

ALGAL GROWTH POTENTIAL OF WASTE WATER EFFLUENTS
IN HAWAIIAN RECEIVING WATERS

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IN HAWAIIAN RECEIVING WATERS

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ABSTRACT

A laboratory study was conducted to determine the algal growth potential (AGP) of secondary domestic effluents on stream and marine waters in Hawaii. AGP methods developed by the Environmental Protection Agency were used with effluent-receiving water mixtures representative of nutrient levels found in existing effluent disposal situations.

Results of this study are indicative that growth response follows similar patterns for conventional biologically-treated effluents in the four fresh receiving waters tested, with peak growth occurring at a 20% dilution of the effluent. Peak growth conditions occur at a lesser dilution, 40%, in sea water, but this would be an uncommon existing environmental situation in light of outfall design objectives and current practice. Field conditions exist in fresh receiving streams in Hawaii where the effluent dilution is 20% or less, so in situations of excessive stimulation or at lesser dilutions, some inhibition of planktonic growth occurs.

The growth potential response of "standard" test alga with Hawaiian waste waters and receiving waters has been demonstrated.

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INTRODUCTION

Dissolved materials such as PO_4 , CO_2 , Mg, Ca, Fe, B, Mo, Mn, S, K, Na, Co, Cu, and Zn along with N, H, O, and C supply the building blocks for the synthesis of algae and, hence, the formation of organic material. The phenomena is sometimes termed primary productivity and the process is the basis of the food chain. Receiving waters with a small turnover rate, in terms of inflow and outflow, will eventually accumulate enough of the necessary inorganic and organic nutrients from natural sources so that primary productivity will take place. Once reached, such conditions will continue to exist via nutrient recycling unless the nutrients are removed. Such accumulation and recycling over a long period of time will result in eutrophic (nutrient-rich) waters (Dugan 1972). The addition of a nutrient-rich effluent into receiving waters creates an artificial situation. It has the effect of accelerating the input of dissolved nutrients and, correspondingly, causing an increase in primary productivity. Eutrophication thus may occur over a relatively short period of time.

Measuring the potential for algal growth is a direct means of gaging the trophic level in a water. The algal growth potential (AGP) measures the weight of algae which will grow in a water when no other factor other than nutrient level is limiting (McGauhey 1968). The basis of the test is Liebig's law of the minimum which can be stated as "growth is limited by the substance that is available in minimal quantities in respect to the needs of the organism" (EPA 1971). Hence, any essential element which is used before other elements for cell synthesis in a water will determine the maximum mass of the cells. Various authors have indicated that the C, N, and P ratio in a water will normally govern algal productivity and that the ratio may help to indicate the amount and type of algae a water will support (EPA 1971). Of course, this is a gross oversimplification since other factors, such as light, temperature, trace elements, water chemical characteristics, will also influence algal production but, still, the ratio allows a rough insight into the amount and type of algal production (King and Sievers 1973; Gerloff and Fishbeck 1973). An estimate of the C:N:P ratio in algal protoplasm is indicated below:

Reported C:N:P Ratios in Algal Protoplasm by Weight

C:N:P	Source	Organism
41:7:1	Fair, Geyer, and Okun (1968)	Algae
--:5.3:1	Eckenfelder and O'Connor (1961)	Algae
40:7:1	McGregian (1967)	Algae
--:11.4:1	Gerloff and Fishbeck (1973)	Macrophyte
5:1:--	McKinney (1962)	Algae (<i>Elodea occidentalis</i>)
--:4.5:1	Dustan and Menzel (1971)	Average marine phytoplankton

It should be noted that the critical ratio, that is, the minimum amount of each element necessary for cell synthesis, is difficult to predict since many factors are involved. For example, some algae have the ability to store excess P in what is known as luxury uptake (Gerloff and Fishbeck 1973), and C is not usually considered limiting since it may be available from the air-water interface as CO₂, from bacterial respiration, and from bicarbonate-carbonate alkalinity (King and Sievers 1973; Gerloff and Fishbeck 1973).

Fair, Geyer, and Okun (1968) state that since lake waters are generally colder than waste water effluents, sewage discharges at or near the surface may overrun the denser receiving water. Dustan and Menzel (1971) report that for estuaries and coastal marine areas affected by domestic sewage, N is usually the limiting nutrient to algal growth since the N:P ratio is usually about 2.3:1 by weight while in marine phytoplankton it averages around 4.5:1. If one applies similar logic to freshwater algae, N may also be expected to be limiting on the surface of freshwater bodies which receive sewage.

There have been relatively few studies of receiving water productivity in Hawaii for effluent disposal situations. One study was performed for the Oahu Water Quality Program in which untreated, primary, and secondary effluents were assayed in combination with sea water and some indigenous algae (Caperon, Cattell, and Krasnick 1971). Growth response indicated that N was the limiting nutrient and primary effluent was most inhibiting to productivity. This study did not use the recommended Environmental Protection Agency (EPA) procedures, however, since the assay for marine waters (EPA 1974) has only recently been published.

Some recent work has been accomplished using the EPA assay procedures

for fresh waters. Chang (1974) reported on the effect of incinerator quench water on the productivity of a waste water stabilization pond and Young et al. (1975) and Wong (1976) reported on the effect of secondary effluent on the productivity of Lake Wilson, a multi-use reservoir.

The scope of this limited past work reveals a considerable area for further research of this type to fully establish the impact of effluent discharge on receiving water productivity. This effect is the most immediate biological growth response in the receiving water and there are no currently available criteria to regulate or manage this potential problem. The research results can be used to define mixing zones and nutrient limitations for Hawaiian waters.

The need for this information is further emphasized by EPA requirements for water quality monitoring. There are biological/bioassay requirements instituted through provisions of PL 92-500, however, there have been no fixed or standardized procedures employed to date in this state, other than the acute bioassay test utilizing fish as the test organism. This project can provide a data base for bioassay at the primary trophic level which can be incorporated into any monitoring scheme.

OBJECTIVES

The effect of nutrient contributions on receiving water productivity has not received much close attention in Hawaii despite the fact that this has been a major world-wide problem, particularly for fresh receiving waters. Both fresh and marine waters need to be assayed here to determine growth potential response to waste water input. The objective of this research was to determine the algal growth potential (AGP) of untreated primary and secondary domestic waste water effluents on stream, reservoir, estuarine, and marine waters of the state.

RESEARCH PROCEDURES

Algal growth potential methods developed by the EPA for both fresh (EPA 1971) and marine (EPA 1974) waters were used in laboratory testing with effluent/receiving water mixtures representative of a range of nutrient levels

found in existing effluent disposal situations.

Fresh Water

Waters from the Kalihi, Manoa, Waihee, and Waikele streams were spiked with chlorinated sewage effluent from both the Pacific Palisades and Mililani Sewage Treatment Plants (STP) in increments of 20%. Stream waters were collected from the most upstream USGS gaging station of each stream. Chlorinated sewage was taken after the Cl contact chamber of both treatment plants. All samples were collected in acid-washed, 1-l polyethylene bottles.

The samples were autoclaved for 30 min at 121°C and inoculated with enough *Selenastrum capricornutum* to give a cell concentration of 1,000 cells/ml. Incubation took place in a constant temperature room set at 20°C with culture flasks set on shelves and with fluorescent lamps to provide for the required illumination. The major problem of this test procedure was maintaining the temperature within the required range (see Discussion).

Samples were shaken once a day just before measuring the fluorescence using a Turner Model III Fluorimeter, etc. (see p. 6).¹ Fluorescence units were calculated using the relationship:

$$\text{fluorescence unit} = \frac{\text{reading}}{\text{slit size} \cdot \text{filter}}$$

Readings were kept within the 20 to 75 range. Slit sizes of 3, 10, and 30, were used with 10% and 100% filters.

Correction factors for fluorescence unit values when going from one slit size or filter to another were determined using a 100% filter and a slit size of 10 as a base.

1. 0.75 • fu using slit size of 3 and 100% filter
2. 1.00 • fu using slit size of 30 and 10% filter
3. 0.95 • fu using slit size of 10 and 10% filter
4. 0.71 • fu using slit size of 3 and 10% filter

A relationship between fluorescence unit and cell count was established by using a counting chamber for direct counts at different fluorescence values (Fig. 1).

$$\text{cell count} = (1.37 \cdot 10^4) (\text{fu})^{1.29}$$

Triplicates were run for each sample. The maximum growth rate, μ_{max} , was determined by plotting cell count versus time and finding the maximum

¹Fluorometer by G.K. Turner Associates, California.

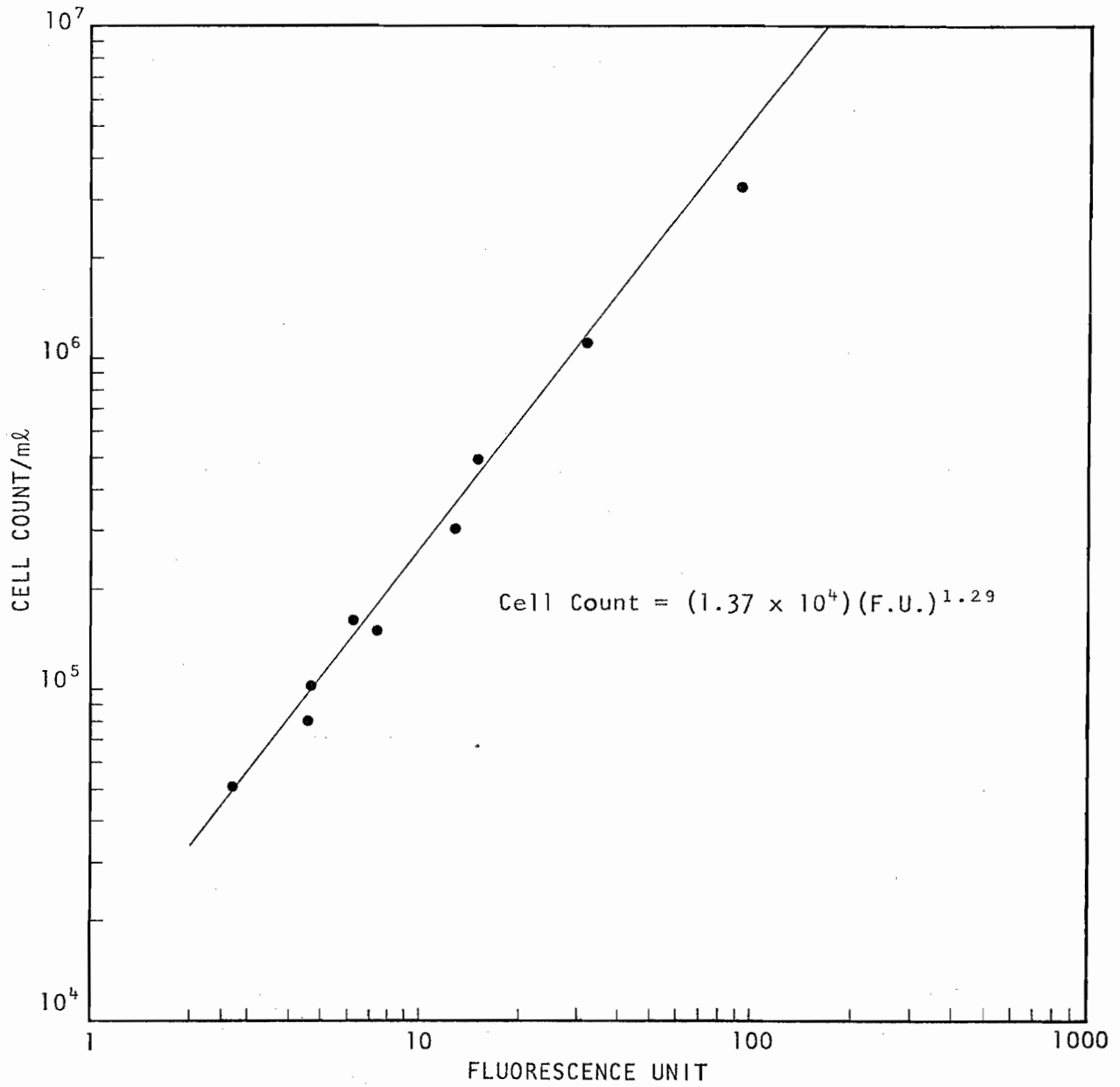


FIGURE 1. CELL COUNT CALIBRATION FOR FRESH WATER

differential during the growth period.

Sea Water

Seawater samples were drawn from the influent well at the Waikiki Aquarium. The source of the well is located 24.38 m (80 ft) below the ocean surface. Chlorinated sewage effluent samples from the Pacific Palisades and Mililani STPs were used as spikes for the sea water. These samples were collected at the Cl contact chamber discharge. One-liter, acid-washed polyethylene containers were used for sample holding and storage. The samples were filtered through 0.45- μ m membrane filters before testing began.

The assay procedure outlined in the Marine Algal Assay Procedure Bottle Test (EPA 1974) was followed. After filtering the samples, the sea water was spiked with chlorinated sewage effluent at dilutions ranging 0 to 100%, using 20% increments. Each dilution was prepared in triplicate utilizing 100 ml liquid volumes. All dilutions were inoculated with *Dunaliella tertiolecta* to give a cell concentration of 10^3 cells/ml. Incubation was under constant light of 400 ± 430.561 m/m² (40 ft-c) and at a temperature of $20 \pm 2^\circ\text{C}$. A Turner fluorometer (Model III with ultra-violet source #F4T58, high sensitivity sample holder, 47B Wratten primary filter, Wratten 25 secondary filter, and 10% and 1% transmittance filters, and 10 mm ID cuvettes) was used to monitor algal growth through in vivo fluorescence. Samples were shaken once a day, prior to measuring the fluorescence. Correction factors in as noted for the freshwater assays were applied to calculate the relative fluorescence in this section.

A relationship was established between relative fluorescence and cell counts in Figure 2. This calibration curve was obtained by plotting the logarithm of cell count against the logarithm of relative fluorescence. A regression curve was fitted by least square analysis and the relationship arrived at is:

$$\text{Cell Count} \approx (8.705 \cdot 10^3) (\text{relative fluorescence})^{0.932} \quad (1)$$

RESULTS

The results, in terms of maximum growth rate μ_{max} and maximum standing crop (number of cells), are provided in Tables 1 to 6. Table 1 includes the activated sludge (Mililani) and trickling filter (Palisades) effluent tests

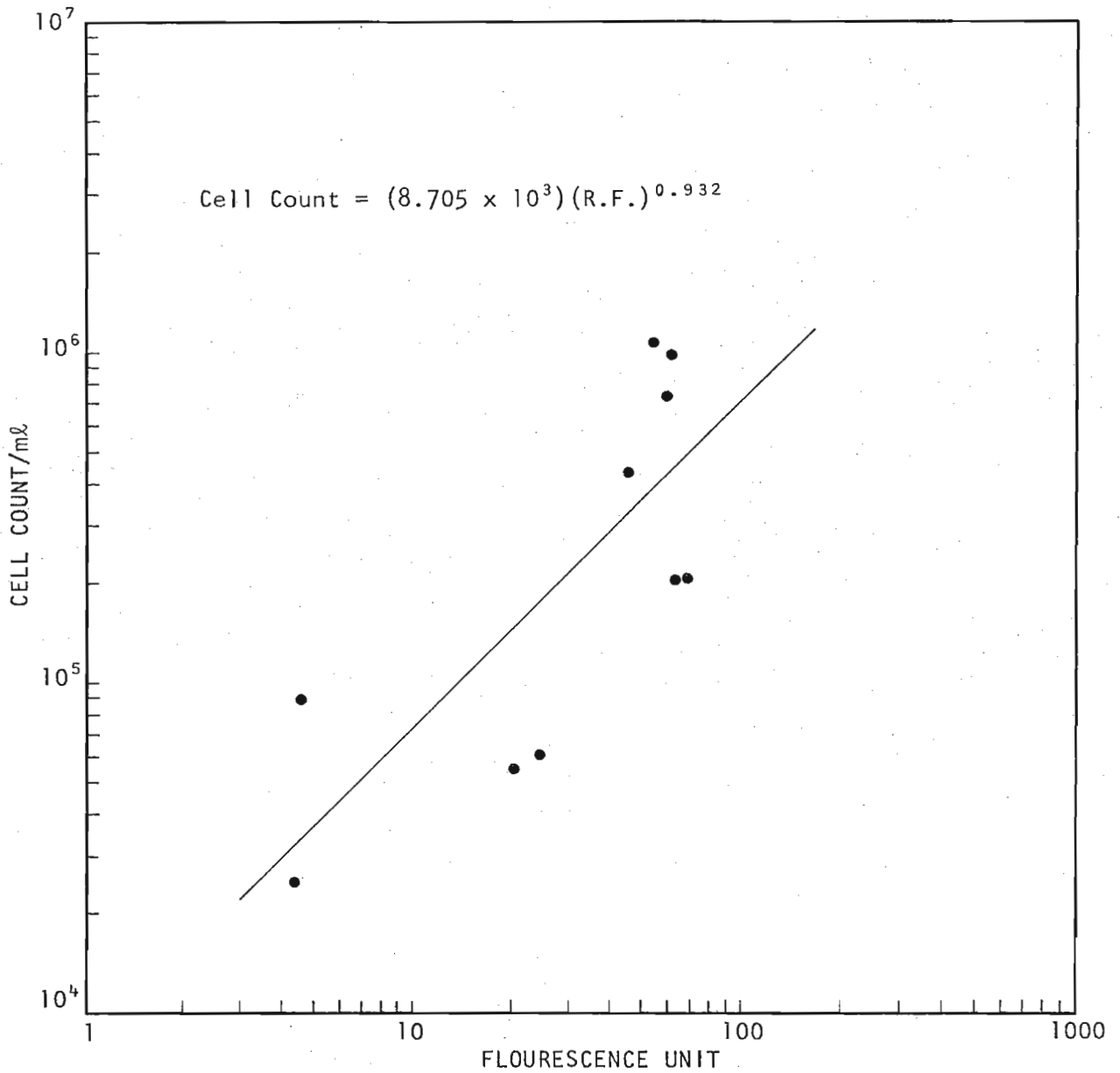


FIGURE 2: CELL COUNT CALIBRATION FOR SEA WATER

TABLE I. AGP FRESHWATER DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Palisades	0	0.28	0.20	0.05 - 0.76	2.8×10^4	1.5×10^4	$0.4-7.0 \times 10^4$
	20	1.68	1.79	1.24 - 2.26	5.2×10^6	5.9×10^6	$3.1-6.9 \times 10^6$
	40	1.29	1.34	0.83 - 1.55	5.3×10^6	5.6×10^6	$3.1-8.9 \times 10^6$
	60	1.14	1.15	0.77 - 1.39	4.6×10^6	4.5×10^6	$3.0-8.8 \times 10^6$
	80	1.10	1.16	0.82 - 1.41	4.6×10^6	4.4×10^6	$3.4-7.0 \times 10^6$
	100	0.97	1.10	0.22 - 1.16	4.5×10^6	4.5×10^6	$3.3-5.7 \times 10^6$
Mililani	0	0.39	0.42	0.04 - 0.76	3.6×10^4	2.3×10^4	$1.0-7.9 \times 10^4$
	20	1.40	1.44	0.90 - 1.92	3.5×10^6	3.3×10^6	$2.2-6.7 \times 10^6$
	40	1.58	1.59	1.21 - 1.84	5.4×10^6	5.8×10^6	$3.3-7.3 \times 10^6$
	60	1.28	1.28	0.94 - 1.65	4.6×10^6	5.0×10^6	$3.4-5.3 \times 10^6$
	80	1.12	1.08	0.82 - 1.43	4.3×10^6	4.3×10^6	$3.1-5.6 \times 10^6$
	100	1.19	1.14	0.96 - 1.53	4.6×10^6	5.0×10^6	$3.2-5.4 \times 10^6$
Combined	0	0.33	0.37	0.04 - 0.76	3.2×10^4	2.2×10^4	$0.4-7.9 \times 10^4$
	20	1.54	1.64	0.90 - 2.26	4.4×10^6	3.9×10^6	$2.2-6.9 \times 10^6$
	40	1.43	1.45	0.83 - 1.84	5.4×10^6	5.7×10^6	$3.1-8.9 \times 10^6$
	60	1.21	1.21	0.77 - 1.65	4.6×10^6	4.6×10^6	$3.0-8.8 \times 10^6$
	80	1.11	1.10	0.82 - 1.43	4.4×10^6	4.3×10^6	$3.1-7.0 \times 10^6$
	100	1.08	1.06	0.22 - 1.53	4.6×10^6	5.0×10^6	$3.2-5.7 \times 10^6$
Total		1.12	1.30	0.04 - 2.26	3.9×10^6	4.6×10^6	$0.004-8.9 \times 10^6$
Total less zero		1.27	1.29	0.22 - 2.26	4.7×10^6	4.6×10^6	$2.2-8.9 \times 10^6$

