POTENTIAL FOR REUSE OF WASTE STABILIZATION POND EFFLUENT FOR IRRIGATED AGRICULTURE[1]

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1 ABSTRACT

The potential for reuse of a waste stabilization pond effluent was evaluated for irrigated agriculture. This system consists of anaerobic, facultative and maturation ponds and is located in Ajapi, District of Rio Claro -Brazil. Samples of raw domestic wastewater and of the final clarified wastewater were collected and analyzed for pH, COD, BOD_5, electrical conductivity, total and suspended solids, N, P, Ca, Mg, Na and the heavy metals: Cd, Cu, Cr, Ni, Fe, Mn, Pb and Zn. The results demonstrated that the treatment system showed a good efficiency of COD, BOD_5 and suspended solids removal of 77.7 %; 91.6 % and 63.1%, respectively. Heavy metal concentrations in the effluent were often below detectable levels. The results of BOD_5, suspended solids and faecal coliforms for the effluent, enable the crops that can be irrigated with this effluent, to be specified based on the World Health Organization (WHO) guidelines. Thus, the results demonstrated that this effluent has potential to be reused for irrigation of crops.

KEYWORDS: irrigation wastewater reuse, waste stabilization pond system, pollution risks

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2 RESUMO

No presente trabalho foi avaliado o potencial do reuso de efluente de sistema de lagoas de estabilização na irrigação. O sistema estudado localiza-se em Ajapi, Distrito de Rio Claro (SP-Brasil) e recebe as águas residuárias de uma população de aproximadamente 3.000 habitantes. Consiste de lagoa anaeróbia, facultativa e de maturação, dispostas em série. Amostras do esgoto bruto e do efluente final do sistema foram coletadas e analisadas quanto aos parâmetros pH, DQO (demanda química de oxigênio), DBO (demanda bioquímica de oxigênio), condutividade elétrica, sólidos suspensos, N, P, Ca, Mg, Na e quanto aos metais pesados Cd, Cu, Cr, Ni, Fe, Pb e Zn. Os resultados demonstraram que o sistema de tratamento apresenta boa eficiência de remoção de DQO, DBO e sólidos suspensos, próximas de 77,7 %, 91,6 % e 63,1 %, respectivamente. Os metais pesados no efluente na maioria das amostras não foram detectados, encontrando-se em concentrações abaixo do limite de detecção do aparelho. Com os resultados de DBO, sólidos suspensos e coliformes fecais para o efluente foi possível determinar as culturas que podem ser irrigadas no caso de reuso desse efluente, com base nas normas da Organização Mundial da Saúde (OMS). Portanto os resultados demonstraram que o efluente do sistema estudado tem um considerado potencial para ser utilizado na irrigação.

UNITERMOS: reuso de águas residuárias, irrigação, lagoas de estabilização, riscos de poluição.

3 INTRODUCTION

The reuse of domestic wastewater for crop irrigation has been described since the time of ancient Greece. During the second half of the 19th century there was a considerable increase in the number of reuse systems in Europe, where the pollution levels of many rivers had reached unacceptable levels. The distribution of domestic wastewater in the soil was thus one of the most feasible treatment and disposal alternatives.

However, with the increase in the domestic wastewater production as a result of the growth of the cities, the development of sewage systems in the beginning of the 20th century and the lack of pollution control of the waters, has lead to a significant reduction in the domestic wastewater use for irrigation (Hespanhol, 1990).

In the last two decades, the use of domestic wastewater for crop irrigation has been revived in many arid and semi-arid regions of the world as an answer to population increase, lack of water and the demands of agriculture (Hespanhol & Prost, 1994). Bartone & Arlosoroff (1987) presented data that show that several countries have large areas irrigated by sewage but these systems do not respect the necessary cautionary measures. Some of these, such as in Mexico and Chile, in some areas and at the driest periods of the year, reuse almost 100% of the total domestic wastewater production from these areas. In Florida /USA/ experiments in the reuse of domestic wastewater for irrigation have been performed with citrus crops and demonstrate positive results (John & Jackson, 1993).

At present, it is strongly recommended to reuse only treated domestic wastewater due to the problems related to the spread of pathogens. With respect to the reuse of effluents of domestic wastewater treatment plants for irrigation, the use of the effluents of waste stabilization pond systems has shown itself to be one of the most satisfactory (Hespanhol, 1990).

