Chlorination dose and response for biological effluent used for drip irrigation

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Abstract. *Control of biological growth within subsurface drip irrigation (SDI) systems is important to keep the system operating properly for many years. The traditional method of control is through the injection of chlorine into the SDI system. Little is known about the effectiveness of chlorine injection into livestock effluent (wastewater) used with SDI systems. This project measured the residual chlorine concentration and coliform count after treatment with chlorine at concentrations between 10 and 120 mg/L and at pH levels of about 8.0 (approximately the unadjusted pH in most effluents), 7.5, and 7.0. Effluent was sampled at four beef cattle feeding facilities (feedlots), two dairies, and two swine feeding facilities. Chlorine and coliform responses varied considerably. The residual chlorine concentrations in effluent from three sites were nondetectable even at chlorine addition of 120 mg/l. At two of those sites, coliforms grew in abundance at all tested Cl concentrations while coliform growth was prevented at 120 mg Cl/l in effluent from the third site. In effluent used in previous SDI research, coliform growth was prevented with a pH adjustment to 7.0 and addition of 10 mg Cl/l.*

Introduction

Management of biological effluent (wastewater) resources from animal feeding operations in the Midwest and Great Plains of the USA is an important issue. This resource represents a potentially important source of nutrients for crops. Because the nutrients are so concentrated, the effluents- if mismanaged- also represent a pollution threat.

One method of effluent utilization is application to field crops via irrigation systems. Proper management of irrigation with effluent fosters the efficient use of nutrients and water components of the effluent. Traditionally, effluent utilization is accomplished with sprinkler (most often center pivot) or furrow irrigation systems.

Subsurface drip irrigation (SDI) with effluent has been shown to be technically feasible (Trooien et al., 2000). Some potential advantages for the use of effluent through SDI systems include (Trooien et al., 2000): reduced human contact; reduced odor; reduced potential for runoff; reduced potential for phosphorus runoff into surface waters; greater uniformity of application resulting in better control of water, nutrients, and salts; reduced irrigation system corrosion; reduced application constraint by weather (winds and temperatures); and increased flexibility in matching field and irrigation system shapes and sizes.

The SDI system must be economically feasible or these advantages are of no consequence. The key to economic feasibility of SDI systems lies in getting many years of efficient operation from the installed system, thus amortizing the initial investment over many growing seasons (O'Brien et al., 1998). To maintain efficient system operation for many years, one must keep the driplines and emitters free from clogging by bacterial and algal growth because emitter clogging is a major problem associated with microirrigation systems (Nakayama and Bucks, 1986). In freshwater SDI systems, biological growth is often controlled with occasional or continuous injection of chlorine. The question that must be asked is, "How can I use effluent through my SDI system and still keep the driplines and emitters free from bacterial and algal clogging using the traditional chlorination approach?"

To address this question, we initiated the research reported here. Our objective was to measure the residual chlorine content and number of coliform colonies in response to treatment of livestock effluent with various concentrations of chlorine at three different pH levels. Coliforms were used as an indicator of potential for emitter clogging and because of the health issues associated with human exposure to coliforms.

Methods

Effluent samples from eight livestock facilities were used in this study. Four sites were beef cattle feeding facilities (feedlots), two were dairies, and two were swine feeding facilities. All facilities except one were located within 200 km of Brookings, SD. The exception was the effluent obtained from the beef feedlot in southwest Kansas used for previous research with SDI and effluent (Trooien et al., 2000). Samples were collected from the effluent containment ponds (sometimes called lagoons) at each site.

Samples were collected by placing an intake about 3 m from the pond bank and about 0.3 m beneath the pond surface. Effluent was pumped from the pond and through a 200 mesh disk filter prior to placement in sample bottles. The samples were kept cool until delivery to the laboratory, usually less than one hour after sampling. One sample required overnight transport so it was stored in a cooler at 4°C until delivery to the laboratory.

The following parameters were measured shortly after receipt of the sample in the lab: pH, alkalinity, biological oxygen demand (BOD), electrical conductivity (EC), total suspended solids (TSS), and total dissolved solids (TDS), and total coliform count. Ammonia concentration was measured for effluent from sites 3 through 8.

Chlorine dose/response testing took place at three different pH levels- unadjusted (generally near 8, Table 1) and adjusted to 7.5 and 7.0. After pH adjustment, chlorine was added at concentrations between 10 and 120 mg/l. Concentrations of added chlorine varied among samples. After one hour of

contact time, the residual free and total chlorine concentrations were measured using the amperometric titration method (American Public Health Association, 1998). Residual free chlorine concentration of 1 to 2 mg/l is generally recommended for disinfection of effluent (Feigin et al., 1991).