TABLE 2. KALIHI STREAM FRESHWATER AGP DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Kalihi-P	0	0.22		0.07 - 0.37			4.0x10 ³
Kalihi-M		0.42					4.6x10 ⁴
Kalihi		0.29	0.37		2.5x10 ⁴		0.4-4.6 x 10 ⁴
Kalihi-P	20	1.58		1.36 - 1.79			3.8-6.5 x 10 ⁶
Kalihi-M		1.41			5.15x10 ⁶		2.2-2.7 x 10 ⁶
Kalihi		1.49	1.58		2.45x10 ⁶	3.25x10 ⁶	
Kalihi-P	40	0.94		0.83 - 1.05			3.5-6.0 x 10 ⁶
Kalihi-M		1.59			4.75x10 ⁶		3.3-6.0 x 10 ⁶
Kalihi		1.27	1.31		4.65x10 ⁶	4.75x10 ⁶	
Kalihi-P	60	0.97		0.77 - 1.16			3.0-4.6 x 10 ⁶
Kalihi-M		1.21			3.8x10 ⁶		3.4-4.6 x 10 ⁶
Kalihi		1.09	1.18		4.0x10 ⁶	4.0x10 ⁶	
Kalihi-P	80	0.94		0.82 - 1.05			0.7-5.3 x 10 ⁶
Kalihi-M		1.22			3.0x10 ⁶		3.1-3.7 x 10 ⁶
Kalihi		1.08	1.05		3.4x10 ⁶	3.2x10 ⁶	
Kalihi-P	100			1.16			5.7x10 ⁶
Kalihi-M		1.20			4.4x10 ⁶		3.6-5.1 x 10 ⁶
Kalihi		1.18	1.16		4.8x10 ⁶	5.1x10 ⁶	
Kalihi 20-100		1.22	1.16	0.77 - 1.87	4.0x10 ⁶	3.7x10 ⁶	0.7-6.5 x 10 ⁶

TABLE 3. MANOA STREAM FRESHWATER AGP DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Manoa-P	0	0.07		0.05 - 0.09			--
Manoa-M		0.06		0.04 - 0.07			--
Manoa		0.06	0.06				
Manoa-P	20	1.82		1.79 - 1.85	5.85×10^6		$5.2-6.5 \times 10^6$
Manoa-M		1.10		0.90 - 1.29	2.5×10^6		$2.5-2.5 \times 10^6$
Manoa		1.46	1.54		4.2×10^6	3.85×10^6	
Manoa-P	40	1.43		1.31 - 1.55	7.45×10^6		$6.0-8.9 \times 10^6$
Manoa-M		1.34		1.21 - 1.47	5.7×10^6		$4.1-7.3 \times 10^6$
Manoa		1.38	1.34		6.6×10^6	6.65×10^6	
Manoa-P	60	1.26		1.12 - 1.39	6.7×10^6		$4.6-8.8 \times 10^6$
Manoa-M		1.04		0.94 - 1.13	4.55×10^6		$3.6-5.3 \times 10^6$
Manoa		1.15	1.13		5.6×10^6	4.95×10^6	
Manoa-P	80	1.12		1.07 - 1.17	4.75×10^6		$4.2-5.3 \times 10^6$
Manoa-M		0.93		0.90 - 0.96	4.3×10^6		$3.4-5.2 \times 10^6$
Manoa		1.03	1.02		4.5×10^6	4.7×10^6	
Manoa-P	100	1.16		1.15 - 1.16	4.5×10^6		$3.3-5.7 \times 10^6$
Manoa-M		1.01		0.96 - 1.06	4.15×10^6		$3.2-5.1 \times 10^6$
Manoa		1.08	1.11		4.3×10^6	4.2×10^6	
Manoa 20-100		1.22	1.16	0.90 - 1.85	5.0×10^6	5.15×10^6	$2.5-8.9 \times 10^6$

TABLE 4. WAIHEE STREAM FRESHWATER AGP DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Waihee-P	0	0.42		0.08 - 0.76			7.9x10 ⁴
Waihee-M		0.67		0.58 - 0.76			2.2-7.9 x 10 ⁴
Waihee		0.55	0.67				
Waihee-P	20	1.47		1.24 - 1.69	3.35x10 ⁶		3.1-6.6 x 10 ⁶
Waihee-M		1.81		1.74 - 1.92	3.95x10 ⁶		3.9-4.0 x 10 ⁶
Waihee		1.65	1.72		3.65x10 ⁶	3.95x10 ⁶	
Waihee-P	40	1.40		1.25 - 1.55	4.15x10 ⁶		3.1-5.2 x 10 ⁶
Waihee-M		1.83		1.81 - 1.84	5.55x10 ⁶		4.9-6.2 x 10 ⁶
Waihee		1.61	1.68		4.85x10 ⁶	5.05x10 ⁶	
Waihee-P	60	1.11		0.86 - 1.36	4.15x10 ⁶		3.8-4.3 x 10 ⁶
Waihee-M		1.39		1.34 - 1.43	4.8x10 ⁶		4.3-5.3 x 10 ⁶
Waihee		1.25	1.35		4.4x10 ⁶	4.3x10 ⁶	
Waihee-P	80	1.07		0.95 - 1.19	4.0x10 ⁶		3.5-4.5 x 10 ⁶
Waihee-M		1.21		1.12 - 1.30	4.55x10 ⁶		4.4-4.7 x 10 ⁶
Waihee		1.14	1.16		4.3x10 ⁶	4.45x10 ⁶	
Waihee-P	100	1.05		0.99 - 1.10	4.2x10 ⁶		3.4-5.0 x 10 ⁶
Waihee-M		1.16	1.04	0.98 - 1.34	4.8x10 ⁶		4.6-5.0 x 10 ⁶
Waihee					4.5x10 ⁶	4.8x10 ⁶	
Waihee 20-100		1.35	1.32		4.5x10 ⁶	4.45x10 ⁶	

TABLE 5. WAIKANE STREAM FRESHWATER AGP DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Waikane-P	0	0.42		0.31 - 0.52			1.0-2.0 × 10 ⁴
Waikane-M		0.44		0.31 - 0.56			1.0-2.3 × 10 ⁴
Waikane		0.43	0.42				
Waikane-P	20	1.86		1.46 - 2.26	4.6×10 ⁶		3.3-6.9 × 10 ⁶
Waikane-M		1.27		0.95 - 1.59	5.25×10 ⁶		3.8-6.7 × 10 ⁶
Waikane		1.57	1.53		4.9×10 ⁶	5.25×10 ⁶	
Waikane-P	40	1.40		1.37 - 1.42	4.75×10 ⁶		3.6-5.9 × 10 ⁶
Waikane-M		1.55		1.39 - 1.70	6.1×10 ⁶		5.5-6.7 × 10 ⁶
Waikane		1.47	1.41		5.4×10 ⁶	5.7×10 ⁶	
Waikane-P	60	1.25		1.13 - 1.36	4.0×10 ⁶		3.3-4.7 × 10 ⁶
Waikane-M		1.51		1.36 - 1.65	5.3×10 ⁶		5.3-5.3 × 10 ⁶
Waikane		1.38	1.36		4.7×10 ⁶	5.0×10 ⁶	
Waikane-P	80	1.28		1.14 - 1.41	3.45×10 ⁶		3.4-3.5 × 10 ⁶
Waikane-M		1.13		0.82 - 1.43	5.3×10 ⁶		5.0-5.6 × 10 ⁶
Waikane		1.20	1.28		4.4×10 ⁶	4.25×10 ⁶	
Waikane-P	100	0.62		0.22 - 1.01			4.0 × 10 ⁶
Waikane-M		1.38		1.22 - 1.53	5.2×10 ⁶		5.0-5.4 × 10 ⁶
Waikane		1.00	1.11		4.8×10 ⁶	5.0×10 ⁶	
Waikane 20-100		1.32	1.38		4.95×10 ⁶	5.0×10 ⁶	

TABLE 6. AGP SEA WATER DATA SUMMARY

Sample	% Eff	μ_{\max} (day ⁻¹)			Max. Standing Crop (Cells)		
		Mean	Median	Range	Mean	Median	Range
Palisades	0	0.77	0.75	0.72 - 0.84	5.35×10^4	5.1×10^4	$4.84-6.12 \times 10^4$
	20	1.25	1.10	1.04 - 1.60	5.25×10^5	5.42×10^5	$4.84-5.48 \times 10^5$
	40	0.90	0.92	0.87 - 0.92	4.01×10^5	4.86×10^5	$1.19-5.99 \times 10^5$
	60	1.10	0.79	0.52 - 1.71	1.83×10^5	0.88×10^5	$0.27-4.33 \times 10^5$
	80	0.09	0.09	0.02 - 0.15			--
	100			0.02			--
Mililani	0	--					--
	20	1.42	1.49	1.24 - 1.53	4.11×10^5	4.29×10^5	$3.66-4.38 \times 10^5$
	40	1.25	1.16	1.14 - 1.45	4.43×10^5	5.19×10^5	$2.80-5.31 \times 10^5$
	60	1.86	2.04	1.35 - 2.2	2.14×10^5	1.55×10^5	$0.66-4.21 \times 10^5$
	80	1.49	1.49	1.46 - 1.52	3.13×10^5	3.13×10^5	$0.92-5.33 \times 10^5$
	100	--					
Combined	0	0.77	0.75	0.72 - 0.84	5.35×10^4	5.1×10^4	$4.84-6.12 \times 10^4$
	20	1.33	1.37	1.04 - 1.60	4.68×10^5	4.61×10^5	$3.66-5.48 \times 10^5$
	40	1.08	1.03	0.87 - 1.45	4.22×10^5	5.03×10^5	$1.19-5.99 \times 10^5$
	60	1.44	1.53	0.52 - 2.2	1.98×10^5	1.22×10^5	$0.27-4.33 \times 10^5$
	80	0.79	0.81	0.02 - 1.52	3.13×10^5	3.13×10^5	$0.92-5.33 \times 10^5$
	100			0.02			
Total		1.10	1.12	0.02 - 2.2	3.18×10^5	4.21×10^5	$0.27-5.99 \times 10^5$
Total Less Zero		1.16	1.20	0.02 - 2.2	3.58×10^5	4.31×10^5	

with fresh receiving waters data and the combined data for both effluents. Table 1 was prepared from the data for the Kalihi, Manoa, Waihee, and Waikane streams presented respectively in Tables 2 through 5. The data in Table 6 is for Mililani and Palisades effluents for sea water. Growth curves for the AGP test series are presented in the Appendix. The results are presented subsequently in terms of average values for μ_{\max} and standing crop.

It can be noted from Table 1 that values of μ_{\max} are about the same for all fresh receiving waters, whether the nutrient source was the activated sludge or trickling filter effluent. The maximum growth rate for each stream, with either effluent, was achieved with the 20 or 40% dilution. There appears to be some inhibition, with lesser μ_{\max} , at dilutions of 60% and greater.

The maximum standing crop was about the same for each effluent, about 5×10^6 cells, attained with the 40% dilution. There was no evidence of any change of significant magnitude in standing crop with higher proportions of effluent in fresh receiving waters.

The levels of μ_{\max} attained with the dilutions tested were 3 to 5 times the levels in the controls (no sewage dilution). However, the maximum standing crop for all dilutions was roughly 100 times that in the controls. The growth rates for the windward Oahu streams (Waihee, Waikane) are slightly higher overall than for leeward streams (Kalihi, Manoa) but there is little difference in standing crop values.

Because sea water was obtained from only one site for testing, the amount of data is much less than that for the fresh receiving waters. The results differed from the freshwater results in that higher μ_{\max} levels were achieved with Mililani effluent than with Palisades effluent. The μ_{\max} levels increased over the control at all dilutions except the 80% dilution with Palisades effluent. Note, however, that there was no growth with either effluent at 100% sewage with the test alga. With either effluent, there was a lesser growth rate at 40% sewage dilution than at 20% dilution and maximum μ_{\max} was at the 60% dilution.

The maximum standing crop was attained with the 20% dilution of either effluent in sea water. Although the highest μ_{\max} values were attained at the 60% dilution, this was the level of lowest standing crop for either effluent, about one-third less than the maximum for the Palisades effluent and one-half less for the Mililani effluent.

The levels of μ_{\max} were 1.5 to 2.5 that of the sea water control tests, about 50% less than the increase in the freshwater tests. The increase in

standing crop was only 10 times in the sea water tests compared to 100 times in the freshwater tests.

DISCUSSION

All the results show that the chlorinated effluent spikes had no inhibitory effects to the growth of *Selenastrum capricornutum* in fresh receiving waters. The lag period for each spike (App. Figs.) lasted approximately the same time no matter what concentration of sewage was used. The maximum standing crop and μ_{\max} results yielded approximately the same growth rate and standing crop for all concentrations of sewage. All of these results lead to the conclusion that the sewage effluents added nutrients to the stream waters which enhanced the growth of *Selenastrum capricornutum*.

The only similar previous work done in Hawaii was reported by Wong (1976) who used sewage (Wahiawa STP activated sludge effluent) spikes of 5%, 10%, and 20% diluted with distilled-deionized water and Ku Tree reservoir waters. The maximum standing crop with the Ku Tree waters was 0.94×10^6 , 1.4×10^6 and 0.52×10^5 /ml for the 5%, 10%, and 20% dilutions, respectively, about 10 times less than that achieved in this study at the 20% dilutions. No μ_{\max} was determined by Wong.

It should be noted that level of 15,000 cells/ml has been identified as indicative of eutrophic conditions in receiving waters (Mitchell 1973). This level was achieved in all tests with the Mililani and Palisades effluents, indicative that these effluents are readily capable of stimulating algal growth in receiving streams to possible nuisance conditions.

One may question the high dilutions used in this study; they were chosen on the basis of situations such as at Waimano Stream where, for parts of the year, the Palisades STP effluent constitutes nearly the entire streamflow. Table 7 lists some of the treatment plants with effluent disposal into streams on Oahu. Although the majority of the streamflows are high in relation to the plant discharges, it should be kept in mind that the effluent discharge locations are in upper reaches of the streams in the case of the Ahuimanu, Schofield, Waipio, Mililani, and Palisades plants, and, thus, the ratio of effluent discharge to streamflow is higher than would be obtained from the listed data. In any case, the dilutions used in this study are not unrealistic compared to existing field conditions.

TABLE 7. OAHU STPs WITH STREAM RECEIVING WATERS

STP	Plant Flow cfs	Receiving Stream	Stream Gage Location ³	Streamflow ³ cfs
Maunawili Estates	0.16 ¹	Maunawili	Makawao	5.33
Ahuimanu	0.47 ¹	Ahuimanu	Ahuimanu (low-flow)	1.9
Schofield	3.25 ²	Waikele	Waikele (Waipahu)	39.3
Waipio	0.03 ¹	Waikakalua	Waikele (Waipahu)	39.3
Mililani	1.80 ¹	Kipapa	Kipapa	11.1
Palisades	0.79 ¹	Waimano	Waiawa	33.1
Halawa Jail	0.03 ¹	Halawa	N. Halawa	5.18
Animal Quarantine Station	0.09 ²	Halawa	N. Halawa	5.18

¹Source: Average for Oct. 1975 - Sept. 1976, City and County of Honolulu, Division of Sewers.

²Estimated average for 1975-1976, George Richardson 1976: Personal communication.

³USGS 1974.

It is difficult to make an analysis of this work with other salt water algal growth potential studies, for the simple reason that dilutions in this study are broad in comparison. In the Oahu Water Quality study done for the City and County of Honolulu (Engineering-Science 1971), waste water concentrations utilized were 1, 3, 4, and 5%, by volume, whereas in this study waste water concentrations were 0, 20, 40, 60, 80, 100% to conform with the freshwater work.

The results in this study were a general trend where the maximum growth rate decreased as the waste water concentration was increased, except for a high at the 40% dilution. This would be an indication of inhibitory effects upon the algal growth, possibly due to the effect of lowered salinity alone. The plots of the growth curves (App. Figs.) illustrate the inhibition by the increased lag growth period as the waste water concentration was increased. The 80 and 100% effluent concentrations had no growth at all within the 13-day testing period.