Within this context, the object of this work is to demonstrate the potential for the reuse in irrigation of a waste stabilization pond system effluent. The system consists of anaerobic, facultative and maturation ponds.

3.1 Domestic wastewater reuse

Reuse of domestic wastewater in agriculture offers a number of key benefits: (1) an increase in agricultural production due to the increase in irrigated area, multiple planting seasons and an increased productivity per unit area; (2) conservation of scarce water resources for other higher-value uses and (3) prevention of environmental problems caused by other methods of disposal (Bartone & Arlosoroff, 1987).

Some negative effects of domestic wastewater irrigation deserve attention. These include: (1) the risk of disease transmission from wastewater to workers and to the consumers of the products grown in domestic wastewater irrigated fields and (2) the pollution risk of surface and subterranean water by pathogenic organisms and chemical products that effluents of irrigation might contain (Bartone & Arlosoroff, 1987).

Some pathogenic groups show greater risks of disease transmission than others. In the case of infections transmitted by reuse of domestic wastewater, worms present a greater risk due to their long latent period in the soil for transmission and long persistence in the environment. The infection risks due to protozoa and bacteria are intermediate, being located between the risks caused by worms and viruses (Shuval, 1986). Shuval (1986) propose some effective measures for reducing the negative effects on health associated with irrigation by raw domestic wastewater: (1) use of wastewater treatment and/or storage methods that reduce the concentration of the most important pathogens; (2) restrictions on the types of crops irrigated, so preventing the contact of vegetables for raw consumption with domestic wastewater and (3) the use of irrigation methods that minimize contact between crops and domestic wastewater. The scientific group for health standards for the use of domestic wastewater in agriculture and aquaculture of the World

Health Organization (WHO) established basic criteria for the health protection of groups at risk in reuse systems and recommended the norms shown in Table 1.

Table 1 - Microbiological quality guidelines recommended by WHO for the domestic wastewater use in Agriculture

Category	Reuse conditions	Exposed groups	Intestinal nematodes (number of eggs per litre)	Faecal coliforms (number per 100ml)	Domestic wastewater treatment to achieve microbiological quality
A	Irrigation of vegetables consumed raw, sports fields, public parks	Workers, consumer, public	< 1	< 1,000	A series of stabilization ponds or equivalent treatment
B	Irrigation of cereals, industrial crops, pastures and trees	Workers	< 1	Not applicable	Retention in stabilization ponds for 8-10 d
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment by irrigation technology

Source: Hespanhol (1990)

Blumenthal (1996) suggests a stricter guideline quantity of 0.5 egg of intestinal nematodes per litre. Some countries established their own regulations according to their local conditions. Mexico, which is possibly the country that most utilizes domestic wastewater irrigation, has its own standards according to the local conditions and has demonstrated a great effort in restricting irrigation only to crops destined for industrial processing, cereals and vegetables that will not be consumed uncooked (Bartone & Arlosoroff, 1987).

Generally, conventional sewage treatment processes without final disinfection are inefficient for pathogenic organisms removal. However, in addition to removing the BOD_5, waste stabilization pond systems with hydraulic retention times of 10 to 50 d (depending on the temperature), have been shown to effectively remove worms and a large number of bacteria and virus, producing effluents within the standards of emission of such pathogens (Bartone & Arlosoroff, 1987).

The waste stabilization pond system, normally comprising an anaerobic, a facultative, and a maturation pond, in serial arrangement, is considered an efficient, easilly-operated, low cost wastewater treatment system (Shereif, 1995). Raw wastewater initially enters the anaerobic pond for organic matter digestion, resulting in removal of the greater part of the organic load (BOD_5). The wastewater is then conducted to a facultative pond where both BOD_5 and pathogens are removed. Finally, the wastewater enters the maturation or polishment pond, for pathogen removal (CETESB, 1989).

Daniel & Campos (1993), studied three domestic wastewater treatment plants and observed that a waste stabilization pond system consisting of an anaerobic, a facultative and a maturation pond, with a total hydraulic retention time of 16.5 d, showed a coliform removal efficiency of 99%, which was superior to the removal percentages attained by a septic tank followed by an anaerobic filter and anaerobic baffled reactor, that gave 52% and 94% respectively. Hespanhol (1990) shows the results of a waste stabilization pond system in the northeast of Brazil, in terms of the removal of BOD_5, suspended solids, faecal coliforms and intestinal nematode eggs. These results are shown in Table 2.