After the 60 minutes of chlorine contact, 100 ml of sample were dechlorinated with sodium thiosulfate. Dechlorinated sample volumes of 1, 2, and 5 ml were each added to 1.5 ml of total coliform broth. Coliform incubation followed the ASTM standard. Coliform colony counting also followed the standard ASTM procedure. For compactness of presentation, all coliform counts greater than 1000 colonies/100 ml are presented as 1000. For the same reason, all nondetectable concentrations of residual chlorine (free or total) are charted as a value of 0.

Results

Effluent chemistries varied widely from site to site (Table 1). All had pH greater than 7.45 and six were 7.75 or greater. The four beef feedlots had the four highest pH values. Of the eight tested sites, three had ammonia concentrations greater than 400 mg/l. Effluent from seven of the sites had EC greater than 3 dS/m, making them very high salinity hazard for use as irrigation water. Even the lowest-salinity effluent, with EC of 1.89 dS/m, would be classified as high salinity hazard irrigation water (Richards et al., 1954). Total suspended solids content varied tenfold, from 208 mg/l to 2044 mg/l. Also, BOD values varied more than tenfold, from 218 to 3140 mg/l. Finally, coliform variation was even greater. Site 8 had a very low coliform count of 13 while site 5 had a coliform count of nearly 500,000.

Table 1. Selected characteristics of the sampled sites.

Site	Type	pH	Alk	Ammon	EC	TSS	TDS	BOD	Colif
			mg/l as $CaCO_3$	mg/l	dS/m	mg/l	mg/l	mg/l	#/100ml
1	Beef	7.98	584	NA	1.89	260	1311	235	8976
2	Dairy	7.45	1122	NA	3.63	208	3267	240	237
3	Beef	8.07	1094	40	3.13	338	2465	218	8862
4	Beef	7.87	3694	412	10.10	2044	8990	>1870	55000
5	Swine	7.59	5044	823	12.23	675	3880	2320	477493
6	Dairy	7.80	3558	587	7.98	1162	7360	3140	7746
7	Swine	7.75	2398	9	6.25	453	2944	751	81872
8	Beef	8.02	1730	164	5.13	394	3289	<700	13

NA: Not analyzed, Alk: alkalinity, Ammon: ammonia, EC: electrical conductivity,
TSS: total suspended solids, TDS: total dissolved solids,
BOD: biochemical oxygen demand, Colif: coliform count.

The effluent from site 1 grew no coliforms when treated at any concentration of chlorine at any of the three tested pH levels (Fig 1). Total chlorine residual concentration and free residual chlorine concentration behaved similarly for site 1 so they are discussed interchangeably. Residual chlorine was greater than 1 mg/l (which should control bacterial growth, Feigin et al., 1991) at addition of 10 mg Cl/l when the pH was adjusted to 7.0. At pH levels of 7.5 or 8 (the unadjusted level), additions of chlorine at concentrations of 20 to 25 mg/l were required to attain residual chlorine concentrations of greater than 1 mg/l.

Effluent from site 2 required greater additions of chlorine to attain any measurable residual chlorine concentration. At pH of 8, addition of 75 mg Cl/l was required to attain any measurable residual chlorine (Fig 2). When the pH was adjusted to 7, however, addition of 25 mg/l resulted in total residual chlorine of 0.75 mg/l and no coliform growth, even though no measurable free residual chlorine was detected.

Site 3 had effluent similar to site 1 in that no coliforms grew in any of the chlorine dose/response treatments (Fig 3). At the unadjusted pH (8.07), addition of chlorine at 45 mg/l was required to attain detectable free residual chlorine and total residual chlorine greater than 1 mg/l. At pH of 7, only 35 mg Cl/l were required to achieve the same result.

Effluent samples from sites 4, 5, and 6 all had high chlorine demand. No residual chlorine was detected at any treatment up to 120 mg Cl/l and any pH (Figs 4 and 5). Additionally, effluent from site 6 grew numerous coliforms at all chlorine levels. Effluent from site 4 grew no coliforms when chlorine was added at a concentration of 120 mg/l, even though no detectable residual chlorine was found (Fig. 4). Effluent from Site 6 had high ammonia content (Table 1), which reduced the effectiveness of the chlorine disinfection. Even addition of chlorine at the rate of 120 mg/l did not completely control coliform growth (Fig. 5). Sites 4 and 5 also had high ammonia concentrations and they also had high initial coliform counts (Table 1). The effluent from Site 5, although treated with chlorine concentrations of 90 to 120 mg/l, showed no residual chlorine and coliform counts were all greater than 1000 colonies per 100 ml (data not shown).

The effluent sampled at site 7 grew numerous coliforms when chlorine was added at concentrations less than 30 mg/l (Fig 6). Total residual chlorine concentrations were greater than 1 mg/l at additions of 30 mg Cl/l or greater, except at the Cl breakpoint. The residual chlorine data from Site 7 illustrate the chlorine “breakpoint” addition/concentration curve although the free residual chlorine concentration does not increase with increasing Cl addition. When the addition concentration is increased from 30 to 40 mg/l, chloramines are oxidized and the residual chlorine in solution is reduced (Feigin et al., 1991). No free residual chlorine was detected at any chlorine addition concentration and any pH.

