EFFECTS OF SEWAGE SLUDGE DUMPING ON THE CONSUMPTION OF OXYGEN IN THE WATER COLUMN AT THE NEW YORK BIGHT APEX DISPOSAL SITE DURING A SLUDGE TRACKING AND ACOUSTICAL EXPERIMENT 11-16 JULY 1976

by

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ABSTRACT

It is important to determine the behavior of wastewater sludge in the marine environment because, at present, ocean dumping remains one of the least expensive means of waste disposal. This study examined the effects of sewage sludge dumping on water column oxygen consumption at the sewage sludge disposal site in the New York Bight apex during July 1976. Three test dumps were examined. Undigested and digested sewage sludge line dumps were examined on 12 and 14 July, respectively, and an undigested sewage sludge spot dump was examined on 16 July. Oxygen consumption was determined by measuring the difference in oxygen concentrations between initial and incubated (at *in situ* temperature) whole water unconcentrated samples collected as a time series for each dump. The dumps were followed using both drogue buoys and high frequency acoustics.

Definable impacts of sewage sludge disposal on water column oxygen consumption were observed. The initial effect of a dump was to stimulate oxygen consumption at the surface within minutes. This initial stimulation disappeared within an hour following the dump. The next observable effect was the stimulation of oxygen consumption at the pycnocline about 30 to 80 minutes after the dump. This influence subsided with time and was followed by background rates of oxygen consumption being measured at the pycnocline 3 to 6 hours following the dump. At the same time, though less understood, was the increase in oxygen consumption at the surface again. For the water column below the pycnocline, we were unable to document a definable impact of sewage sludge on oxygen consumption. Thus, it appears that sewage sludge disposal in the New York Bight apex effects water column oxygen consumption chiefly above the pycnocline and not below it as one might expect.

INTRODUCTION

Duedall et al. (1977) have stated "It is important to determine the behavior of wastewater sludge in the marine environment because, at present, ocean dumping remains the least expensive means of wastewater disposal (Guarino et al., 1975), and the rate of wastewater sludge produced in metropolitan New York is increasing because of upgraded wastewater treatment plants."

One of the ways to investigate the behavior of sewage sludge dumped at sea is to examine water column oxygen consumption. Consumption of oxygen in the water column has been used as a measure of planktonic community metabolism to help understand energy flow and carbon cycling in marine ecosystems (Pomeroy and Johannes, 1968). It also can be used to indicate the quantity of organic material being mineralized and, therefore, organic loading, nutrients being regenerated, or the effects of organic loading (including sewage sludge disposal) on planktonic communities.

The New York Bight receives wastes from disposal of sewage sludge, dredge spoils, and industrial acid wastes, as well as input from the Hudson River and other lesser sources originating from the activities of about 15 million people living in the New York-New Jersey coastal zone (U.S. EPA, 1975; Mueller et al., 1975, 1976). These wastes (except acid wastes) contain oxidizable organic material (Smith et al., 1974; NMFS, 1972; Gross, 1972; Horne et al., 1971) which upon oxidation consume oxygen. Others have examined the effects of sewage sludge dumping on the water column of the New York Bight in regard to hydrography, pH, dissolved oxygen, suspended particulate material, nutrients, and chlorophyll (Draxler, 1979; Duedall et al., 1977; Duedall et al., 1975). In this study we examine the effects of sewage sludge dumping on the consumption of oxygen in the water column at the New York Bight apex sewage sludge disposal site during July 1976.

METHODS

All sewage sludge dumping in the New York Bight was halted by EPA Region II from about 1200 hours on 10 July to the time of the first experiment at 1014 EDT on 12 July. Thereafter, sewage sludge disposal was permitted only in areas removed from the site of the experiments. This was done in an effort to enhance the experimental conditions by decreasing background concentrations of sewage sludge and related constituents.