The maximum growth rates achieved in this study were in the same order

of magnitude as attained in the Oahu Water Quality study for *Dunaliella*. The standing crop was also of the same order of magnitude except at the least dilutions, indicative of the inhibition by the sewage on the test organism at the least dilutions. With a general design philosophy of attempting to attain initial dilutions of at least 200:1 with ocean outfalls, it would be more practical to do future testing with lesser dilutions. Current practice in Hawaii, however, yields lesser initial dilutions on the order of 8:1 for the raw waste discharge at Sand Island; thus, the research performed has some practical value for evaluating existing situations.

The results of this study were that the Mililani activated sludge effluent was less inhibitory than the Palisades trickling filter effluent. This fits well with the current Environmental Protection Agency's requirement for minimum 85% BOD removal for ocean discharges. A well-operated activated sludge plant should readily attain an 85% removal efficiency, whereas that figure represents nearly an upper limit for trickling filter plant operation.

Some of the original research objectives were not attained including the testing of reservoir and estuarine waters, effects of N and P spikes, and use of indigenous algae as a test organism. Limitations on scope of work were due to difficulties in obtaining and culturing the test alga as well as personnel changes in the laboratory.

Another problem was keeping the temperature within the recommended range of $24 \pm 2^\circ\text{C}$. For tests run before 19 August 1975, the bookshelf on which the samples were placed was kept in the lab at room temperature (approximately 24°C). However, due to the heat of the fluorescent lamps, the sample temperature was 33°C . On the tenth day of the tests started on 19 August, an electric fan was used to lower the sample temperature to 26°C . However, continuous use resulted in the breakdown of the fan motor. Therefore, all tests after and including those started on September 18 were conducted in a constant temperature room of 20°C . The temperatures for each level of the bookshelf are presented in the Figure 3 diagram.

SUMMARY

The AGP test can be used to assay biological response to sewage effluent discharge into receiving waters. Its utility is in that the response is monitored at the primary production level rather than at some predator level

or at the highest end of the aquatic food chain, i.e., the commonly used fish bioassay. The tests results reported herein are indicative that growth response follows similar patterns for conventional biologically treated effluents in fresh receiving waters, but that peak growth conditions occur with about a 20% dilution of the effluent. Peak growth conditions occur at a lesser dilution, 40%, in sea water, but this would be an uncommon environmental condition in the light of outfall design objectives and current practices. It would not be unusual, however, to have field conditions with fresh receiving streams in Hawaii where the effluent dilution is 20% or less. Thus, situations can exist where, with excessive stimulation or at lesser dilutions, some inhibition of planktonic growth occurs. In any case, the growth potential response of "standard" test alga with Hawaiian waste waters and receiving waters has been demonstrated.

ACKNOWLEDGEMENTS

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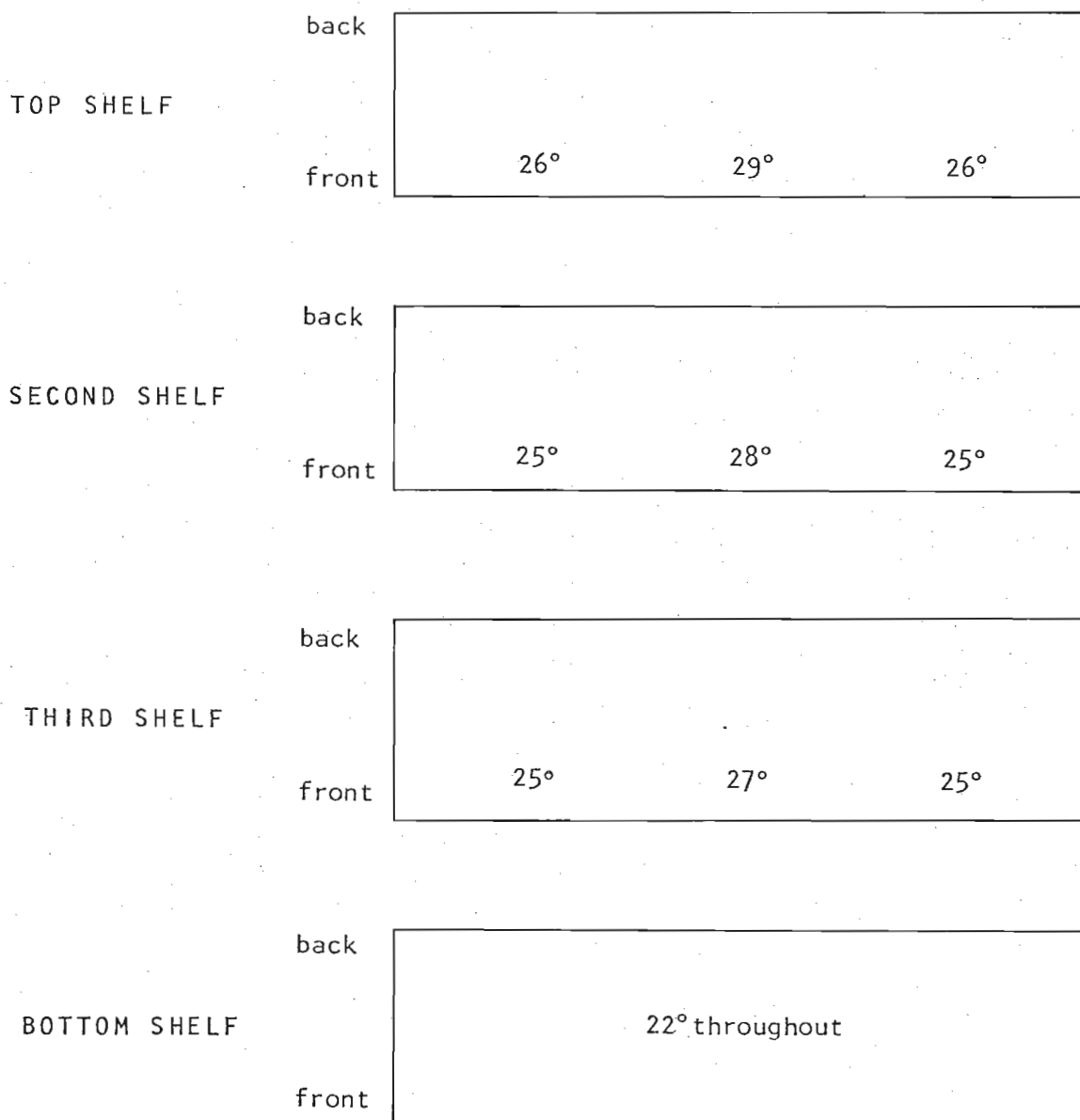