Decreasing the pH level decreased the amount of chlorine required to increase residual chlorine content and coliform growth in the effluent from site 8 (Fig 7). At the unadjusted pH of 8.02, addition of 30 mg Cl/l resulted in a detectable total residual chlorine concentration and no coliform growth. Addition of chlorine at 20 mg /l stopped coliform growth at pH of 7.5, while at pH of 7.0, even the addition of chlorine at 10 mg/l prevented coliform growth. The initial coliform count in the effluent from Site 7 was low (Table 1) and the coliform counts, if non-zero, after all treatments were also low.

Summary

Responses of residual chlorine concentrations and coliform growth in livestock effluent were variable. Addition of chlorine to one effluent (swine) with high coliform counts and high ammonia concentrations resulted in no residual chlorine and no coliform control while addition of chlorine to another effluent (beef) resulted in no residual chlorine for any treatment but no coliform growth at addition of 120 mg/l. Addition of chlorine to effluent with high coliform count and low ammonia concentration resulted in measurement of residual total chlorine (except at the Cl breakpoint) and complete control of coliform growth at addition concentrations of 30 mg/l or greater.

Acknowledgements

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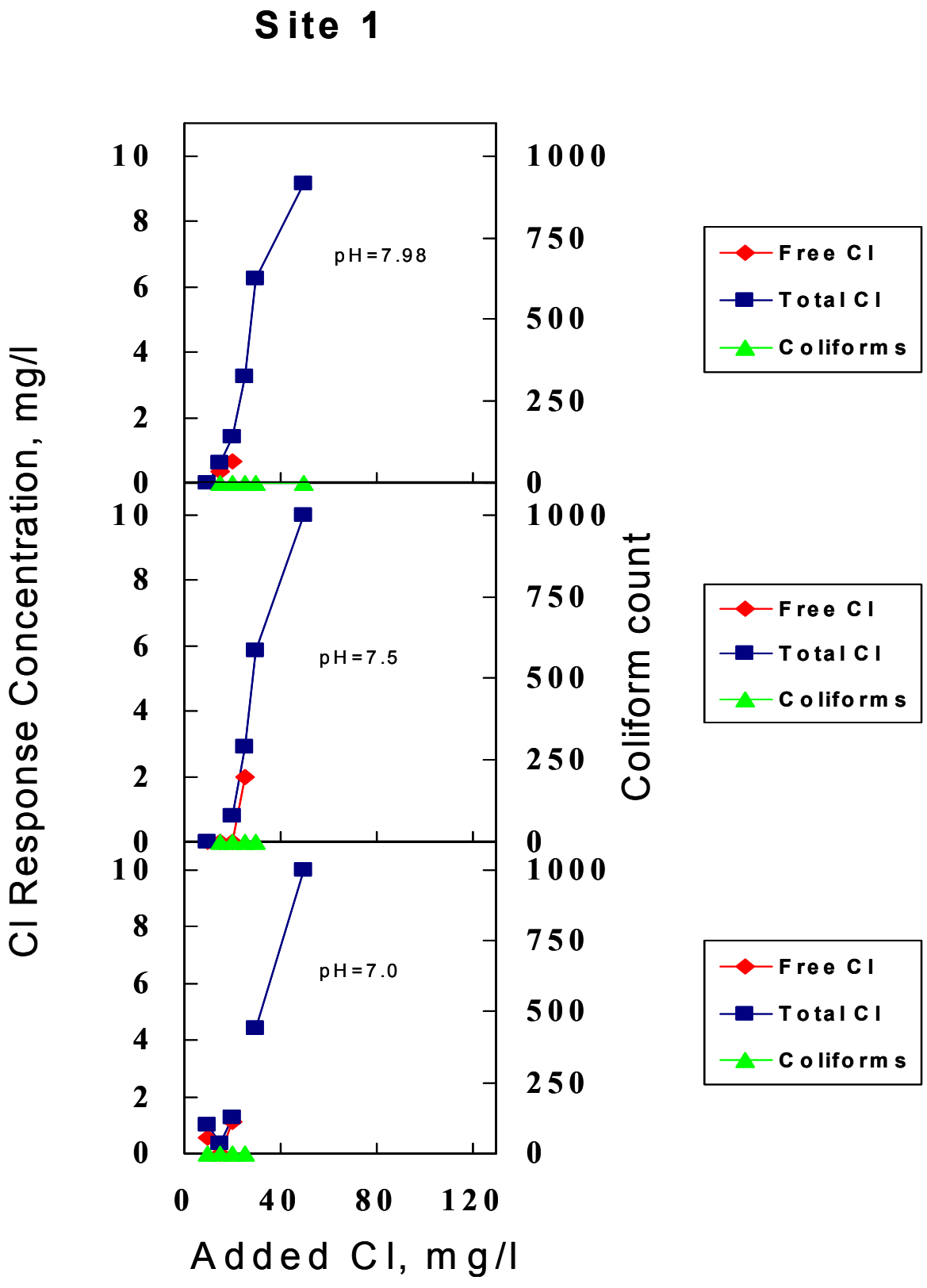

Figure 1. Chlorine dose/response for effluent from Site 1.