A pre-test station that was representative of a partially-cleared water column was occupied on 11 July 1976. Line dumps of sewage sludge were investigated on 12 and 14 July, and a single spot dump was examined on 16 July. The dumps were separated by a day in between to allow the water column to clear. All dumps were 2889 m^3 of sewage sludge. The first and third were from the Wards Island Treatment Plant (undigested sludge) and the second was from the Newtown Creek Treatment Plant (digested sludge). As part of the experiments drogue buoys were set and high frequency (20 kHz and 200 kHz) acoustics were used to track the sludge (Proni et al., 1976).

All samples were collected from the NOAA Ship <u>Kelez</u> using Niskin water bottles. Station locations are listed in Table 1, Figure 1. From each Niskin ten replicate 300 ml samples were drawn into standard BOD bottles. Five of these bottles were fixed immediately to determine dissolved oxygen concentrations and five were incubated (11 to 16 hrs) at <u>in situ</u> temperature (±2°C). Following incubation these samples were fixed and all samples were titrated according to the azide modification of the Winkler method

(American Public Health Association, 1965) except that 0.0375N phenylarsine oxide (PAO) was used in place of sodium thiosulfate (Kroner et al., 1964). The averaged concentration of dissolved oxygen in the incubated bottles (C.V. generally less than 2%) was subtracted from the averaged concentration in the initial bottles (C.V. generally less than 1%) and divided by the incubation time to obtain oxygen consumption. In situ dissolved oxygen concentrations were considered to be the averaged dissolved oxygen concentrations of the initial bottles.

RESULTS

On 11 July 1976, one day prior to the first test dump, a background station (K-1) was taken at 1322 EDT (Figure 2). Only two depths were sampled. However, this abbreviated sampling demonstrated that temperature and total plankton respiration were highly stratified.

On 12 July, the first line dump of 2889 m^3 of sludge occurred at 1014 EDT. Thirty minutes after the dump (Figure 3, K-2) dissolved oxygen concentrations appear to have been decreased in bottom water (18 m) and water column oxygen consumption appears to have been stimulated at 14 m, the top of the thermocline. Two and one-half hours following the dump (station K-3) dissolved oxygen concentrations at the bottom appear to have returned to normal. At the thermocline water column oxygen consumption was less. Oxygen consumption at the bottom appears higher, but this may not be caused by sewage sludge.

On 14 July, the second line dump of 2889 m^3 of sludge occurred at 0957 EDT. Sixteen minutes after the dump (Figure 4, K-6) a sag in dissolved oxygen was observed throughout the water column. At the surface a decrease in temperature and an increase in water column oxygen consumption were observed. One hour eighteen minutes after the dump (station K-7), dissolved oxygen concentrations appeared to be higher throughout the water column. Generally oxygen consumption was also higher throughout the water column except for the surface. Of particular interest was the high rate of oxygen consumption on top of the thermocline. Three hours six minutes after the dump (station K-8), oxygen consumption was highest at the surface, perhaps due to floatable material. Four hours twenty-nine minutes following the release of sewage sludge (station K-9), the highest measured rates of oxygen consumption were still at the surface. Dissolved oxygen concentrations were noticeably lower in bottom water, but not necessarily because of sewage sludge. By six hours eleven minutes following the dump (station K-10), oxygen consumption was still highest at the surface with a secondary peak at the thermocline. Dissolved oxygen concentrations continued to be stratified.

On 16 July, seventy-five minutes before a spot dump, a nearby control station was sampled (Figure 5, K-15). At 0956 EDT a spot dump of 2889 m^3 of sewage sludge occurred. Nine minutes later, station K-16 in the dump was occupied. At the surface, dissolved oxygen concentration decreased and water column oxygen consumption increased. Oxygen consumption deeper in the water column was very low. Seventy-two minutes following the dump (station K-17), oxygen consumption was highest at the thermocline and decreased with depth. Two hours forty minutes after the dump (station K-18), oxygen consumption was highest at the surface and at the bottom. Four hours eleven minutes after the dump (K-19) the surface dissolved oxygen concentration had recovered. Generally the entire water column had higher oxygen concentrations. This was particularly true for bottom water. Oxygen consumption still appeared elevated at the surface. The apparent increase in oxygen consumption probably was not caused by sewage sludge.

