond series is of 3 to 6 log units.

Table 4. Raw sewage and effluent mean concentration, and performance of WSP on the removal of BOD, COD and faecal coliform, according to system configurations.

Configuration*	Raw sewage - effluent mean concentration			Efficiency (%)		
	BOD (mg/L)	COD (mg/L)	Coliform (UFC/100ml)	BOD	COD	CF (unit log - %)
F1	439 - 217	648 - 333	4,83E+07 – 3,58E+06	50	48	≈ 1,0 - 92,58%
F1+M1	351 - 107	530 - 200	1,13E+07 – 3,42E+05	69	62	≈ 1,0 - 96,97%
F1+M1+M2	429 - 136	699 - 240	2,87E+07 – 1,88E+05	69	65	≈ 2,0 - 99,34%
ST+F2	590 - 294	751 - 391	2,80E+07 – 3,19E+06	50	47	< 1,0 - 88,60%
Others	789 - 177	2450- 319	2,97E+07 - 7,98E+05	78	87	1,0 - 97,31%

* F1 (primary facultative); F1+M1(primary facultative + maturation pond); F1+M1+M2 (primary facultative + 2 maturation ponds); ST+F2 (Septic tank + secondary facultative pond) and Others (aerated ponds; anaerobic).

The higher efficiency on BOD and COD removal by the configuration “Others” is related to the presence of an anaerobic pond in the series. It is well know the high efficiency of these reactors on the removal of organic matter which can improve the total removal in series up to 85 % (Jordão e Pessoa, 2005). Values of pH, dissolved oxygen, and temperature were within the ranges cited in the literature.

The relationship DBO/DQO observed for the affluent (0.55) and effluent (0.59) were within the range reported as usual for domestic sewage indicating their high degradability as well as in the final effluent.

CONCLUSIONS

Only 38 WSP systems have a preliminary treatment (screening and grit removal) and the frequency of solid materials removal in around 25 of them, is daily or weekly. Casual removals occur in the others 40 WSP.

There is no operator in 33% of the WSP. In the others 66%, which have operator, daily operation and maintenance practices are far from the desired quality. Majority of WSP are completely abandoned, with excess of grit, sludge and vegetation.

Raw sewage mean concentration in term of BOD and COD were 458 mg/L and 821 mg/L, respectively and BOD/COD relation was 0.55. Value of DBO was 30% higher than common value adopted in projects.

Mean BOD removal of 70% was observed in series of F1+M1 and F1+M1+M2. In systems comprised by single facultative pond (F1) and septic tank followed by secondary facultative ponds (ST + F2) the removal decreased to 50%. This poor removal found in a series with an anaerobic pre-treatment is probably related with the low level of operation on these tanks as they are working for many years without being cleaned. On the other hand the highest removal of around 80% was found in series with an anaerobic pond and is also associated with high values of DBO found in affluent raw sewage.

Many facts can be pointed out as pushing down the performance of the WSP in the Rio Grande do Norte State. Among them: the lack of correct operational and maintenance procedures; the use of inefficient configurations and unrealistic design parameters; and the construction of just a part of the whole system.

REFERENCES

ANDRADE NETO, C. O. Sistemas simples para tratamento de esgotos sanitários: experiência brasileira. Rio de Janeiro: ABES, 1997.

APHA et al.. Standard methods for the examination of water and wastewater. 18. ed. New York : Public Health Association Inc, 1998.

ARAÚJO, A. L. C. et al. Avaliação de quatro séries de lagoas de estabilização na Grande Natal na remoção de matéria orgânica e coliformes fecais. In: XXII CONGRESSO BRASILEIRO DE ENGENHARIA SANITÁRIA E AMBIENTAL. Joenvile-SC. 2003.

ATLAS do Rio Grande Do Norte. Natal: Governo do RN, 2004.

BRASIL. Portaria Nº 357, de 19 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamentos de efluentes, e dá outras providências. Brasília: Ministério do Meio Ambiente, 2005.

CEBALLOS, B. O. Aspectos sanitários do reúso de águas. In: SEMINÁRIO NACIONAL DE REÚSO DE ÁGUAS, 2005, Natal. Anais... Rio de Janeiro: ABES, 2005. 1 CD.

JORDÃO, E. P.; PESSOA, C. A. Tratamento de esgotos domésticos. 4. ed. Rio de Janeiro: ABES, 2005.

SILVA, S. A.; MARA, D. D. Tratamento biológico de águas residuárias: lagoas de estabilização. Rio de Janeiro: ABES, 1979.

UEHARA, M. Y.; VIDAL, W. L. (Org.). Operação e manutenção de lagoas anaeróbias e facultativas. São Paulo: CETESB, 1989.

VON SPERLING, M. Lagoas de estabilização. 2. ed. rev. e atual. Belo Horizonte: UFMG/DESA, 2002.

VON SPERLING, M. Introdução à qualidade das águas e ao tratamento de esgotos. 3. ed. Belo Horizonte: UFMG/DESA, 2005.