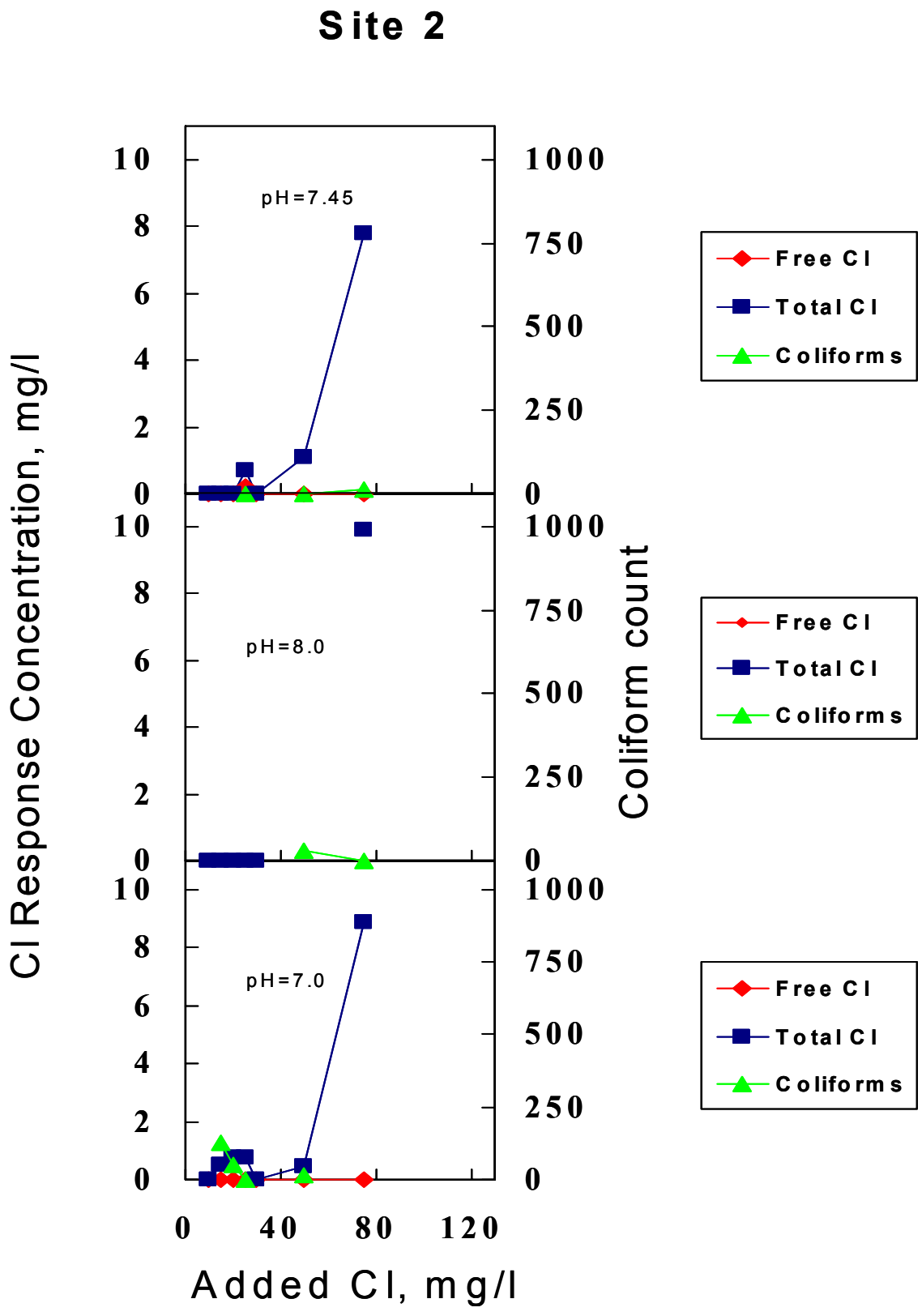

Figure 2. Chlorine dose/response for effluent from Site 2.