Table 2 - Performance of a series of five waste stabilization ponds in the northeast of Brazil.

Sample	Hydraulic retention time, d	*BOD_5, mg/l	Suspended solids, mg/l	Faecal coliforms, number per 100ml	Intestinal nematode eggs
Raw wastewater	—	240	305	$4,6x10^7$	80^4
Effluent of:					
anaerobic pond	6.8	63	56	$2.9x10^6$	29
facultative pond	5.5	45	74	$3.2x10^5$	1
maturation pond 1	5.5	25	61	$2.4x10^4$	0
maturation pond 2	5.5	19	43	450	0
maturation pond 3	5.8	17	45	30	0

* BOD_5: biochemical oxygen demand Source: Hespanhol (1990)

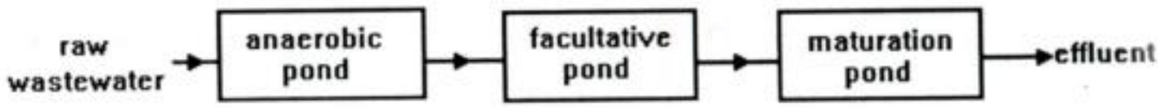
In Israel the greater part of the domestic wastewater system is treated by stabilization pond systems and a significant portion of the effluent produced is reused in agriculture (Shelef, 1987). Ceballos (1995) studied a waste stabilization pond system in the NE of Brazil with a hydraulic retention time of 61 d and achieved a 95 % BOD_5 removal efficiency which no helminth eggs in the effluent.

When considering the use of water for crop irrigation, it is necessary also to consult the irrigation water classification diagram of the U.S. Salinity Laboratory Staff (Bernardo, 1989) and to verify the possibility of its use for irrigation because of the possibility of soil salinization, as well as alkalization hazard.

4 MATERIALS AND METHODS

The study was conducted on the Ajapi waste stabilization pond system in the district of Rio Claro, Brazil, a project of the Consórcio Intermunicipal dos Rios Piracicaba e Capivari (Intermunicipal Agency for the Piracicaba and Capivari Rivers). The importance of the domestic wastewater treatment of Ajapi lies in the fact that the river that receives the Ajapi wastewater supplies water for the urban demand of a city of 150,000 inhabitants.

This system was designed to serve a population of approximately 3,000 inhabitants, being made up of two pond systems in parallel, without any type of automation (i.e. aerators, stirring devices, and collectors). In each system an anaerobic, a facultative and a maturation pond are present. Figure 1 shows a simplified sketch of this system.



Flow: 1,000 m^3/d

Anaerobic pond: retention time 4.6 d; organic charge rate 0.036 kg $BOD_5/m^3.d$; depth 3.5 m

Facultative pond: Retention Time 6.0 d; organic charge rate 204 kg BOD_5/ha.d; depth 1.5m

Maturation pond: Retention Time 6.0 d; depth 1.0 m.

Figure 1 - Simplified sketch of waste stabilization pond system.

Campaigns for sample collection from the system were undertaken in two seasons (spring and summer). Composite samples of raw wastewater, anaerobic, facultative and maturation pond effluents were taken and analyzed for the following parameters: pH, COD, BOD_5; total, suspended, fixed and volatile solids; nitrogen, phosphorus, calcium, magnesium, potassium and heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn). These parameters were determined by the following methods: pH and alkalinity: potentiometric; N-ammoniacal: titrimetric method; P: digestion with persulphate plus vanadomolybdophosphoric acid colorimetric method; COD (chemical oxygen demand) and BOD_5 (biochemical oxygen demand) using the methods described in American Public Health Association (1992). Kjeldahl total nitrogen (Malavolta, 1989). Heavy metals and Ca, Mg and K, were determined through digestion of samples with nitric and perchloric acid and subsequently using atomic absorption spectrophotometry (Malavolta, 1989). The metal detection limits of the AA-275-type atomic absorption spectrophotometer used are shown in Table 3.