FIGURE 3. TEMPERATURE DISTRIBUTION IN LIGHT BOX

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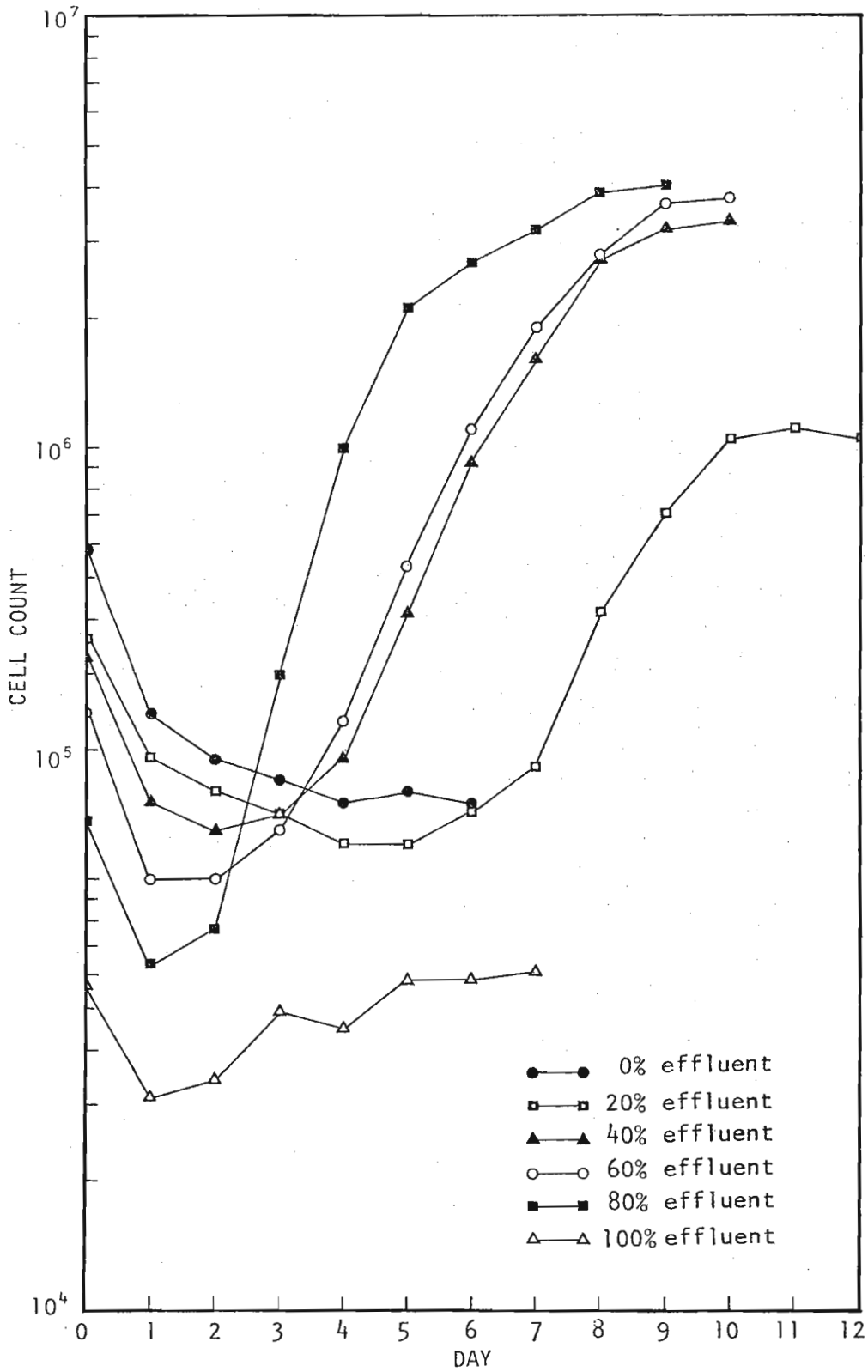
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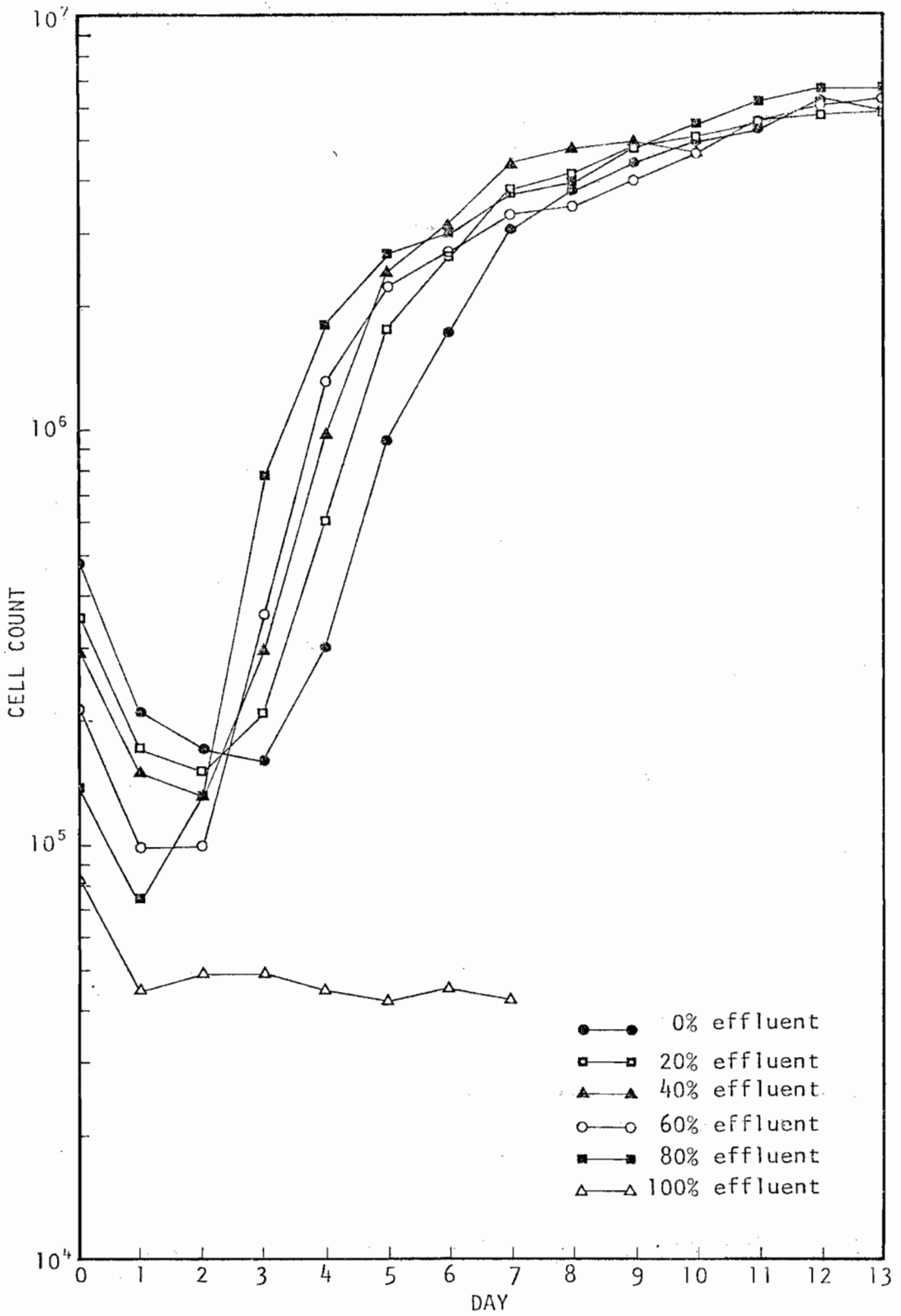
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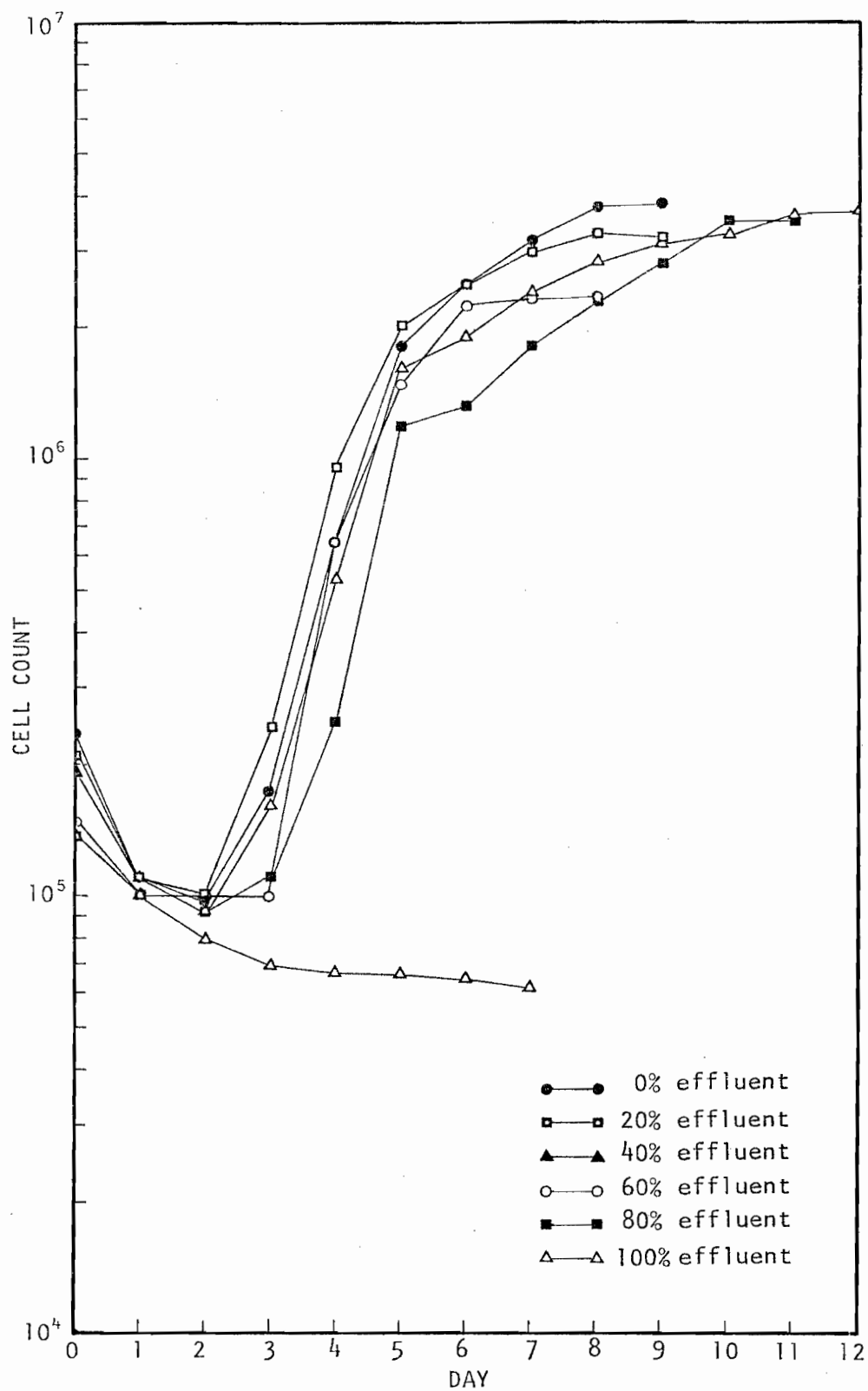
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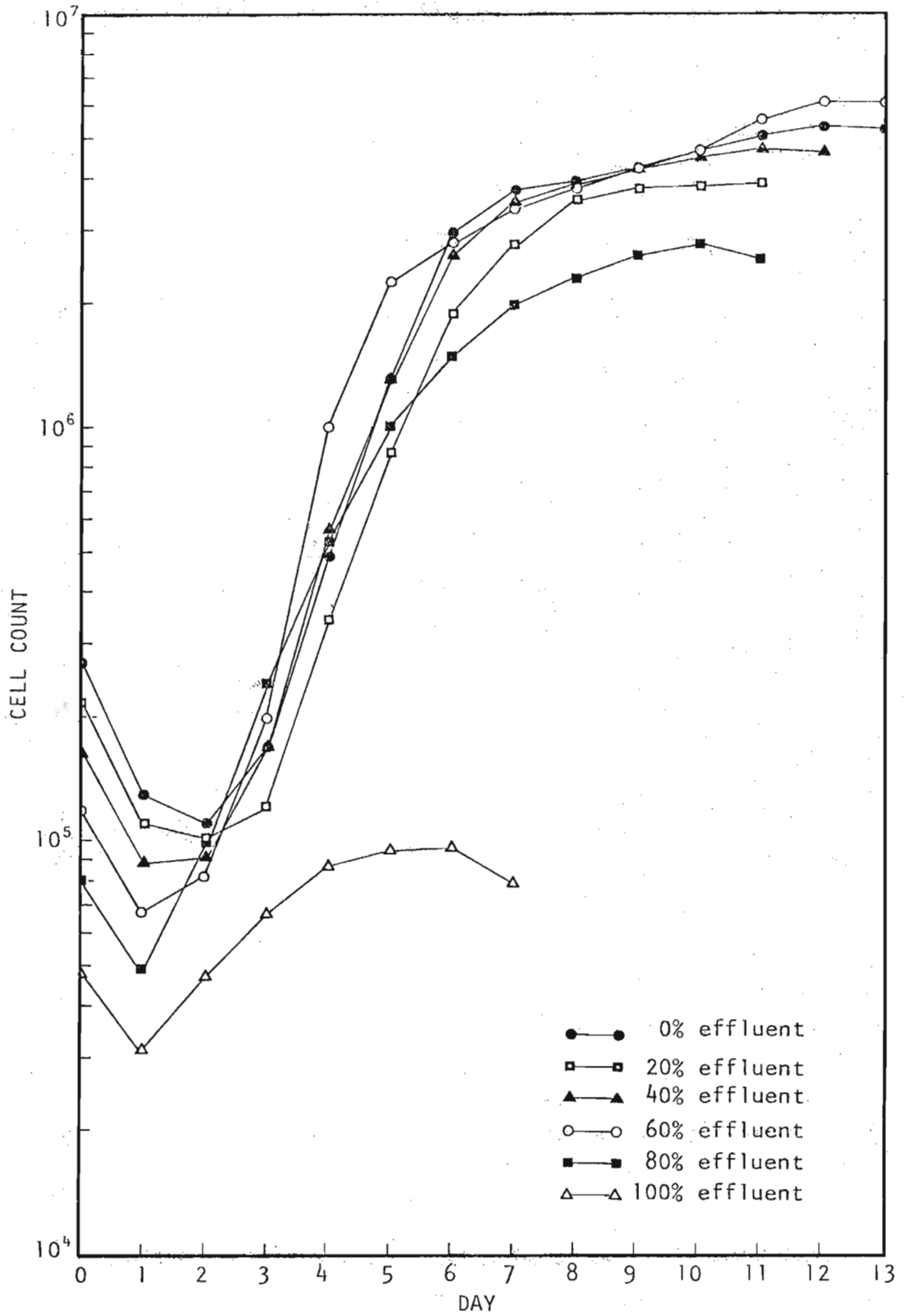
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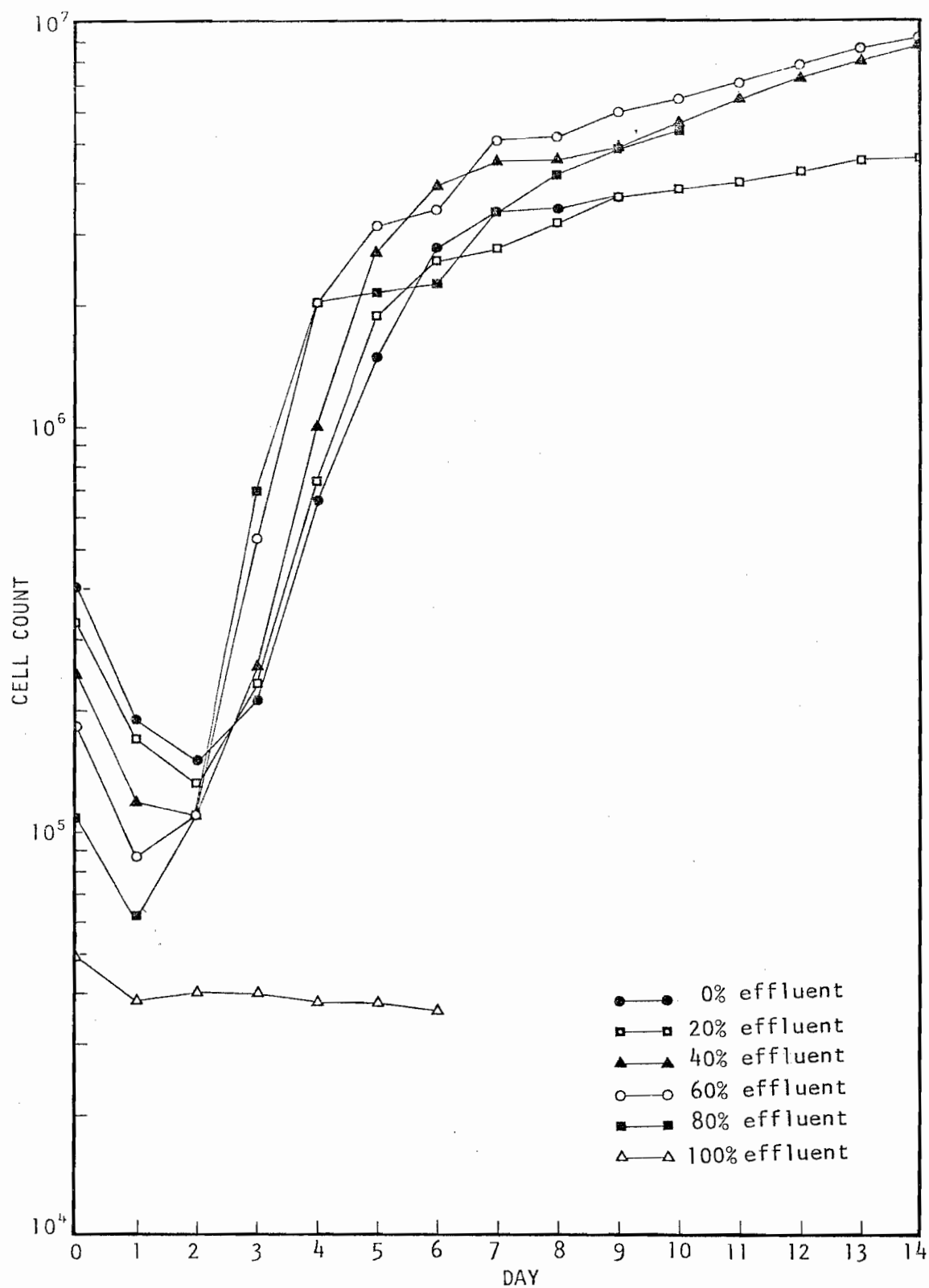
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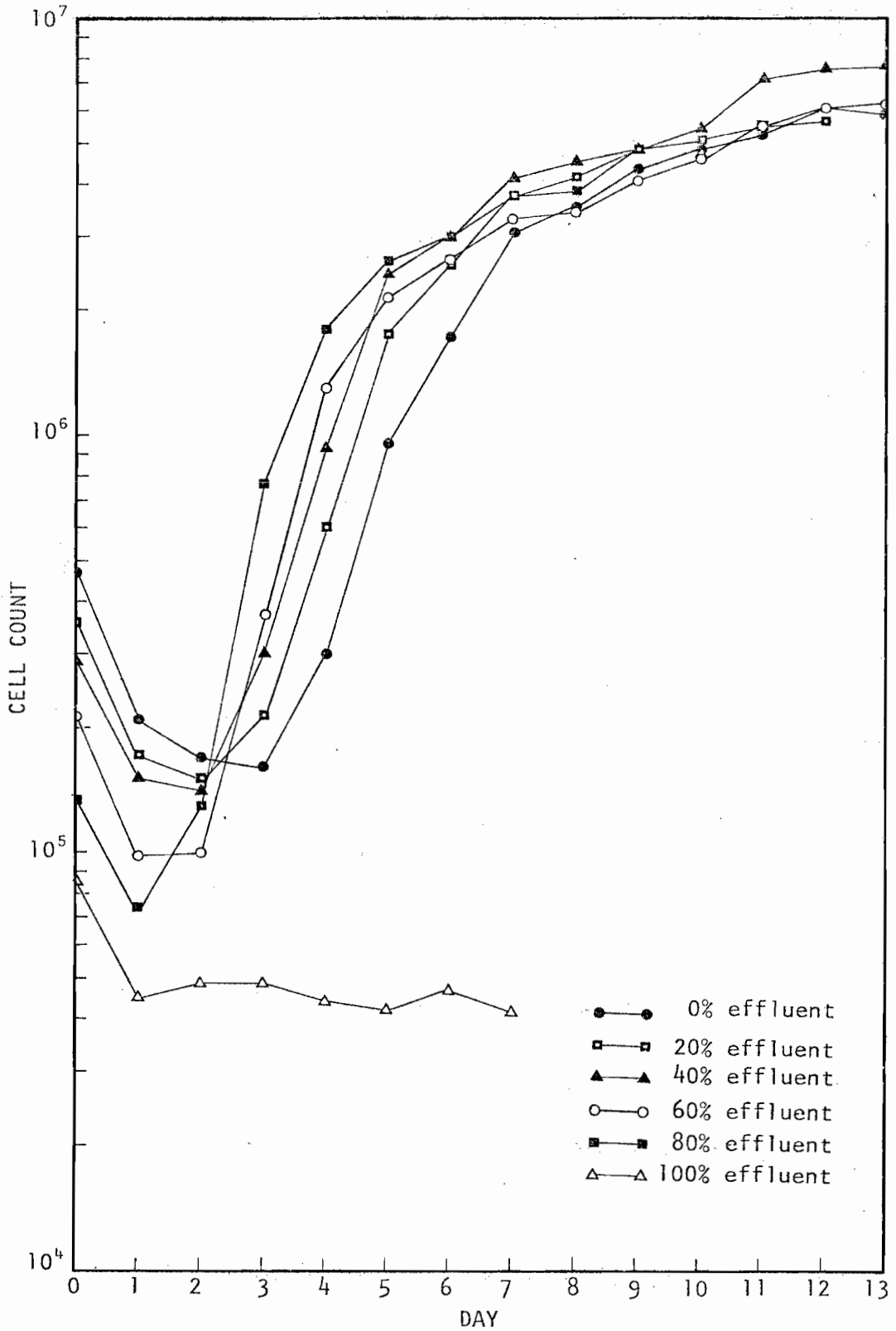
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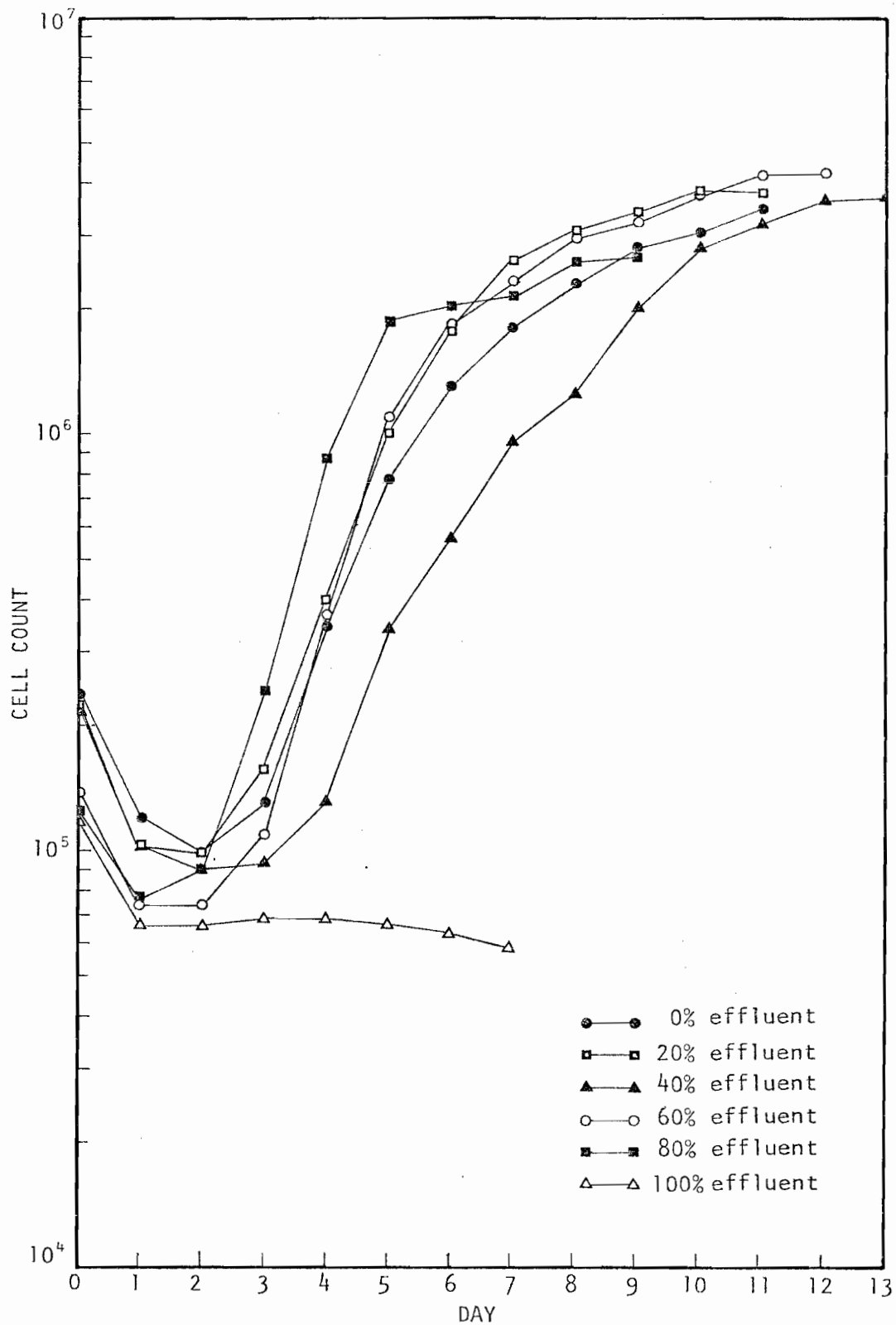
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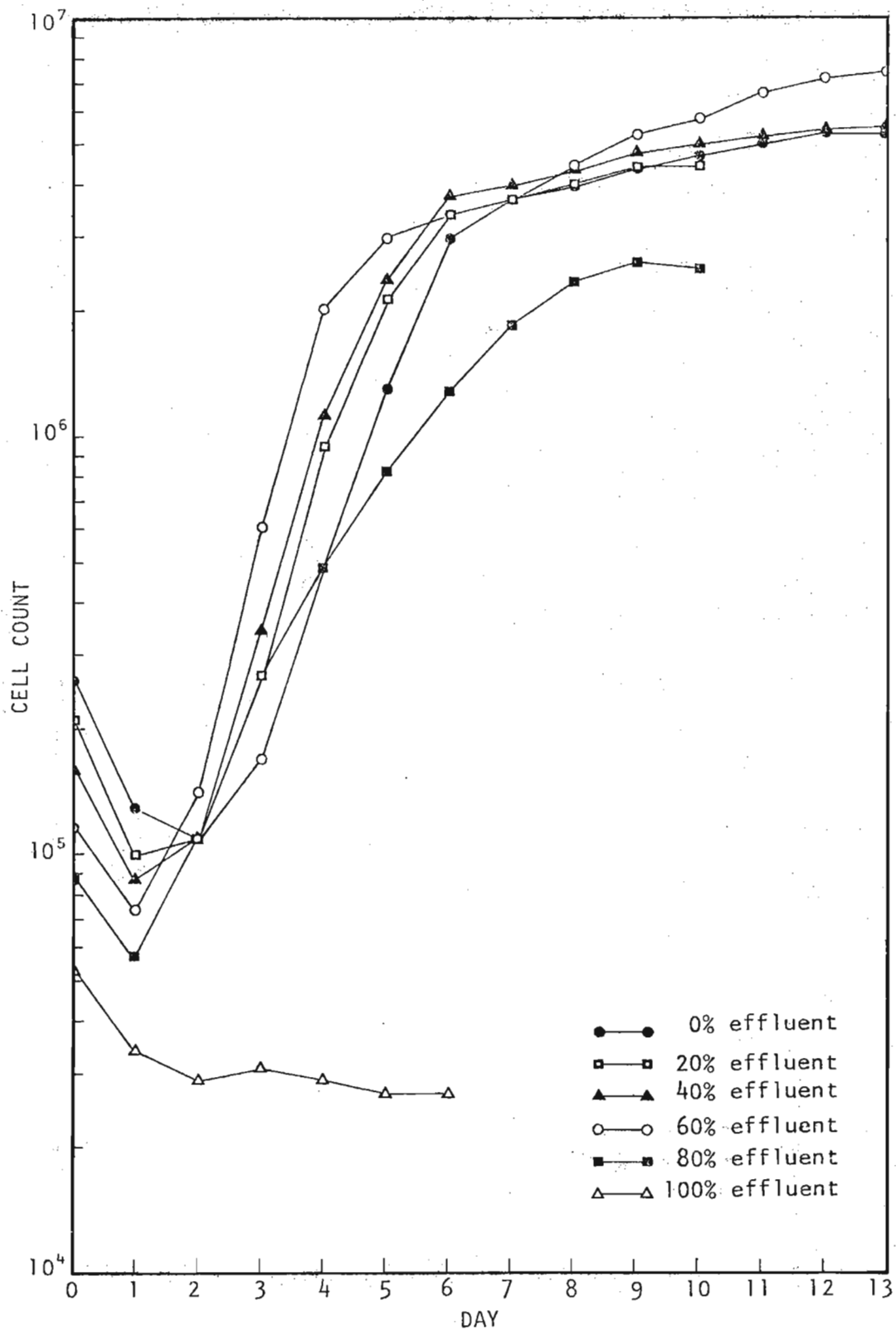
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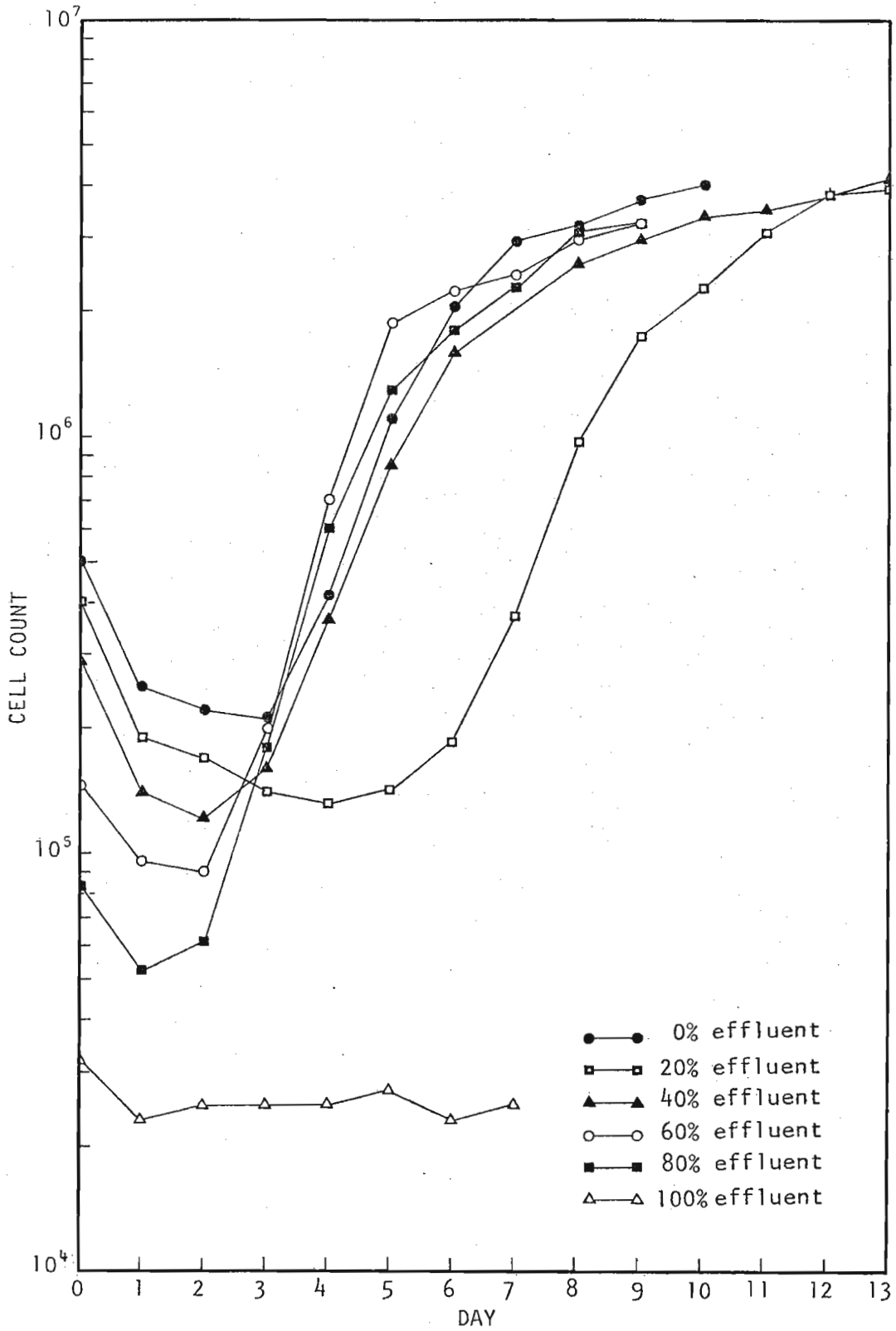
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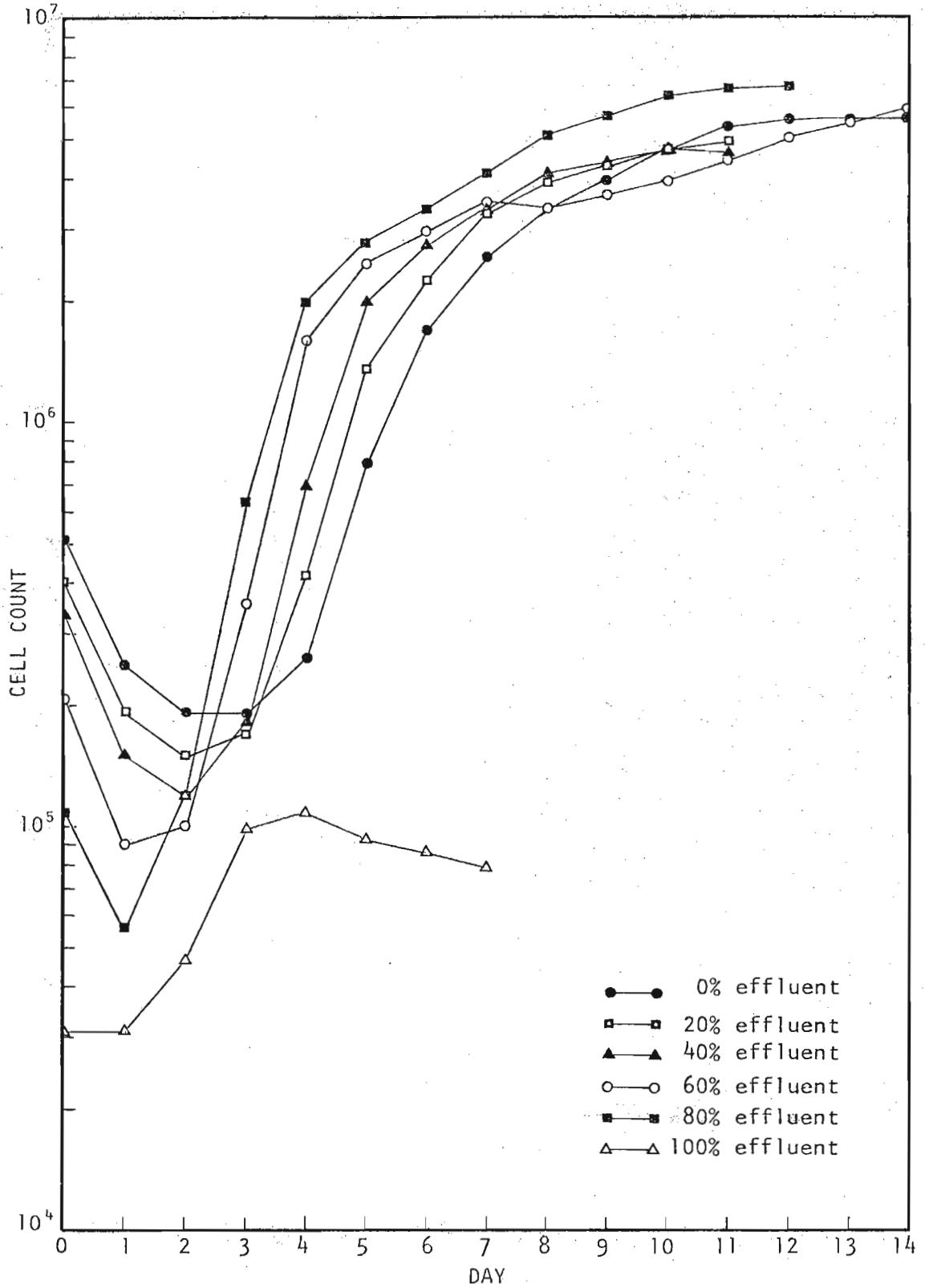
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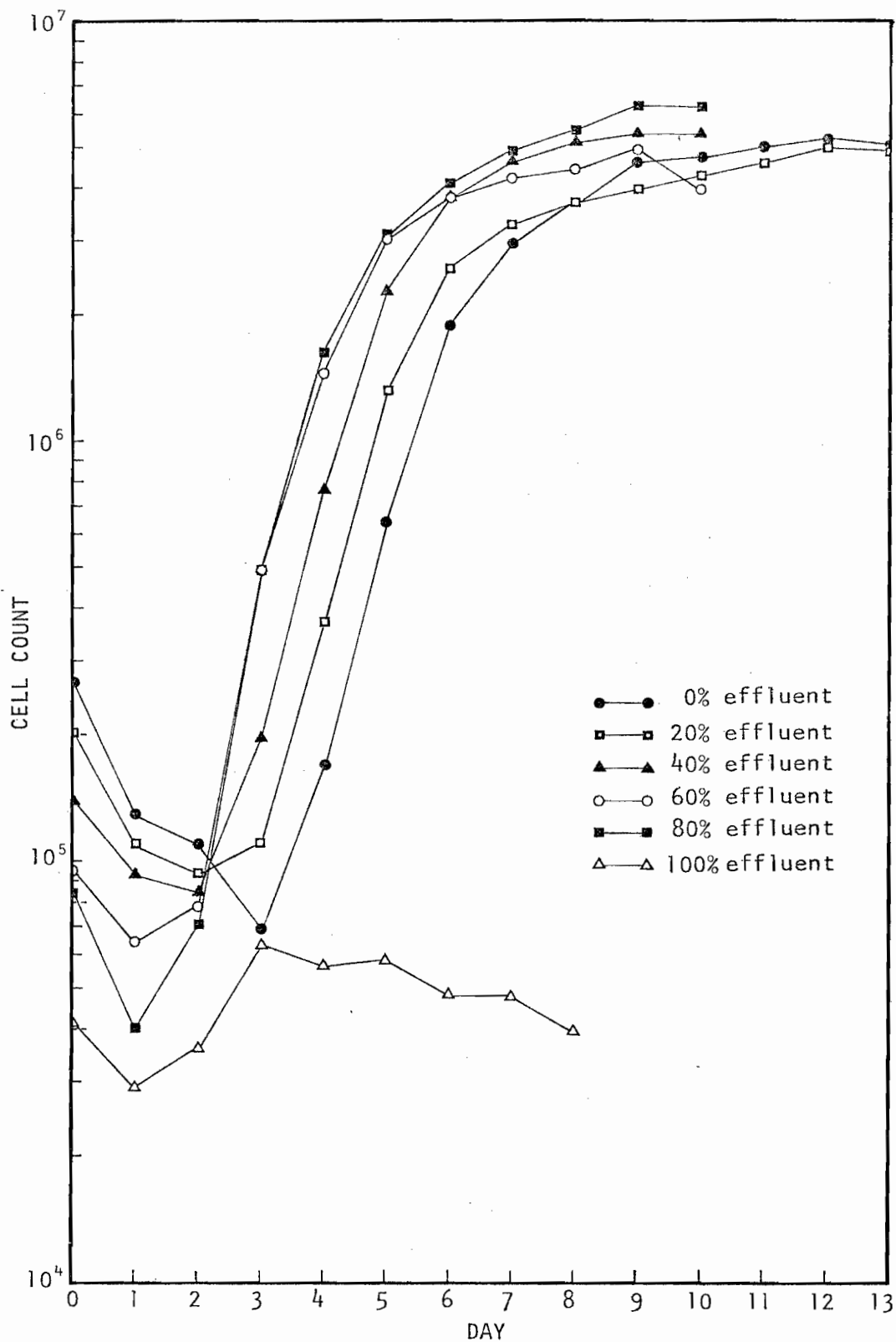