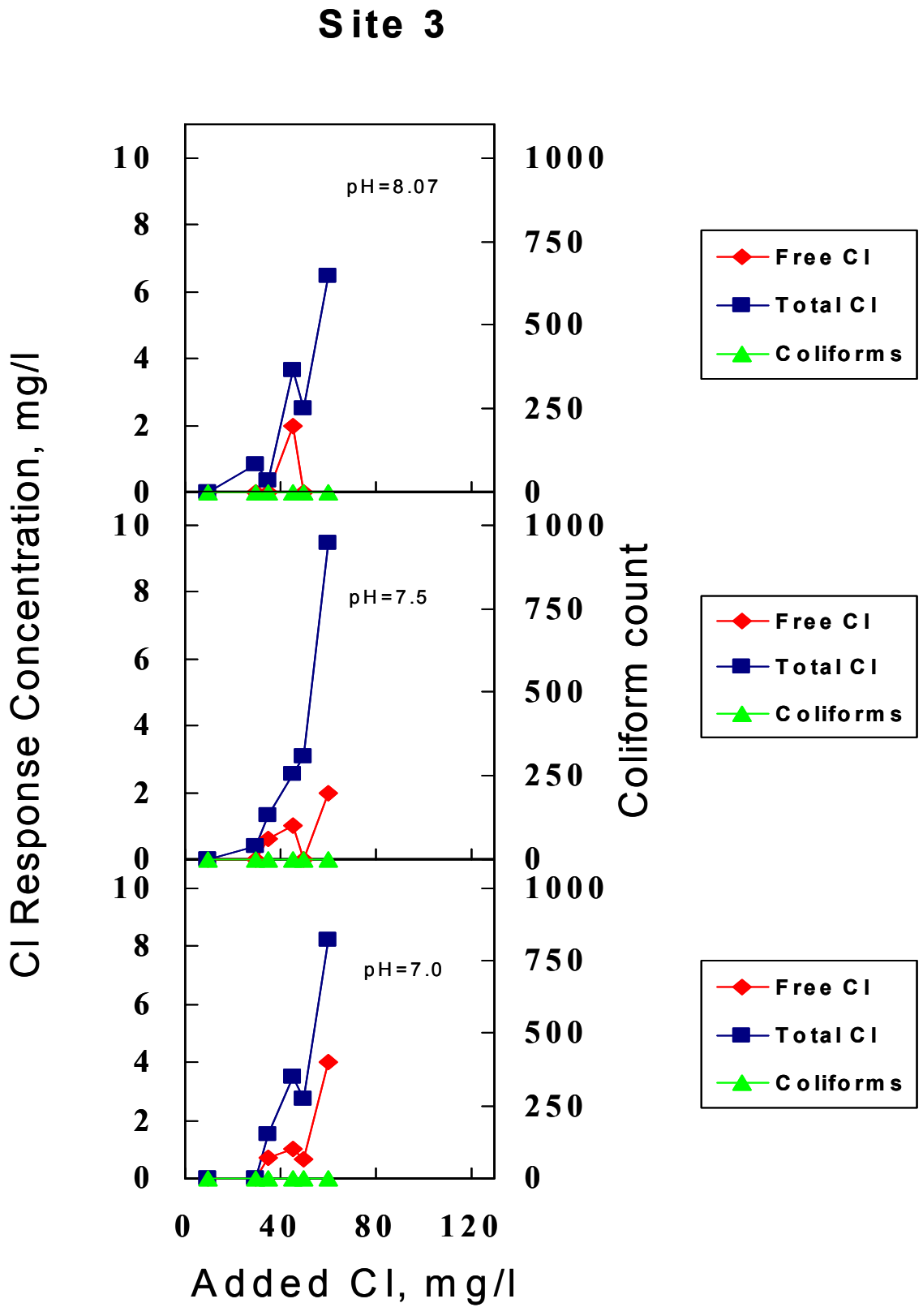

Figure 3. Chlorine dose/response for effluent from Site 3.