Table 3 - The metal detection limits of the atomic absorption spectrophotometer, mg/l.

Element	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Zn
Detection limit	0.0005	0.0006	0.005	0.003	0.005	0.0003	0.003	0.008	0.02	0.002

5 RESULTS AND DISCUSSION

The following results refer to the average values of composition obtained from the samples.

Mean temperatures at the two experimental sites were 28°C and 30°C, respectively. From Table 4 it is possible to evaluate the efficiency of the waste stabilization pond system under study, with respect to the BOD_5 and COD removal.

Table 4 - Values of BOD_5 and COD for the raw wastewater, anaerobic, facultative and maturation pond effluents

Sample	BOD_5, mg/l	COD, mg/l
Raw wastewater	323	413
Anaerobic pond effluent	51	178
Facultative pond effluent	47	124
Maturation pond effluent	27	92
Total system removal, %	91.6	77.7

These results show that the system presents good removal of the organic load, and are similar to the efficiency data presented by Hepanhol (1990) in Table 2. The largest reduction occurs in the anaerobic pond.

As the present work has as its aim demonstrating the reuse potential of Ajapi waste stabilization pond effluent in irrigation, the values of the other parameters are regarding only raw wastewater and system effluent or final clarified wastewater samples.

Table 5 presents the results of the physical parameters determined.

Table 5 - Values of pH, electrical conductivity, sodium adsorption ratio and total and suspended solids

Sample	pH	EC, ms/m	SAR	Total solids, mg/l	Suspended solids, mg/l
Raw wastewater	6.9	—	—	647	198
System effluent	7.1	36	6.86	326	73
Total system removal (%)	—	—	—	49.6	63.1

EC: electrical conductivity

SAR: Sodium adsorption ratio = $$\frac{Na^{+}}{\left[\left(Ca^{++} + Mg^{++}\right)/2\right]^{1/2}}$$

The sodium adsorption ratio (SAR) for the system effluent, determined by Na, Ca and Mg concentrations presented a value of 6.86. This, along with the value of 36 ms/m of the electrical conductivity, made it possible to use the irrigation water classification diagram (U.S. Salinity Laboratory Staff). The effluent presented a medium salinization risk and low alkalization risk, which makes it acceptable for practically all types of irrigation. The system presents good suspended solids removal efficiency, similar to the data by Hespanhol (1990) shown in Table 2.

Table 6 presents values of chemical parameters and faecal coliforms concentration.

Table 6 - Values of chemical parameters, mg/l, and faecal coliforms

Parameter	Raw wastewater	System effluent
Total nitrogen	59.1	7.0
Ammoniacal nitrogen	29.1	1.8
Phosphorus	5.7	2.4
Calcium	151.8	73.6
Magnesium	22.4	8.3
Sodium	—	43.9
Copper	0.04	ND
Iron	1.3	0.37
Manganese	0.15	0.15
Faecal coliforms*, number per 100ml	360,000	9,100

ND: Not detected

*Extracted from Daniel & Campos (1993)

The system under study, referring exclusively to domestic wastewater, presents very low concentrations of heavy metals (Table 6). In the system effluent the heavy metal concentrations are lower than maximum permissible concentrations for irrigation presented by Ayers & Westcost (1991). The metals Cr, Cd, Ni, Pb and Zn were not detected in the samples from the raw wastewater and system effluent.

Thus in this situation the presence of the metals does not imply restrictions for their reuse in agriculture, when taking the necessary care specifically case by case.

As to the values of faecal coliforms presented by Daniel & Campos (1993) in Table 6 for the system effluent, it can be observed that it may be used for the irrigation of crop groups B and C of the WHO guidelines (Table 1), in which are found cereals, pasture, trees, fruit with skin, areas of forest replanting, sugar cane, cotton and crops for industrial processing.

Thus with the present study, it was possible to determine the potential for the reuse of the effluent of the Ajapi waste stabilization pond system in crop irrigation. This option is shown to be of interest as it permits both better development of plant life due to the water provided by irrigation and the recycling of nutrients.

6 CONCLUSIONS

This work intended to demonstrate that the waste stabilization pond system effluents have potential for the reuse in agriculture and that other similar work, should be done to evaluate waste stabilization pond effluent qualities, mainly in arid and semiarid regions, where water resources are scarce.

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