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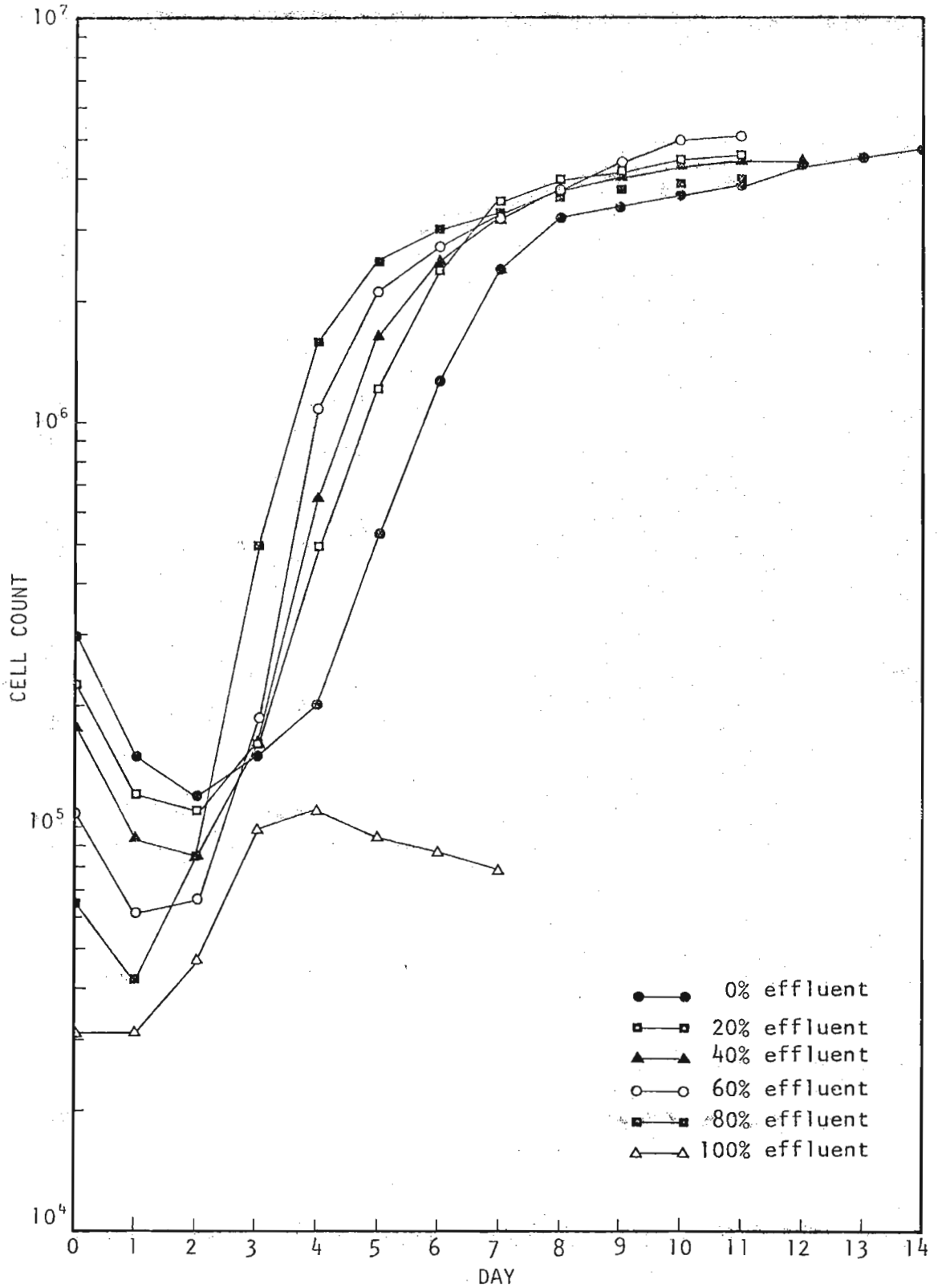
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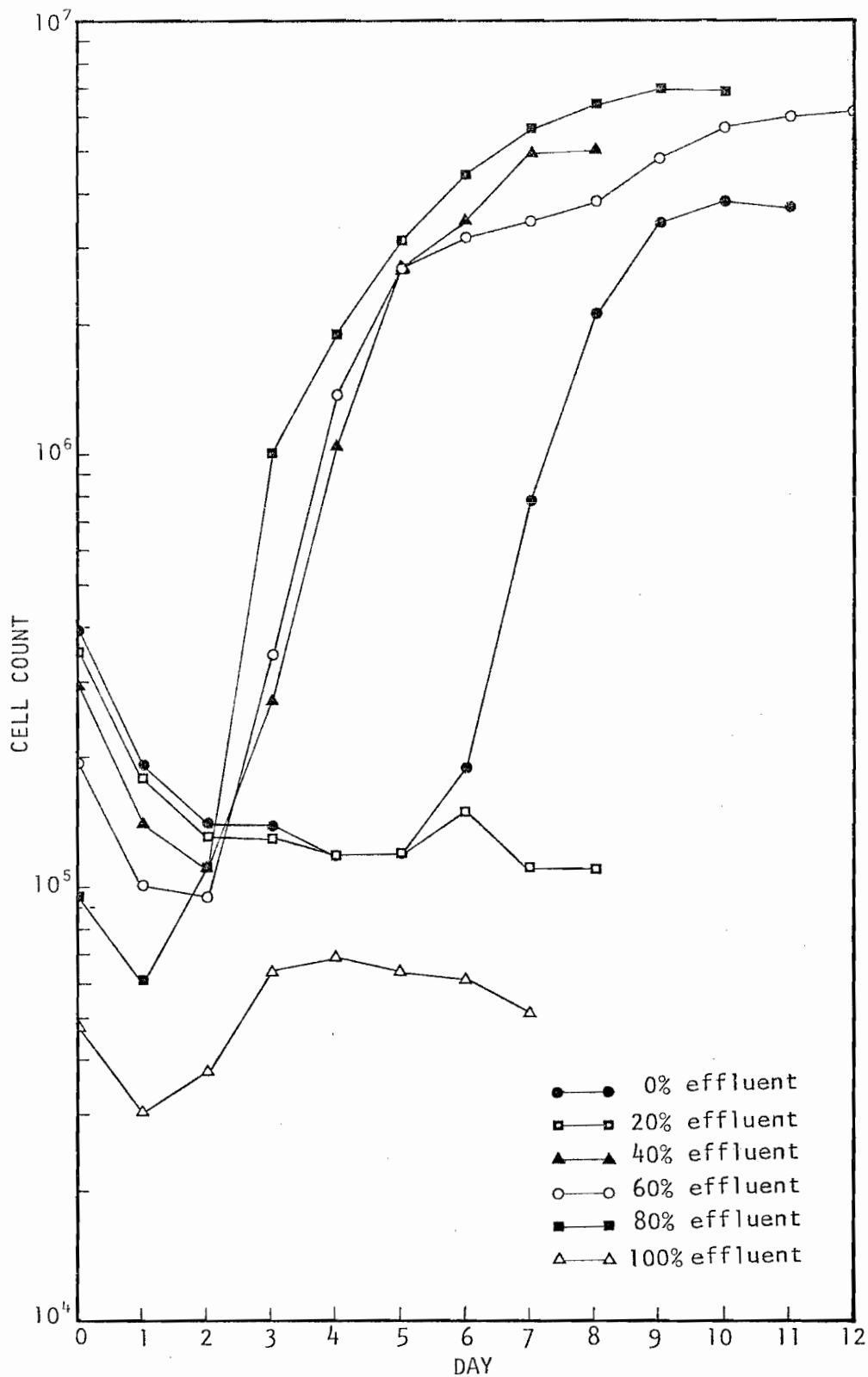
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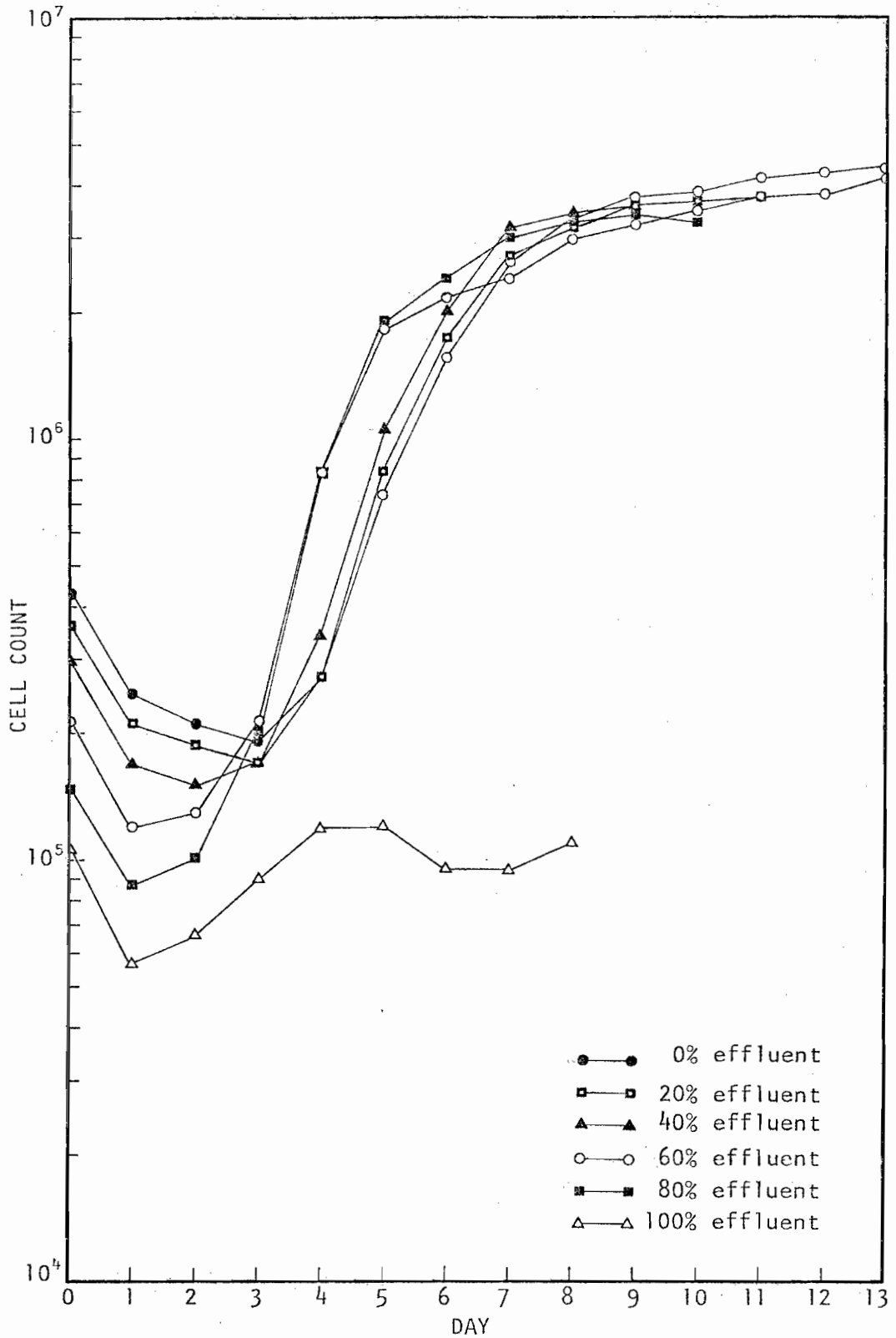
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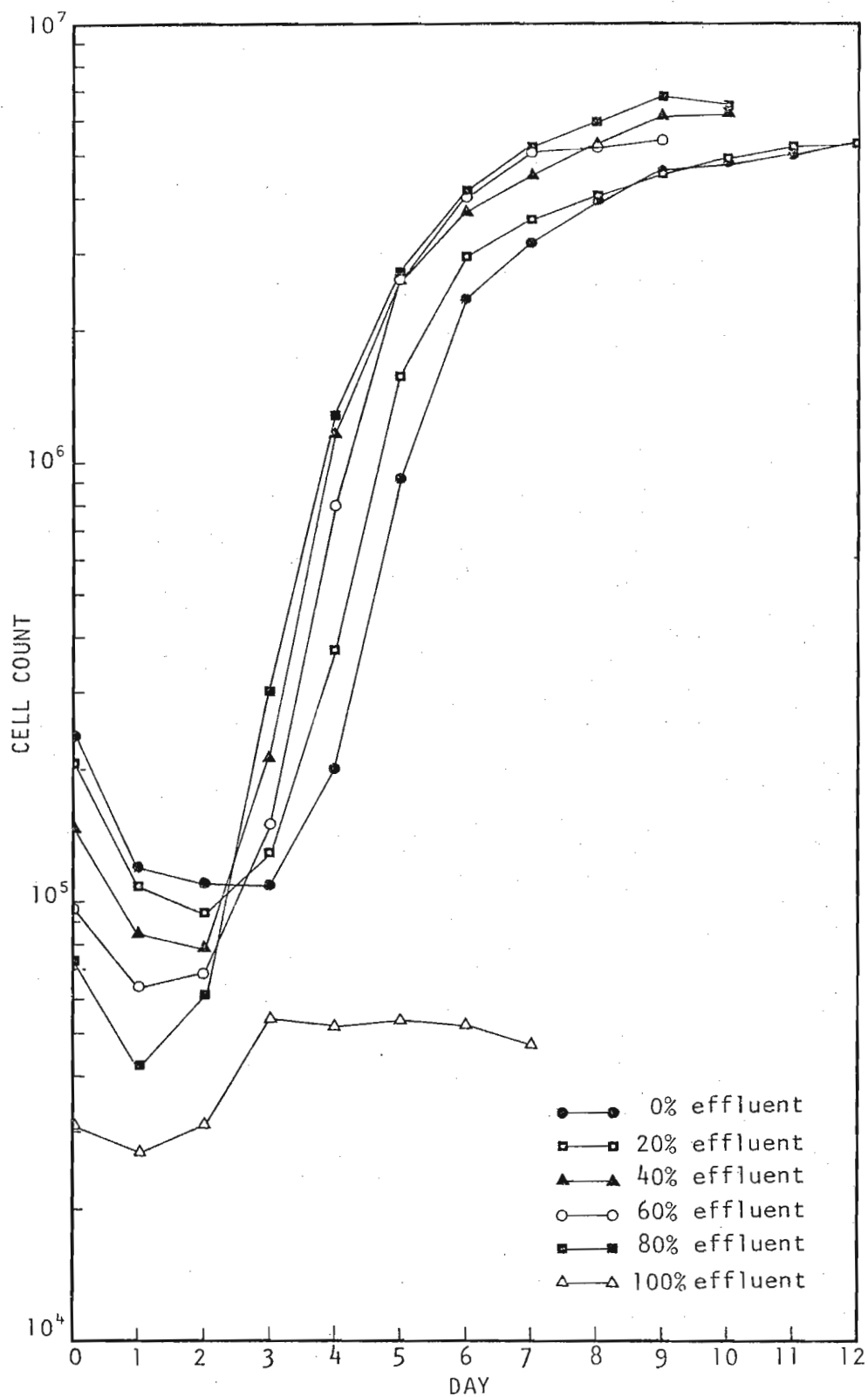
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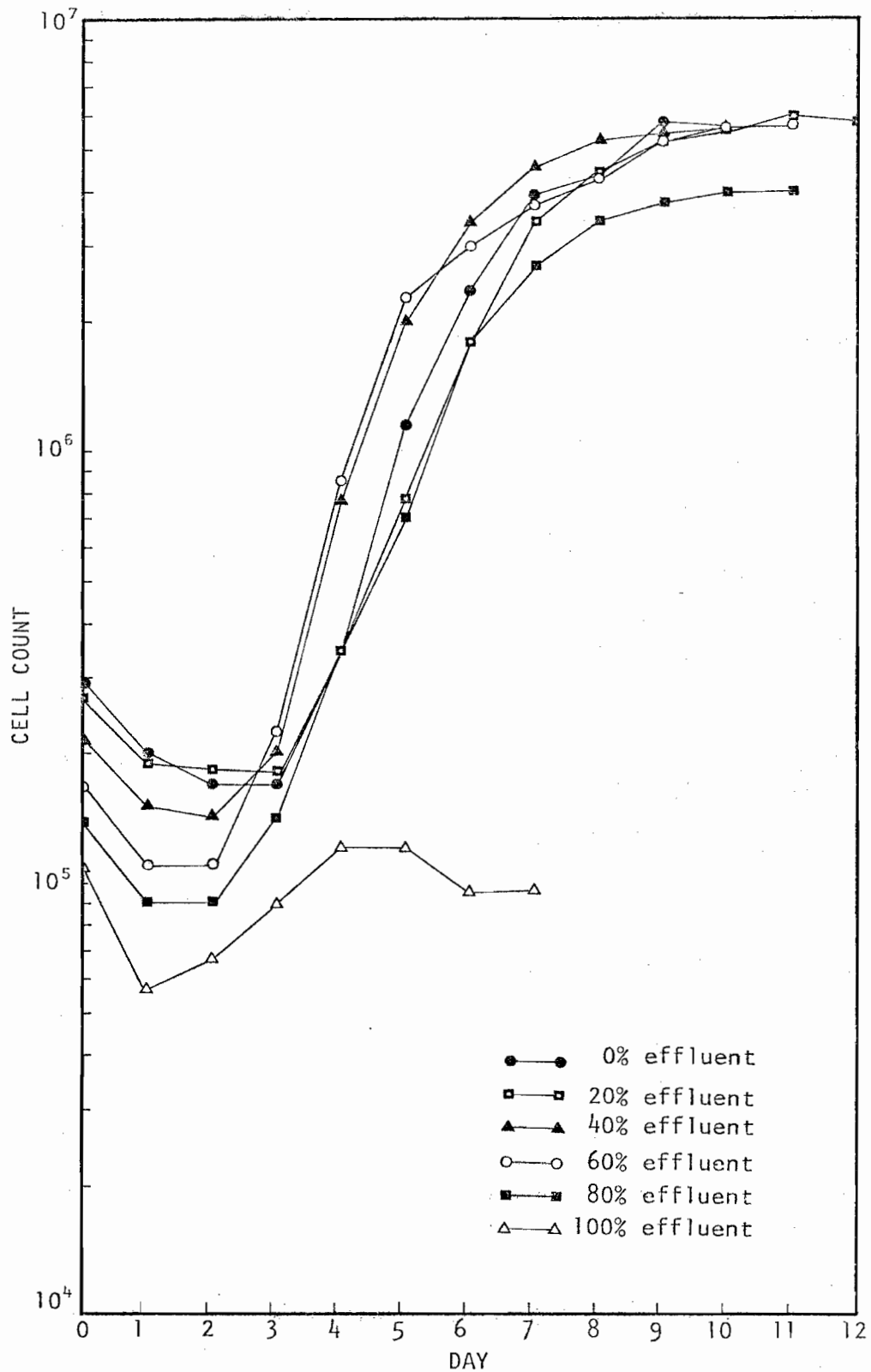
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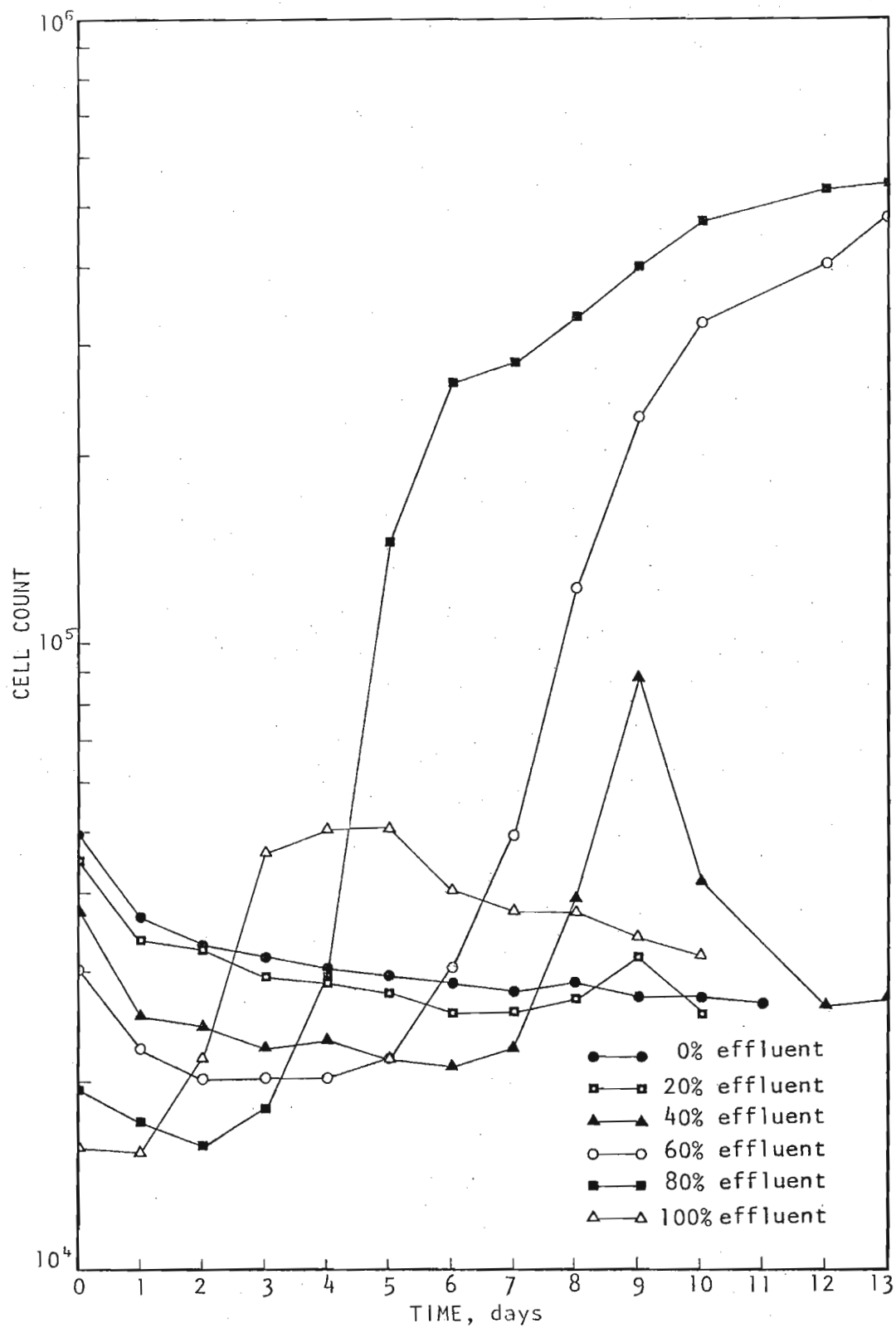
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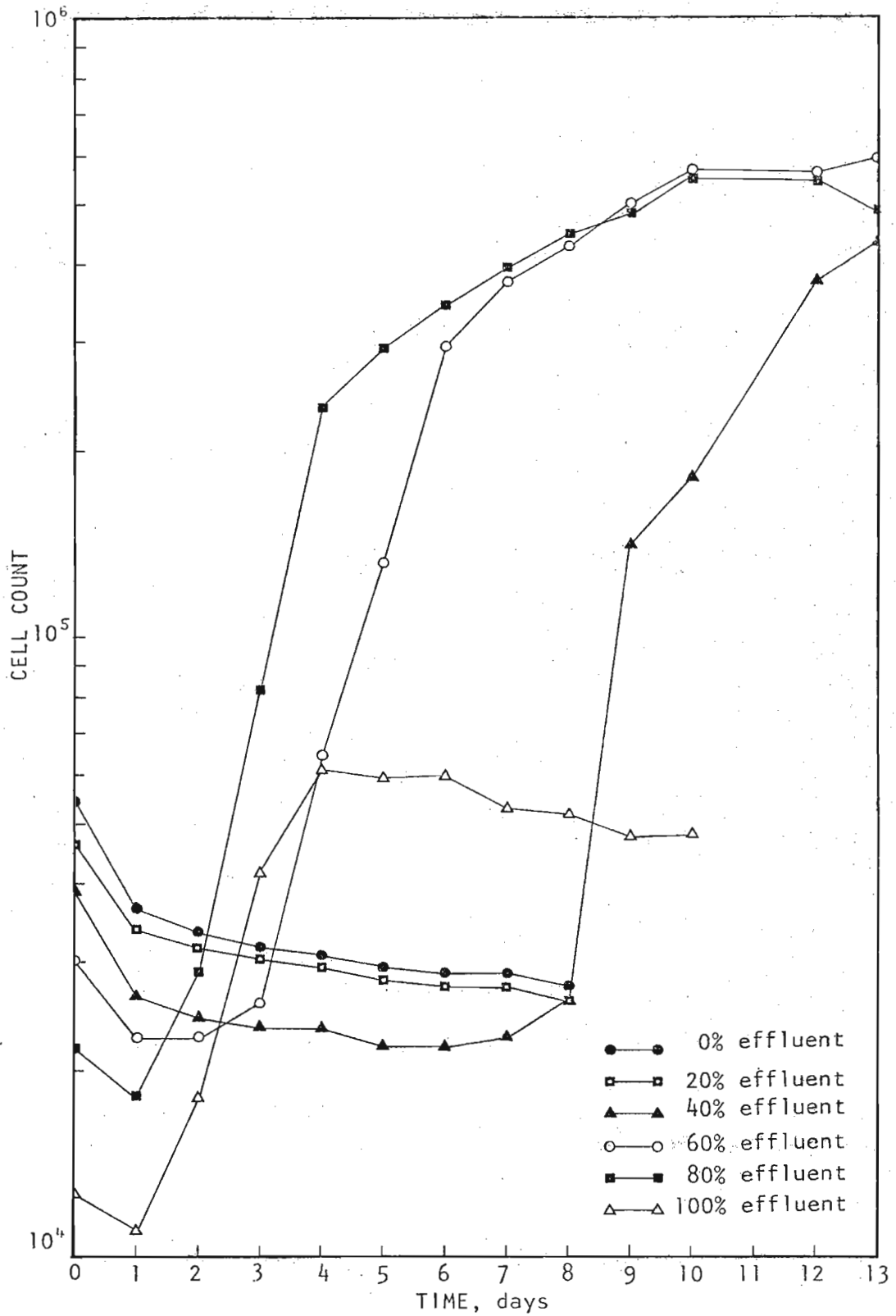
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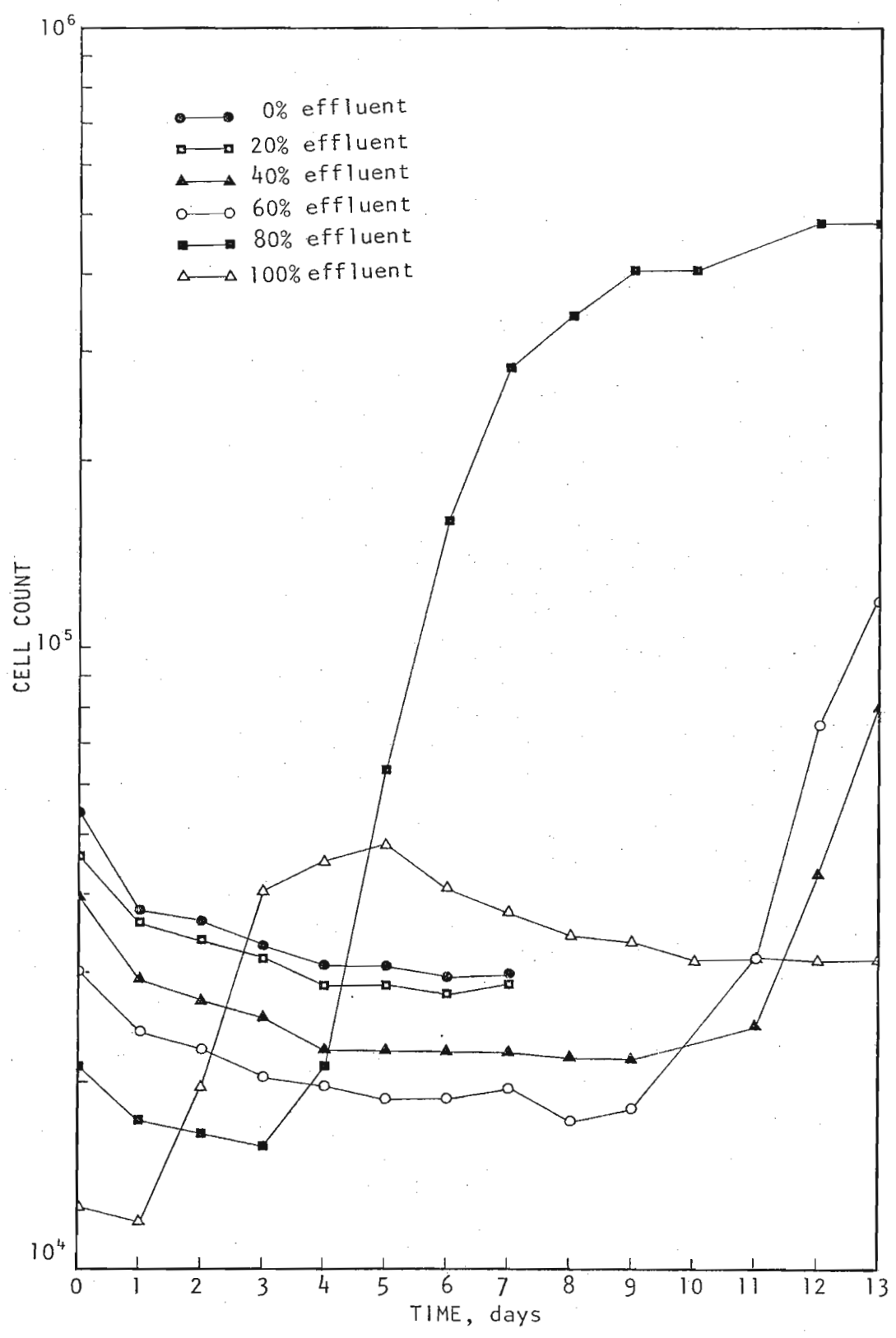
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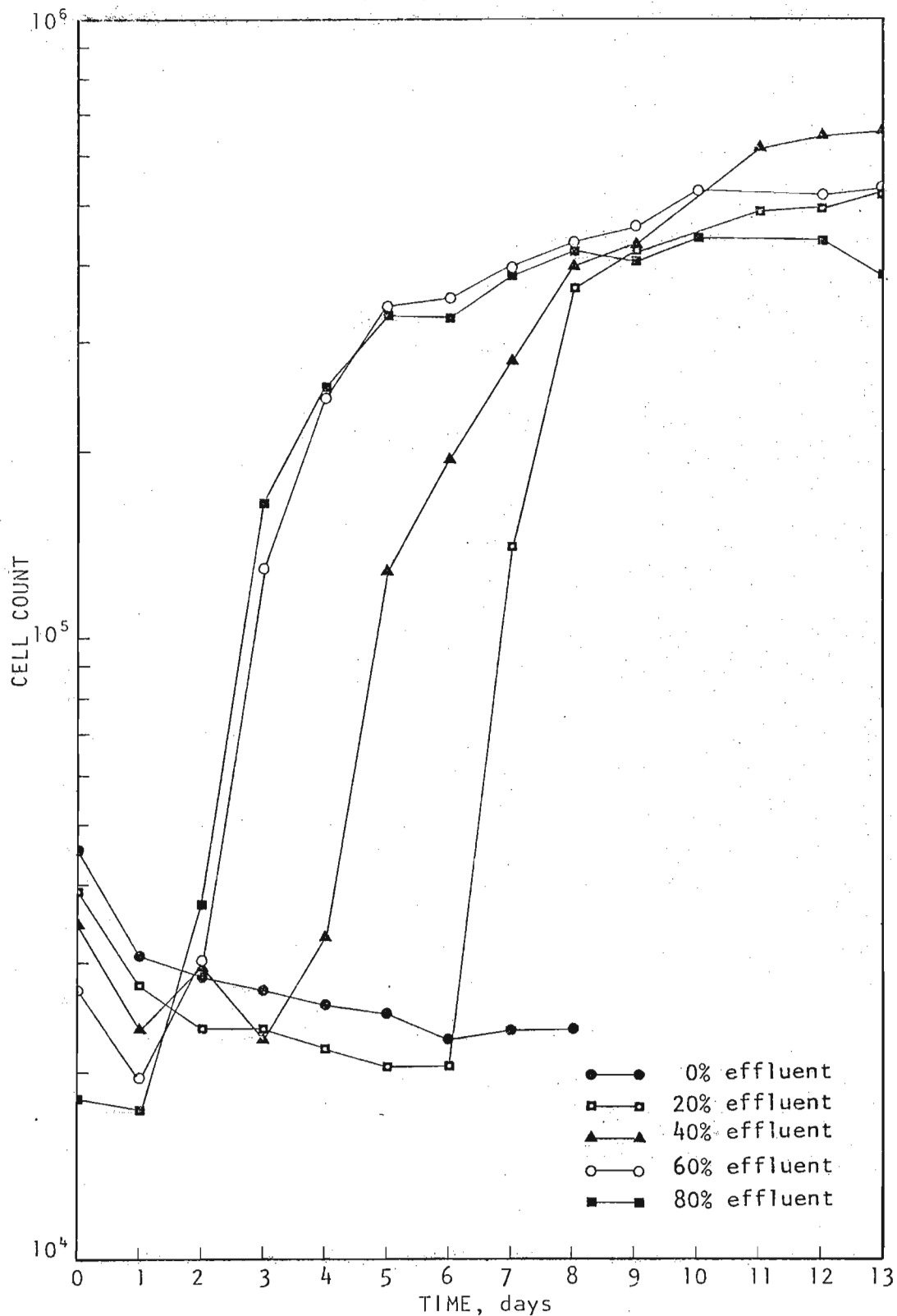
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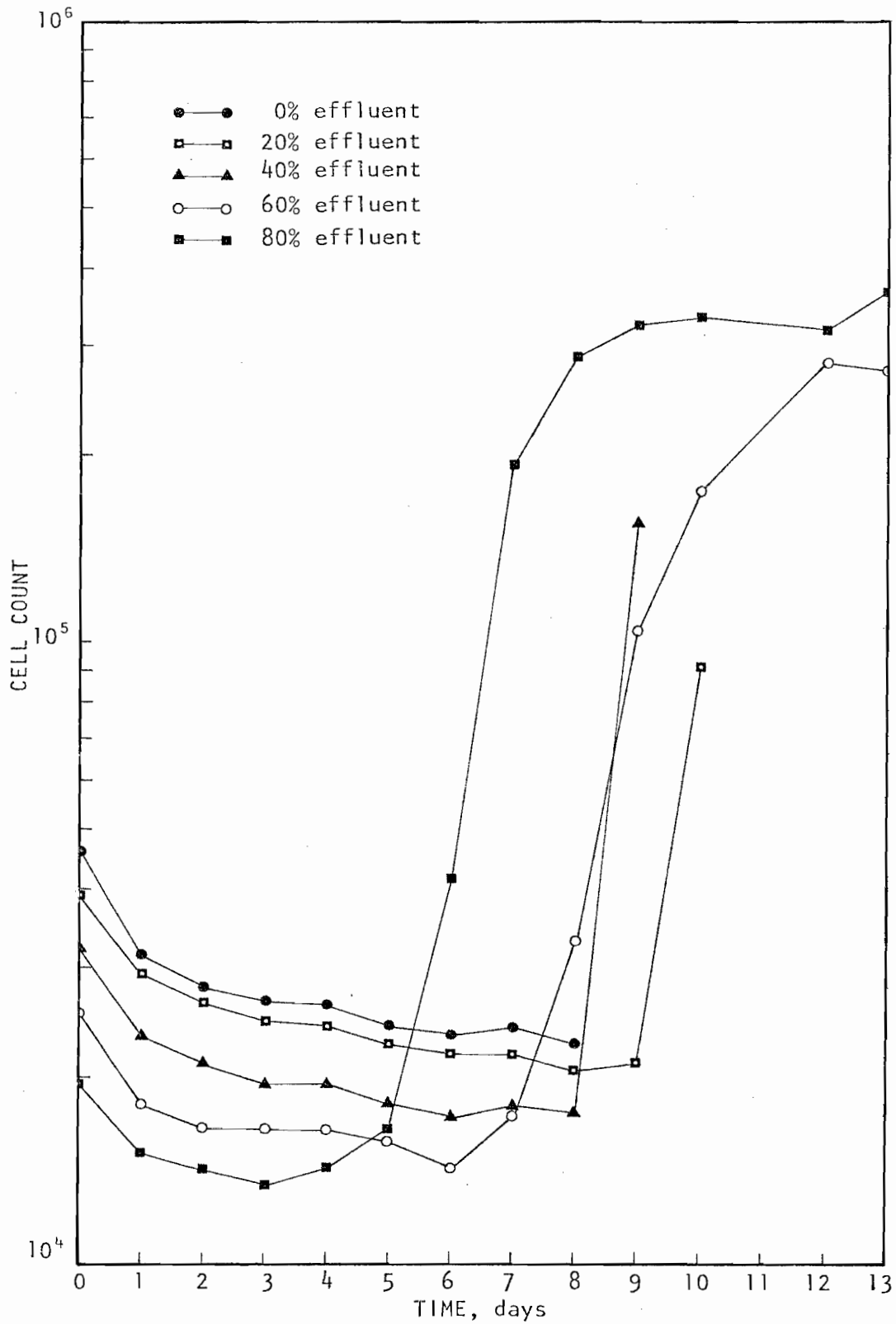
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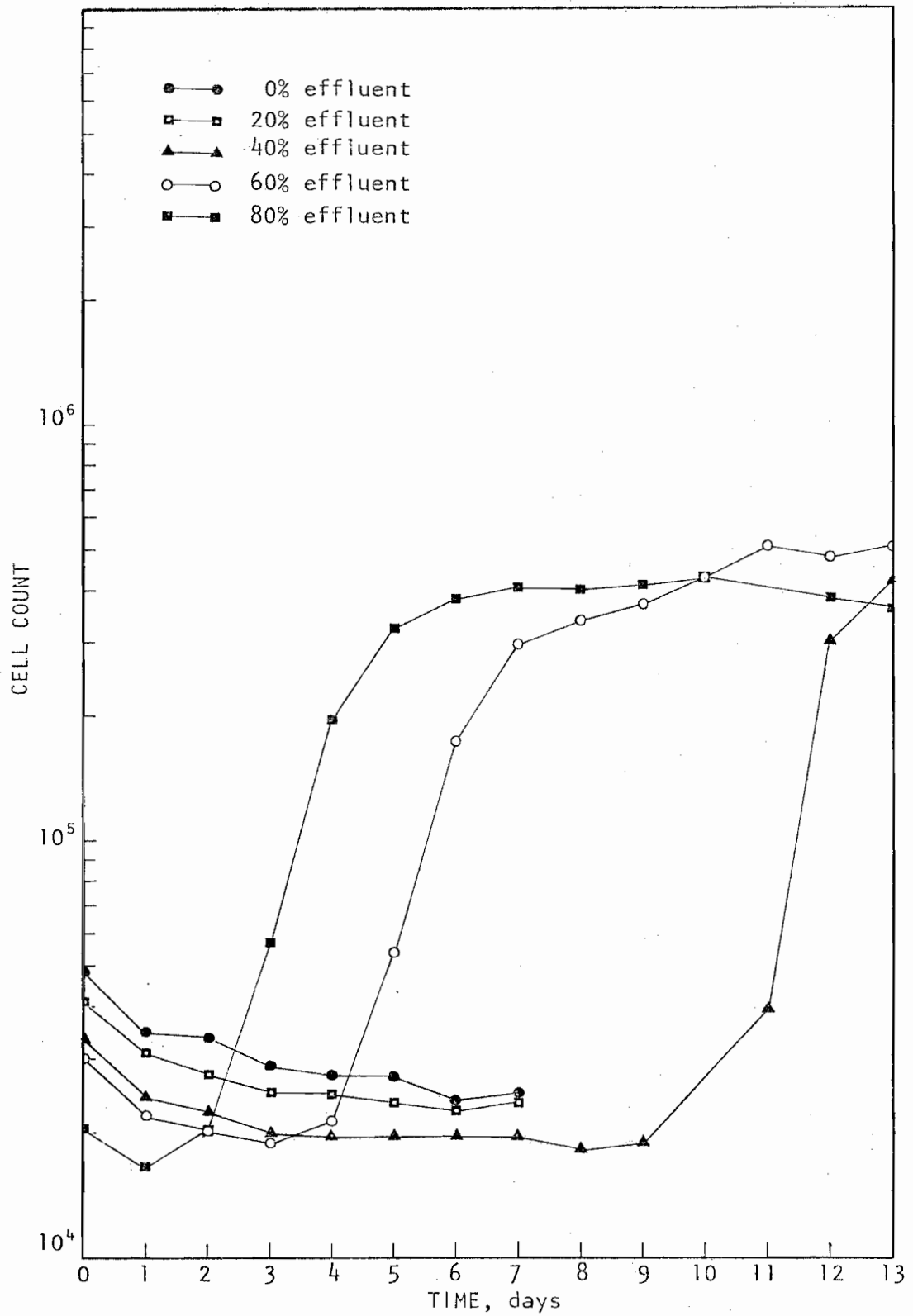
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APPENDIX TABLE C.1. FLUORESCENCE UNITS FOR STREAM RECEIVING WATERS