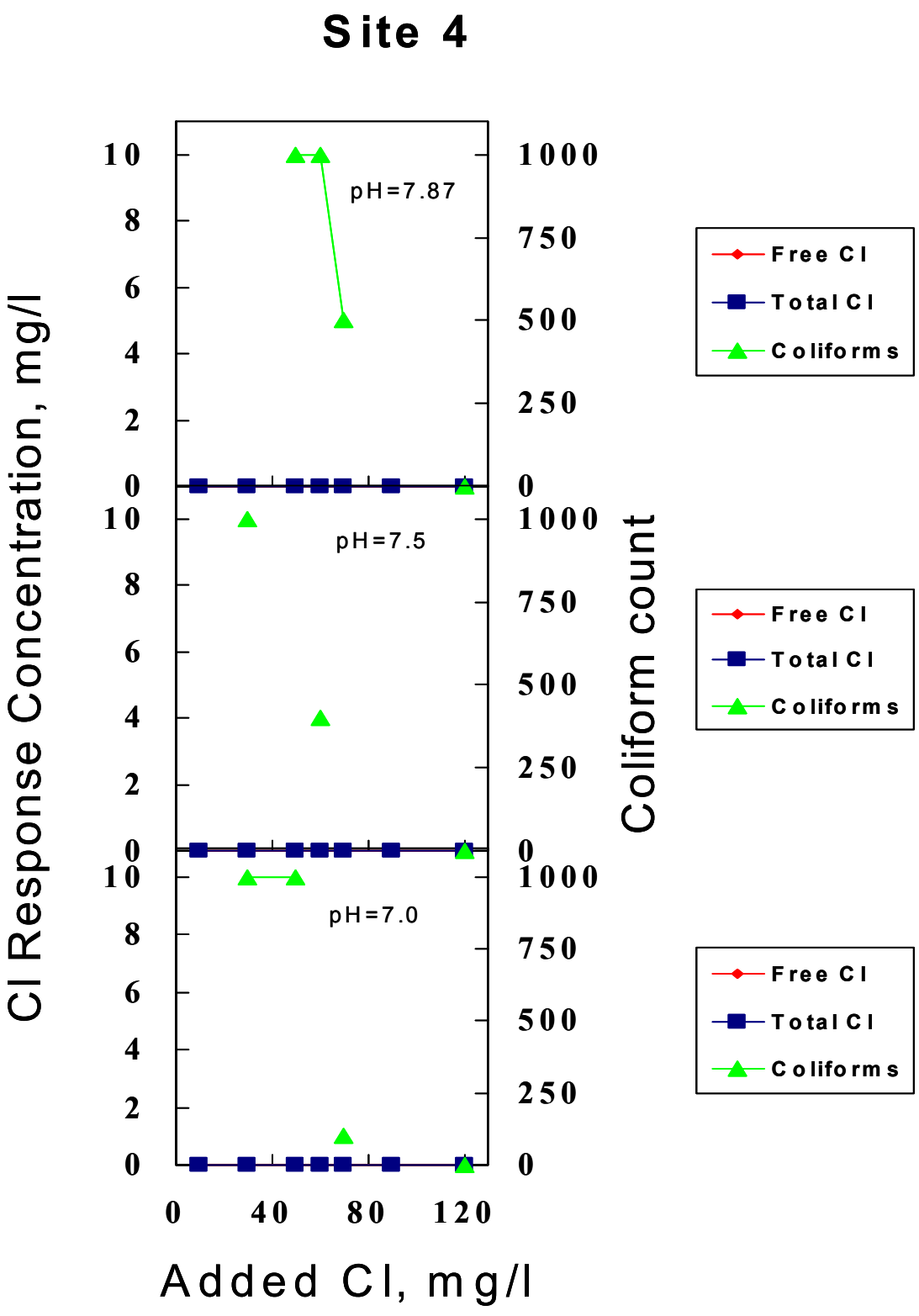

Figure 4. Chlorine dose/response for effluent from Site 4.

