WASTE STABILIZATION POND DESIGN FOR PUERTO AYORA, GALAPAGOS ISLANDS

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INTRODUCTION

This report outlines the design of a simple, efficient, cost-effective wastewater treatment facility for use by the city of Puerto Ayora, located on the island of Santa Cruz in the Galapagos Islands, Ecuador. Puerto Ayora has a population of approximately 15,000 residents. There is currently no effective system in place for treating the entirety of the wastewater generated by the residents; hotels and important public areas use septic systems, but the effluent is not treated and has led to outbreaks of cholera in the past twenty years (CDC). A new design would ensure that public health is preserved.

WASTE STABILIZATION POND

The implementation of a waste stabilization pond system is the best solution for treating the wastewater generated by Puerto Ayora. This method is inexpensive, not requiring heavy machinery or electricity, and having need of only two workers to oversee the facility. While land area is generally restricted on islands, Santa Cruz is highly undeveloped and thus has plenty of space for construction of waste stabilization ponds.

Two ponds, an anaerobic pond and a facultative pond, will be constructed approximately 400 meters to the southwest of Puerto Ayora. This region is relatively flat, and far enough away from the residents that negative pond aesthetics or other disruptions will be avoided. Embankments of each site will be constructed of soil excavated from the site to save costs. A map of the location of the waste stabilization ponds is included in the attached appendix.

The anaerobic pond, designed to remove BOD from the influent wastewater by settling the solids, is designed to accommodate the city at temperatures greater than its average annual minimum temperature of 20°C. The pond will process 1500 m^3 of influent per day (assuming each individual in the city produces 100 L of wastewater per day). The dimensions of the pond will include a length of 31.6 m, a width of 15.8 m, and a depth of 3 m. The length and width follow a 2:1 ratio recommended by Mara (2003) to avoid formation of sludge banks near the inlet to the pond, as well as a depth that will ensure that the pond remains fully-mixed. Total pond surface area is 500 m^3, with a retention time of one day.

Assuming influent BOD is 300 $g{\cdot}m^{-3}day^{-1}$, there will be a 76% removal of BOD from the anaerobic pond. Remaining effluent, 72 $g{\cdot}m^{-3}$ BOD, is too high to be discharged and will require a secondary facultative pond for further disinfection.

The secondary facultative pond, designed to remove BOD by bacterial digestion, will be adjoined to the anaerobic pond along its length. A weir will allow influent BOD at a flow rate of 1500 m^3 per day to enter the pond to begin the disinfection process. The dimensions of the pond will include a length of 178.8 m and a width of 87.4 m, following the 2:1 length-to-width ratio recommended by Mara (2003). The depth of the pond will be a recommended 1.5 m. The surface area of the pond is 4000 m^2, with a retention time of 4 days. The pond is situated such that it receives a high level of wind-mixing, allowing for optimal bacterial growth and thus BOD removal. A diagram of both the facultative pond and the anaerobic pond is included in the attached appendix, as well as the equations used to determine the pond specifications.

BOD removal from the facultative pond was calculated using a rate constant for the minimum air temperature of the island, 20°C, as well as the retention time. Final BOD content in the effluent water is calculated as 14 $g{\cdot}m^{-3}$, a level suitable for surface water discharge (acceptable level is less than 25 $g{\cdot}m^{-3}$ BOD).

SUMMARY

The institution of a waste stabilization pond system, which includes an anaerobic pond and a secondary facultative pond, will remedy the poor wastewater treatment system currently in place in Puerto Ayora. This method is simple, cost-effective, and efficient, and will ensure that public health is preserved for the city's residents.

REFERENCES

Mara, Duncan, 2003. Domestic Wastewater Treatment in Developing Countries. Earthscan, London.

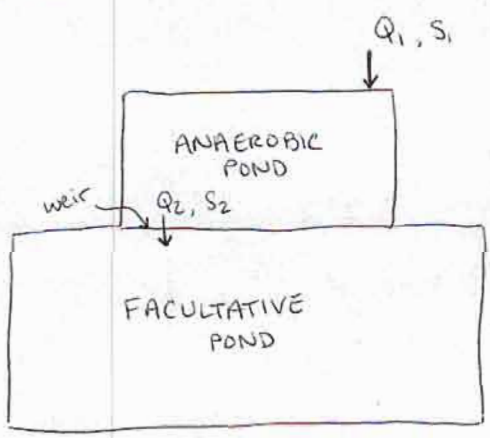
Center for Disease Control (CDC). <http://wonder.cdc.gov/wonder/sci_data/misc/type_txt/outbreak.asp>. Accessed 5/2/05.