Sample (Date)	% Eff.	Fluorescence Units															
		0	1	2	3	4	5	6	Day 7	8	9	10	11	12	13	14	15
Kalihi, C.E. Pal. (8/6/75)	0	3.0	1.9	2.0	2.7	2.5	3.1	3.1	3.2								
	20	6.0	3.3	3.8	11	28	49	60	68	80	81						
	40	9.2	4.8	4.6	5.7	9.0	17	30	46	62	76	78					
	60	12	6.5	5.8	5.9	7.6	14	26	40	61	69	71					
	80	13	7.7	6.8	6.0	5.5	5.5	6.0	7.5	14	21	29	30	29			
100	18	9.1	7.7	7.2	6.4	6.6	6.4										
Kalihi, C.E. Pal. (12/1/75)	0	4.2	2.5	2.7	2.7	2.5	2.4	2.5	2.4								
	20	6.2	3.7	5.7	23	44	59	65	77	80	94	103	114	120	120		
	40	8.7	4.6	4.7	13	34	51	59	70	72	82	91	105	112	115		
	60	11	6.3	5.8	11	27	55	67	87	92	95	91					
	80	13	7.2	6.3	8.3	19	43	58	77	83	94	97	104	107	107		
100	16	8.4	7.0	6.6	11	27	42	66	78	87	95	101	114	109			
Kalihi, C.E. Mil. (8/19/75)	0	6.0	4.8	3.9	3.5	3.4	3.4	3.3	3.2								
	20	6.2	4.7	4.7	4.7	20	38	52	54	54							
	40	6.5	4.6	4.4	5.1	9.4	32	34	44	53	62	73	73				
	60	8.0	5.0	4.4	6.7	17	40	46	55	62	67	70	75	76			
	80	8.5	5.1	4.8	9.2	27	48	57	65	70	68						
100	9.1	5.1	4.5	7.0	20	44	57	68	78	79							
Kalihi, C.E. Mil. (10/30/75)	0	2.7	1.9	2.6	3.4	4.2	4.4	4.5	3.9								
	20	4.0	2.7	4.6	9.1	17	28	38	47	53	58	61	57				
	40	5.5	3.4	4.0	8.0	28	52	62	71	78	86	91	105	114	113		
	60	6.9	4.2	4.3	6.9	18	34	58	74	80	85	90	93	90			
	80	8.7	5.0	4.7	5.5	12	25	46	62	74	78	79	80				
100	10	5.6	5.2	7.1	16	34	65	77	80	87	92	97	102	100			
Manoa, C.E. Pal. (10/16/75)	0	2.7	2.2	2.3	2.3	2.2	2.2	2.1									
	20	5.1	3.2	5.0	21	48	50	52	71	84	93	102	111				
	40	7.3	4.2	4.9	17	48	68	72	87	98	110	116	126	137	147	152	
	60	9.2	5.3	4.8	9.4	28	61	80	90	90	94	105	118	128	138	147	154
	80	12	6.9	5.8	8.7	22	46	58	61	68	76	79	81	84	90	90	
100	14	7.8	6.4	8.2	20	38	62	71	72	77	77						