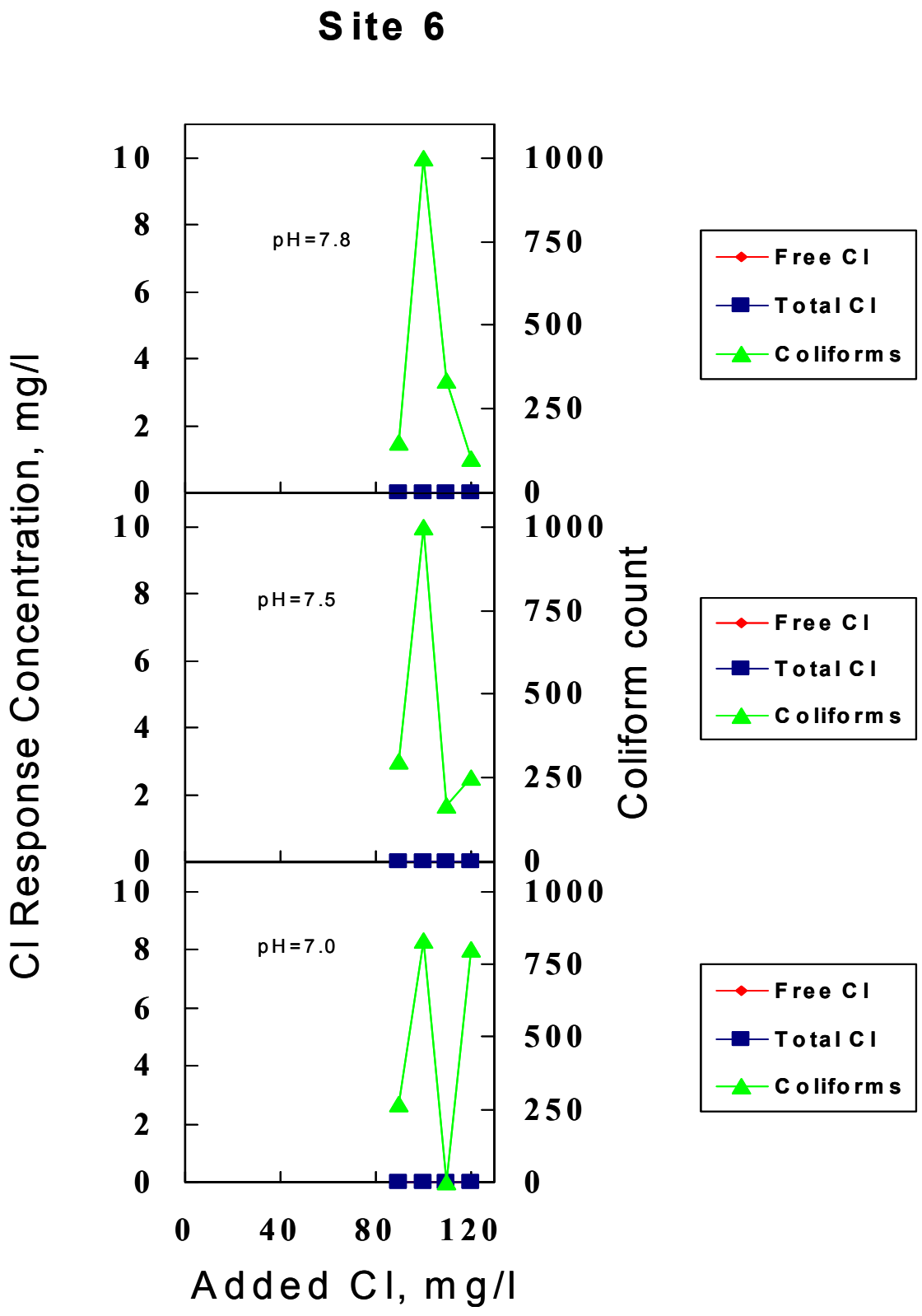

Figure 5. Chlorine dose/response for effluent from Site 6.