APPENDIX A: POND LOCATION AND LAYOUT

(1) LOCATION

◇ - WASTE STABILIZATION POND

(2) LAYOUT



Q_1 = influent flow

S_1 = influent substrate (BOD)

Q_2 = influent flow to facultative pond

S_2 = substrate partially processed from primary treatment

APPENDIX B

CALCULATIONS

1) Anaerobic Pond

$$A_a = \frac{Q\theta_a}{D_a} = \frac{L_i Q}{\lambda_v D_a}$$

(θ_a: hydraulic retention time; L_i: influent BOD; D_a: working depth; λ_v: BOD loading)

Design for 15,000 persons

Assume: each person produces 100 L of wastewater per day

$1\ L = .001\ m^3$

$$100\ L \times \frac{0.001\ m^3}{1\ L} = (0.1\ m^3/\text{person}) \times 15000\ \text{people} = 1500\ m^3$$

$Q = 1500\ m^3$ per day

Lowest $T = 68°F = 20°C$

For air temp of 20°C, loading $= 300\ \frac{g\ BOD}{m^3\ day} = \lambda_v$

(1) Pond Volume:

$$\lambda_v = \frac{L_i Q}{V_a}$$

Assume $L_i = 300\ \frac{mg}{L} \times \frac{1\ L}{0.001\ m^3} \times \frac{1\ g}{1000\ mg} = 300\ g/m^3$

$$V_a = \frac{L_i Q}{\lambda_v} = \frac{(300\ \frac{g}{m^3})(1500\ \frac{m^3}{day})}{300\ \frac{g\ BOD}{m^3 \cdot day}} = \boxed{1500\ m^3}$$

(2) Pond Area

Assuming working depth of 3 m

$$A_a = \frac{L_i Q}{\lambda_v D_a} = \frac{(300\ \frac{g}{m^3})(1500\ \frac{m^3}{day})}{(300\ \frac{g\ BOD}{m^3\ day})(3\ m)} = \underline{500\ m^2}$$

Pond Dimensions:

2:1 length : width ratio

$\therefore A = lw \rightarrow 500 = lw,\ l = \frac{500}{w}$

$2l = w$

$2(\frac{500}{w}) = w$

$1000 = w^2$

$w \approx 31.6\ m,\ l \approx 15.8\ m$

(3) Retention time

$$\theta_a = \frac{A_a D_a}{Q} = \frac{(500\ m^2)(3\ m)}{1500\ m^3/day} = \boxed{1\ day}$$

(4) BOD removal:

Using Table 10.2 : Mara: $\theta_a = 1$ day, BOD removal = 76% Remaining = 24%

$\therefore$ Effluent BOD $= (0.24)(300\ mg/L) = \boxed{72\ mg/L\ BOD} \rightarrow$ GO TO SECONDARY FACULTATIVE POND

2) Secondary Facultative Pond

Effluent BOD = $72\ mg/L = L_i$ (→ g/m^3) $\qquad Q = 1500\ m^3/day$

Assume: optimal depth $D_f = 1.5\ m$

Loading rate $\lambda_s = 350\ kg/ha \cdot day$ (at 25°C ≈ 77°F)

$$350\ \frac{kg}{ha \cdot day} \times \frac{1000\ g}{1\ kg} \times \frac{1\ ha}{10000\ m^2} = 35\ \frac{g}{m^2 \cdot day}$$

(1) Pond Area

$$\lambda_s = \frac{L_i Q}{A_f}$$

$$A_f = \frac{L_i Q}{\lambda_s} = \frac{(72\ \frac{g}{m^3})(1500\ \frac{m^3}{day})}{35\ \frac{g}{m^2 \cdot day}} = 3085.7 \approx \boxed{3086\ m^2}$$

(2) Pond Volume

$$V_f = (A_f)(D_f)$$

$$V_f = (3086\ m^2)(1.5\ m) = \boxed{4629\ m^3}$$

(3) Retention Time

$$\theta_f = \frac{V_f}{Q}$$

$$\theta_f = \frac{4629\ m^3}{1500\ \frac{m^3}{day}} = 3.086\ days \rightarrow \boxed{4\ days}$$ (required minimum)

(4) Recalculated Pond Area (due to new retention time)

$$A_f = \frac{Q\theta_f}{D_f} = \frac{(1500\ \frac{m^3}{day})(4\ days)}{1.5\ m} = \boxed{4000\ m^2}$$

Pond Dimensions

$A = lw \rightarrow 4000 = lw \qquad l = \frac{4000}{w}$

$2l = w \qquad$ 2:1 length:width ratio

$2(\frac{4000}{w}) = w$

$8000 = w^2$

$w = 89.4\ m,\ l = 178.8\ m$

(5) BOD Removal

$$\frac{L_e}{L_i} = \frac{1}{1 + k_1 \theta_f}$$

↑ rate constant

$$k_{1(25°C)} = k_{1(20°C)}\phi = (0.1)(1.05)^{25-20} = 0.13\ days^{-1}$$

$$L_e = \frac{L_i}{1 + k_1 \theta_f} = \frac{72\ g/m^3}{1 + (0.13\ days^{-1})(4\ days)} = 47.4\ g/m^3 \approx \boxed{47\ g/m^3}$$

Filtered BOD:

$$L_e(\text{filtered}) = 0.3(L_e,\ \text{unfiltered}) = (0.3)(47\ g/m^3) = 14.1 \approx \boxed{14\ g/m^3}$$

→ suitable for surface water discharge.

Since $14\ g/m^3 < 25\ g/m^3$

(Mara 2003)