APPENDIX TABLE C.1—CONTINUED

Manoa,	0	4.2	2.5	2.7	2.7	2.5	2.4	2.6	2.4								
C.E. Pal.	20	6.2	3.7	5.7	23	44	59	65	77	80	94	103	114	120	120		
(12/1/75)	40	8.7	4.6	4.7	13	34	50	59	70	72	82	91	105	112	115		
	60	11	6.3	5.9	11	26	55	65	84	89	95	93					
	80	13	7.2	6.3	8.2	19	43	58	77	83	94	97	104	107			
	100	16	8.4	7.0	6.6	11	27	42	66	73	87	95	101	114	109		
Manoa,	0	5.4	3.4	3.4	3.5	3.5	3.4	3.3	3.1								
C.E. Mil.	20	5.7	3.8	4.3	9.2	25	45	48	50	58	59						
(8/19/75)	40	6.0	3.7	3.7	5.2	13	30	45	54	64	69	78	85	85			
	60	8.5	4.7	4.6	6.6	14	28	44	58	66	71	78	78				
	80	9.0	4.7	4.3	4.4	5.7	12	18	27	33	48	62	69	76	76		
	100	9.5	5.3	4.7	5.8	12	23	34	44	53	58	62	66	73			
Manoa,	0	2.9	2.0	1.8	1.9	1.8	1.7	1.7									
C.E. Mil.	20	4.3	3.0	4.9	10	16	24	34	45	54	59	57					
(10/30/75)	40	5.5	3.7	6.1	19	48	65	72	76	88	100	107	120	128	132		
	60	7.0	4.2	5.2	12	31	55	78	81	86	93	95	101	103	104		
	80	8.5	4.7	4.9	10	27	50	72	77	82	88	88					
	100	10	5.6	5.2	7.1	16	34	65	77	80	87	92	97	102	100		
Waihee,	0	2.0	1.5	1.6	1.6	1.6	1.7	1.5	1.6								
C.E. Pal.	20	4.1	2.8	3.2	7.4	19	34	44	53	67	69						
(08/06/75)	40	6.5	4.5	4.3	8.0	21	45	52	55	66	69						
	60	11	6.2	5.5	6.7	13	25	40	48	59	65	71	73	78	83		
	80	14	7.7	7.0	5.9	5.6	5.9	7.3	13	27	43	52	66	78	80		
	100	17	9.5	8.5	8.3	14	30	49	64	69	77	81					
Waihee,	0	1.9	1.9	2.6	4.7	5.2	4.4	4.2	3.9								
C.E. Pal.	20	5.2	3.0	5.3	20	47	62	71	83	98	--	116	122	121			
(12/15/75)	40	8.3	4.3	4.7	12	40	56	64	73	71	--	80	88	97	--	103	104
	60	12	6.3	5.3	7.5	21	47	61	73	83	--	92	90				
	80	14	7.8	6.4	7.1	14	35	52	70	80	--	93	95	96			
	100	17	9.4	7.6	7.7	9.7	23	42	57	71	--	93	101	104	--	104	
Waihee,	0	2.4	1.8	2.1	3.3	3.0	3.1	2.7	2.7	2.3	2.2						
C.E. Mil.	20	3.5	2.3	3.6	16	38	65	79	85	88	95	81					
(9/3/75)	40	4.6	3.3	3.8	16	41	67	83	95	104	116	116					