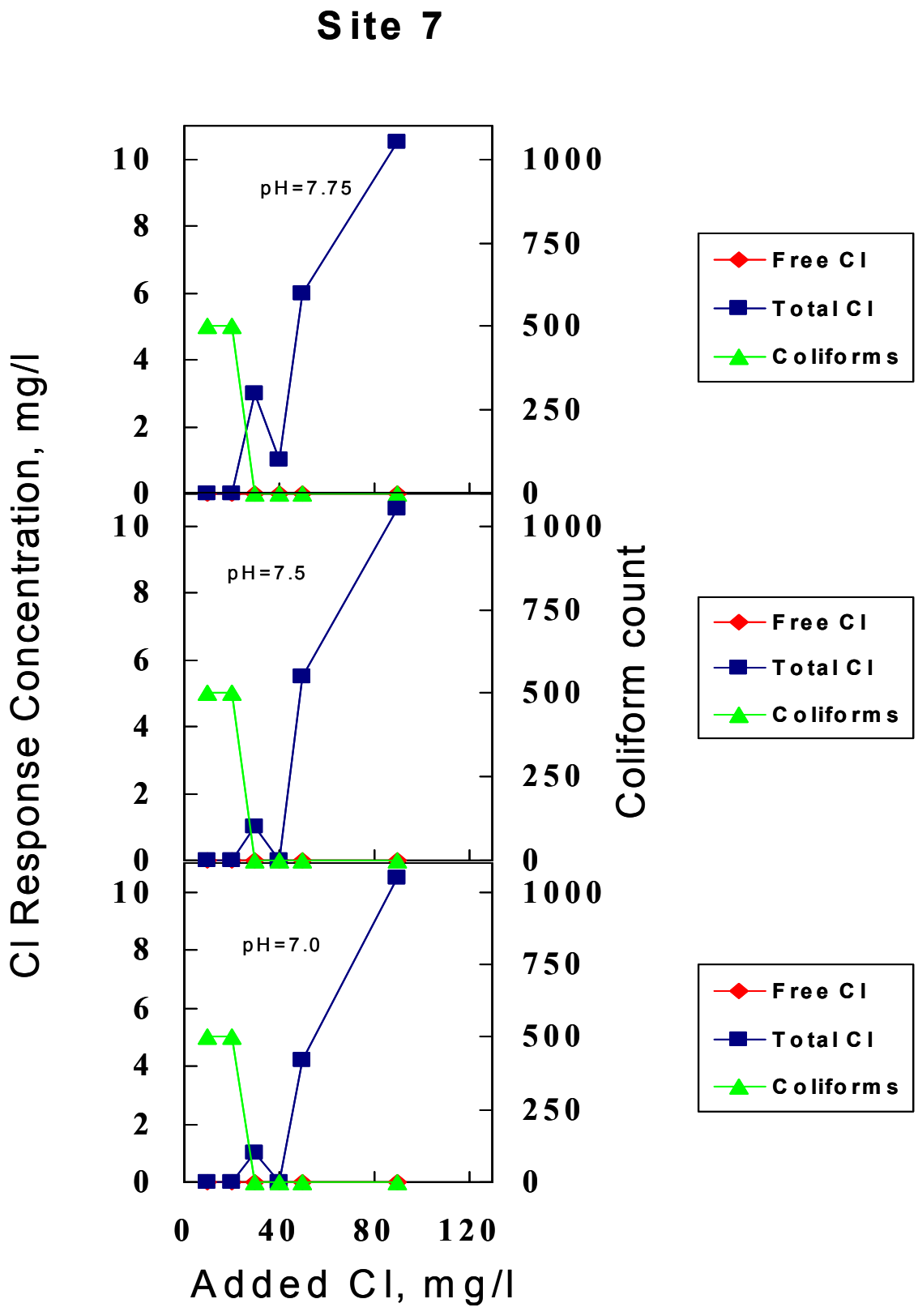

Figure 6. Chlorine dose/response for effluent from Site 7.

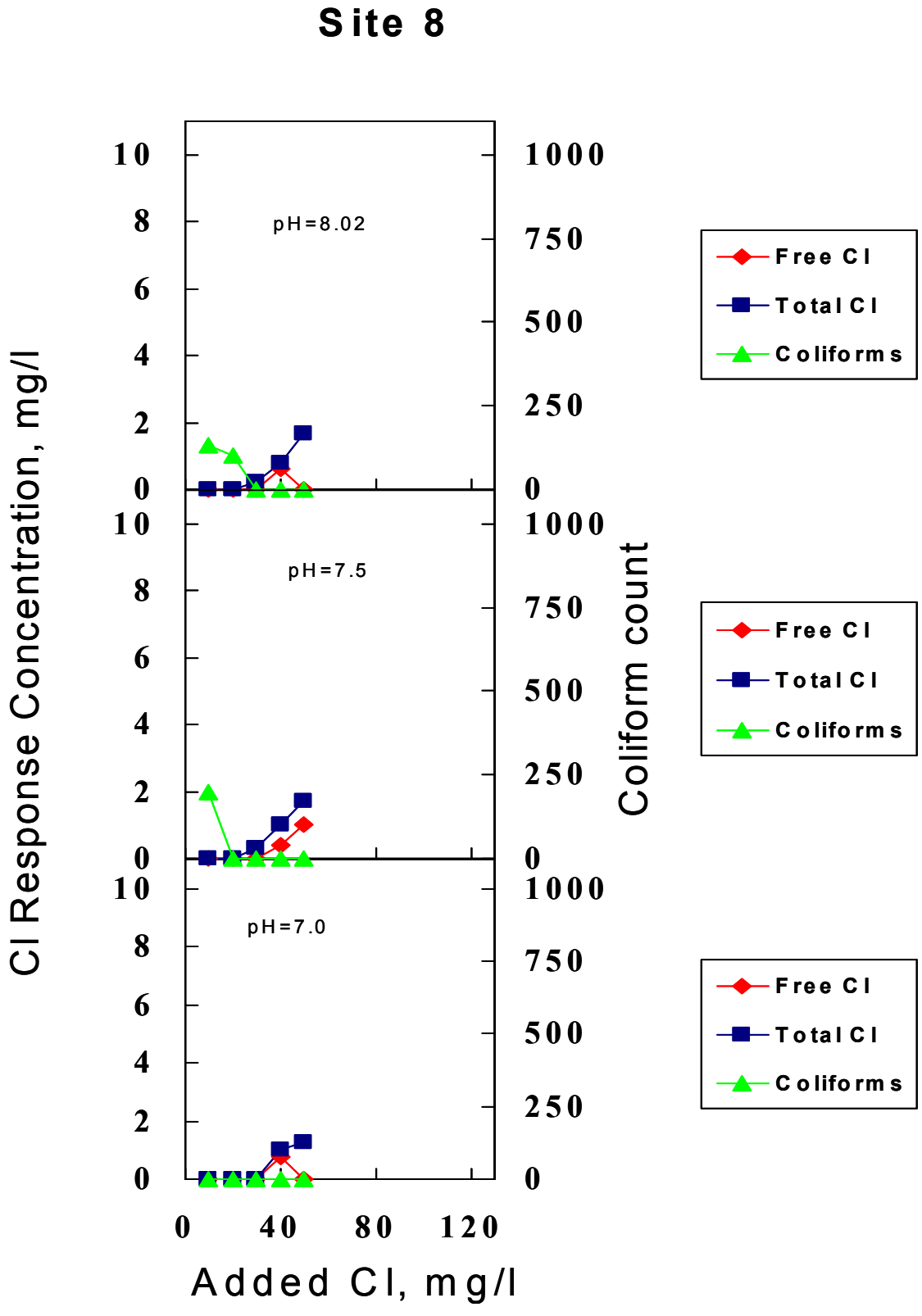

Figure 7. Chlorine dose/response for effluent from Site 8.