APPENDIX TABLE C.1—CONTINUED

	60	6.0	4.4	4.1	7.7	23	53	78	92	99	103	101				
	80	8.2	4.9	4.4	5.1	13	35	58	70	77	81	85	90	96	95	
	100	10	5.8	4.9	3.5	6.9	20	45	64	77	91	92	96	100	97	
Waihee, C.E. Mil. (12/15/75)	0	1.9	1.9	2.6	4.7	5.2	4.4	4.2	3.9							
	20	3.4	2.4	4.2	16	40	57	65	70	76	--	80	82			
	40	5.2	3.2	3.4	7.5	29	50	61	69	79	--	96	97			
	60	7.5	4.4	4.1	7.1	20	41	57	70	78	--	87	89	88		
	80	9.0	5.4	4.9	6.8	16	33	55	73	80	--	89	91			
	100	11	6.4	5.5	6.3	8.0	17	33	55	69	--	76	79	87	--	93 96
Waikane, C.E. Pal. (9/18/75)	0	2.7	1.9	2.2	3.3	3.5	3.3	3.2	2.8							
	20	4.5	3.2	5.0	28	45	66	88	107	118	125	124				
	40	8.0	4.8	4.5	12	36	61	68	73	79	95	106	112	114		
	60	11	6.2	5.1	10	29	60	73	95	97						
	80	13	7.4	5.7	5.6	5.3	5.4	7.7	23	49	72	79	76			
	100	14	7.7	6.1	6.0	5.4	5.4	6.5	5.0	4.9						
Waikane, C.E. Pal. (1/4/76)	0	5.0	3.0	3.4	4.3	5.3	5.4	4.5	4.5	5.1						
	20	6.5	4.2	4.7	8.0	25	46	56	65	70	72	70				
	40	8.7	5.4	5.6	8.3	24	44	51	55	65	69	73	78	78	84	
	60	11	7.0	6.5	7.1	12	29	48	67	72	75	75	74	76	89	
	80	13	8.2	7.6	7.2	10	24	43	61	69	75	76	77	78	81	
	100	15	9.4	8.4	7.8	10	22	39	59	72	78	80	84	86	89	
Waikane, C.E. Mil. (9/4/75)	0	2.2	1.7	1.9	2.9	2.8	2.9	2.8	2.6	2.4	2.1					
	20	3.7	2.4	3.2	11	34	62	83	100	111	122	118				
	40	4.6	3.3	3.5	8.6	32	60	78	90	103	115	115				
	60	6.3	4.1	3.9	6.3	23	59	81	97	102	103					
	80	8.2	4.9	4.5	5.6	13	39	64	74	83	91	95	100	101	104	
	100	9.5	5.5	4.9	4.9	8.0	26	54	69	81	91	94	98	100		
Waikane, C.E. Mil. (1/4/76)	0	5.0	3.0	3.4	4.3	5.3	5.4	4.5	4.5	5.1						
	20	6.0	4.3	4.3	5.9	12	21	43	60	72	77	81	80	87		
	40	7.0	5.2	5.0	8.5	25	52	65	77	84	98	106	107	128	140	
	60	8.7	6.3	6.1	8.0	23	48	72	90	100	103	104	120	125	130	
	80	10	7.6	7.5	7.4	12	23	44	70	87	99	104	110	109	112	
	100	11	8.0	7.2	7.2	12	31	54	81	89	107	106	109	106	116	

APPENDIX TABLE C.2. CELL COUNTS FOR STREAM RECEIVING WATERS

Sample (Date)	% Eff.	Cell Count															
		Day															
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kalihi, C.E. Pal. (8/6/75)	0	5.7	3.1	3.4	4.9	4.5	5.9	5.9	6.1								
	20	14	6.4	7.7	30	100	208	269	317	391	397						
	40	25	10	9.8	13	23	53	110	191	281	366	378					
	60	34	15	13	14	19	41	92	160	275	323	335					
	80	37	19	16	14	12	12	14	18	41	70	105	110	105			
100	58	24	19	17	15	16	15										
Kalihi, C.E. Pal. (12/1/75)	0	8.7	4.5	4.9	4.9	4.5	4.2	4.5	4.2								
	20	14	7.4	13	78	181	264	299	372	391	481	541	617	659	659		
	40	22	9.8	10	37	130	219	264	329	341	403	461	555	603	624		
	60	30	15	13	30	96	241	311	435	468	488	461					
	80	37	17	15	21	61	175	258	372	410	481	501	548	568	568		
100	49	21	17	16	30	96	170	305	378	435	488	528	617	582			
Kalihi, C.E. Mil. (8/19/75)	0	14	10	7.9	6.9	6.6	6.6	6.4	6.1								
	20	14	10	10	10	65	150	224	235	235							
	40	15	9.8	9.3	11	25	120	130	181	230	281	347	347				
	60	20	11	9.3	16	53	160	191	241	281	311	329	359	366			
	80	22	11	10	24	96	202	252	299	329	317						
100	24	11	9.5	17	65	181	252	317	378	384							
Kalihi, C.E. Mil. (10/30/75)	0	4.9	3.1	4.7	6.6	8.7	9.3	9.5	7.9								
	20	8.2	4.9	9.8	24	53	101	150	197	230	258	275	252				
	40	12	6.6	8.2	20	101	224	281	335	378	429	461	555	617	610		
	60	17	8.7	9.0	17	57	130	258	353	391	422	455	474	455			
	80	22	11	10	12	34	87	191	281	353	378	384	391				
100	27	13	11	17	49	130	299	372	391	435	468	501	534	521			
Manoa, C.E. Pal. (10/16/75)	0	4.9	3.8	4.0	4.0	3.8	3.8	3.6									
	20	11	6.2	11	70	203	214	224	336	416	477	534					
	40	19	8.7	11	53	203	315	343	507	513	590	633	707	780	858	905	
	60	25	12	11	25	101	274	390	453	453	480	552	650	720	793	866	905
	80	34	17	13	23	74	192	258	274	315	367	383	396	418	453	453	
100	41	19	15	21	66	149	280	336	343	370	370						

APPENDIX TABLE C.2—CONTINUED

Manoa,	0	8.7	4.5	4.9	4.9	4.5	4.2	4.7	4.2							
C.E. Pal.	20	14	7.4	13	78	181	264	299	372	391	481	541	617	659	659	
(12/1/75)	40	22	9.8	10	37	130	213	264	329	341	403	461	555	603	624	
	60	30	15	14	30	92	241	299	416	448	488	474				
	80	37	17	15	21	61	175	258	372	410	481	501	548	568		
	100	49	21	17	16	30	96	170	305	347	435	488	528	617	582	
Manoa,	0	12	6.6	6.6	6.9	6.9	6.6	6.4	5.9							
C.E. Mil.	20	13	7.7	9.0	24	87	186	202	213	258	264					
(8/19/75)	40	14	7.4	7.4	11	37	110	186	235	293	323	378	422	422		
	60	22	10	9.8	16	41	101	181	258	305	335	378	378			
	80	23	10	9.0	9.3	13	34	57	96	125	202	281	323	366	366	
	100	25	12	10	13	34	78	130	181	230	258	281	305	347		
Manoa,	0	5.4	3.4	2.9	3.1	2.9	2.7	2.7								
C.E. Mil.	20	9.0	5.7	11	27	49	83	130	186	235	264	252				
(10/30/75)	40	12	7.4	14	61	202	299	341	366	442	521	568	659	716	745	
	60	17	8.7	11	34	115	241	378	397	429	474	488	528	541	548	
	80	22	10	11	27	96	213	341	372	403	442	442				
	100	27	13	11	17	49	130	299	372	391	435	468	501	534	521	
Wailea,	0	3.3	2.3	2.5	2.5	2.5	2.7	2.3	2.5							
C.E. Pal.	20	8.5	5.2	6.1	18	61	130	181	230	311	323					
(8/6/75)	40	15	9.5	9.0	20	70	186	224	241	305	323					
	60	30	14	12	16	37	87	160	202	264	299	335	347	378	410	
	80	41	19	17	14	13	14	18	37	96	175	224	305	378	391	
	100	53	25	22	21	41	110	208	293	323	372	397				
Wailea,	0	3.1	3.1	4.7	10	11	9.3	8.7	7.9							
C.E. Pal.	20	11	5.7	12	65	197	281	335	410	507	--	631	673	666		
(12/15/75)	40	21	9.0	10	34	160	247	293	347	335	--	391	442	501	--	541 548
	60	34	15	12	18	70	197	275	347	410	--	468	455			
	80	41	19	15	17	41	134	224	329	391	--	474	488			
	100	53	25	19	19	26	78	170	252	335	--	474	528	548	--	548
Wailea,	0	4.2	2.9	3.6	6.4	5.7	5.9	4.9	4.9	4.0						
C.E. Mil.	20	8.6	4.0	7.2	49	150	299	384	422	442	488	397				
(9/3/75)	40	9.8	6.4	7.7	49	165	311	410	488	548	631	631				

APPENDIX TABLE C.2—CONTINUED

	60	14	9.3	8.5	19	78	230	378	468	514	541	528				
	80	21	11	9.3	11	37	134	258	329	372	397	422	455	494	488	
	100	27	13	11	6.9	17	65	186	293	372	461	468	494	521	501	
Wailee,	0	3.1	3.1	4.7	10	11	9.3	8.7	7.9							
C.E. Mil.	20	6.6	4.2	8.7	49	160	252	299	329	366	--	391	403			
(12/15/75)	40	11	6.1	6.6	18	105	213	275	323	384	--	494	501			
	60	18	9.3	8.5	17	65	165	252	329	378	--	435	448	442		
	80	23	12	11	16	49	125	241	347	391	--	448	461			
	100	30	15	12	15	20	53	125	241	323	--	366	384	435	--	474 494
Waikane,	0	4.9	3.1	3.8	6.4	6.9	6.4	6.1	5.2							
C.E. Pal.	20	9.6	6.1	11	101	186	305	442	568	645	695	687				
(9/18/75)	40	20	10	9.5	34	139	275	317	347	384	488	562	603	617		
	60	30	14	11	27	105	269	347	488	501						
	80	37	18	13	13	12	12	19	78	208	341	384	366			
	100	41	19	14	14	12	12	15	11	11						
Waikane,	0	11	5.7	6.6	9.0	12	12	9.5	9.5	11						
C.E. Pal.	20	15	8.7	10	20	87	191	247	299	329	341	329				
(1/4/76)	40	22	12	13	21	83	181	219	241	299	323	347	378	378		
	60	30	17	15	17	34	105	202	311	341	359	359				
	80	37	21	19	17	27	83	175	275	323	359	366	372			
	100	45	25	21	19	27	74	155	264	341	378	391	416	429	448	
Waikane,	0	3.1	2.7	3.1	5.4	5.2	5.4	5.2	4.7							
C.E. Mil.	20	7.5	4.2	6.1	30	130	281	410	521	596	673	645				
(9/4/75)	40	9.8	6.4	6.9	22	120	269	378	455	541	624	624				
	60	15	8.5	7.9	15	78	264	397	501	534	541					
	80	21	11	9.5	13	37	155	293	353	410	461	488	521	528		
	100	25	12	11	11	20	92	235	323	397	461	481	507	521		
Waikane,	0	11	5.7	6.6	9.0	12	12	9.5	9.5							
C.E. Mil.	20	14	9.0	9.0	14	34	70	175	269	341	372	397	391			
(1/4/76)	40	17	11	11	22	87	224	299	372	416	507	562	568			
	60	22	15	14	20	78	202	341	455	521	541	548				
	80	27	19	18	18	34	78	181	329	435	514	548	589	582		
	100	30	20	17	17	34	115	235	397	448	568	562				

APPENDIX TABLE C.3. FLUORESCENCE UNITS FOR SEA WATER

% Eff.	Control Date	Consecutive Days of Tests														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	
0	3/15	1.9	1.8	2.7	6.1	6.6	6.6	5.2	4.8	4.8	4.3	4.0				
	4/06	1.5	1.3	2.2	5.4	8.1	7.8	7.9	6.9	6.8	6.2	6.2				
	4/27	1.5	1.4	2.4	5.2	5.9	6.3	5.3	4.8	4.4	4.3	4.0		4.0	4.0	
20	3/15	2.4	2.1	1.9	2.2	3.7	20.7	38.6	41.8	50.3	61.1	72.6		82.6	84.2	
		2.2	2.1	4.8	23.8	37.7	49.7	49.4	58.9	64.9	61.4	68.1		67	58.0	
	4/06	2.7	2.2	3.6	11.1	34.2	43.4	52.2	59.8	68.4	74.9	86		85.2	75.6	
		2.4	1.8	1.7	1.6	1.7	2.0	5.4	28.1	42.7	49.0	50.0		47.3	55.2	
	4/27	2.6	2.1	2.0	1.9	2.6	8.5	22.9	41.8	51.6	61.5	61.4		74.6	74.2	
		2.5	2.0	2.5	7.5	28.4	47.9	57.6	62.4	61.1	62.4	65.5		57.6	54.0	
40	3/15	3.7	2.8	2.5	2.5	2.5	2.7	3.8	6.4	17.2	33.6	48.6		62.2	74.9	
		3.4	2.4	3.8	18.1	36.6	50.9	53.2	60.3	66.5	71.2	81.7		80.5	82.4	
	4/06	3.8	2.8	2.8	3.2	8.6	23.2	43.7	56.7	65.6	74.9	87.5		86.8	93.8	
		3.2	2.2	2.0	2.0	2.0	1.9	1.7	2.1	4.2	14.4	25.1		41.5	40.2	
	4/27	3.8	3.0	2.8	2.5	2.4	2.3	2.3	2.4	2.1	2.2			4.0	10.1	16.5
		3.9	2.7	2.5	2.3	2.6	7.1	24.7	44.0	50.9	63.6			80.5	74.9	80.4
60	3/15	4.8	3.3	3.1	2.8	2.9	2.7	2.6	2.8	5.1	12.0	5.4		3.3	3.4	
		4.4	2.9	3.7	2.8	50	18.1	28.1	41.8	60.8	66	83		101.9	104	
	4/06	5.0	3.3	3.0	2.9	2.9	2.7	2.7	2.8	3.2	20.1	26.2		56.8	66.3	
		4.1	2.9	2.6	2.4	2.4	2.2	2.1	2.2	2.1	21.9	--	--	--	--	
	4/27	5.2	3.7	3.4	3.2	2.8	2.8	2.8	2.8	2.6	2.7			3.1	5.6	10.9
		4.3	3.0	2.8	2.4	2.4	2.4	2.4	2.4	2.2	2.3	--	--	5.1	45.3	64.2
80	3/15	5.9	4.3	4.1	3.7	3.6	3.5	3.2	3.2	3.4	4.0	3.2				
		5.0	3.5	2.9	2.9	2.7	2.5	2.5	3.9	19.9	55.9	64.9	--	75.6	82.7	
	4/06	6.1	4.3	4.0	3.8	3.7	3.5	3.4	3.4	3.2						
		5.1	3.7	3.3	3.1	3.0	2.8	2.7	2.7	2.5	2.6	12.5	--	--	--	
	4/27	6.0	4.6	4.3	4.0	3.6	3.6	3.5	3.6							
		5.3	3.9	3.5	3.1	3.1	2.9	2.8	2.9	--	--	--	--	--	--	
100	3/15	6.5	4.7	4.3	4.0	3.8	3.7	3.6	3.5	3.6	3.4	3.4	3.3	--	--	
		6.0	3.9	3.6	3.4	3.2	3.1	2.8	2.9	2.9	2.8	2.6				
	4/06	7.1	4.7	4.2	4.1	3.9	3.7	3.6	3.6	3.4	--	--	--	--	--	
		6.0	4.0	3.5	3.3	3.3	3.0	2.9	3.0	2.8	--	--	--	--	--	
	4/27	7.2	4.8	4.6	4.2	3.9	3.9	3.7	3.7	--	--	--	--	--	--	
		6.3	4.4	4.3	3.6	3.4	3.2	2.9	3.0	--	--	--	--	--	--	