DISCUSSION

During the summer of 1976 a hypoxic episode occurred in the New York Bight (Swanson and Sindermann, 1979). As part of a study of that event, the National Marine Fisheries Service investigated other variables during August-September 1976 (Thomas et al., 1979). Water column oxygen consumption ranged from near zero to 25 ml O_2 m^{-3} hr^{-1}. The highest rates of oxygen consumption occurred above the pycnocline and decreased with depth except on the edge of the hypoxic area. There the highest rates occurred below the pycnocline and were indicative of organic loading to subpycnocline waters.

As part of the Marine Ecosystem Analysis (MESA) Program's Synoptic Investigations of Nutrient Cycling (SINC), water column oxygen consumption or total plankton respiration measurements were made during July 1977, in the Hudson-Raritan plume of the New York Bight apex. These rates ranged from near zero to 82 ml O_2 m^{-3} hr^{-1} and were generally highest near the surface and decreased with depth. Occasionally, maximum rates were associated with the pycnocline. Oxygen consumption in bottom water was usually less than 5 ml O_2 m^{-3} hr^{-1}.

During the Sludge Tracking Acoustical Experiment of July 1976 (STAX II) water column oxygen consumption rates ranged from near zero to 31 ml O_2 m^{-3} hr^{-1} and did not appear to be exceptional when compared with other rates mentioned above. The rates generally decreased with depth although examples occurred where increased rates at depth were associated with pycnoclines or the bottom. Such increase should be associated with increases in oxidizable organic carbon or respiring biomass, but may not always be relatable to sewage sludge. During SINC many of the increases at depth occurred with concurrent increases in phytoplankton chlorophyll at density barriers.

In a generalized time-series scenario of a sewage sludge dump it appears that within minutes the initial effects of a dump are evidenced at the surface by increased rates of oxygen consumption and perhaps some decrease in dissolved oxygen concentrations. We guess that this has occurred at station K-6 (Figure 4) and see evidence for it when we compare stations K-15 (75 minutes before dump) and K-16 (9 minutes after dump) (Figure 5).

Next, evidence is seen for a mid water column increase in oxygen consumption associated with a density layer where suspended material may be concentrated. We see this in the data at stations K-2 (+30 minutes), K-7 (+78 minutes), and K-17 (+72 minutes), presented in Figures 3, 4, and 5. This increase in oxygen consumption at the pycnocline appears to decrease with time as the particulate material is dispersed but may persist for at least six hours (station K-10). At the same time it appears that oxygen consumption at the surface has decreased; compare stations K-6 and K-7, and K-16 and K-17. The decrease in one instance was to background level. Compare station K-15 (pre-dump) with station K-17 (+72 minutes). This decrease may be caused by the downward movement of particulate material and water from the sewage sludge barge and thereby causes surrounding ocean surface waters to move into the area.

Following this it appears that oxygen consumption in the surface layer may increase again, perhaps due to the rising of less dense sewage related material to the surface. Compare station K-7 (+78 minutes) with stations K-8 (+186 minutes), K-9 (+270 minutes), and K-10 (+371 minutes); also station K-17 (+72 minutes) with K-19 (+251 minutes). Station K-18 was sampled at 4 m depth and is not comparable with stations K-17 and K-19.

What is happening in bottom water is less certain because the entire experiment has been drifting in three dimensional space and time. Fractionation or separation of sewage sludge materials in the water column based on density acts both to disperse and concentrate the sewage. The lighter than water phase will concentrate at the surface and be dispersed or oxidized based on surface conditions. The somewhat heavier material will concentrate at the pycnocline and may move separately from the surface layer (Proni et al., 1976). The heaviest material will sink to the bottom over some trajectory and be spread on the bottom based on the net result of settling time and currents above and below the pycnocline. Thus we are uncertain what is happening in bottom waters.

Oxygen consumption in the water column typically decreases with depth, particularly when the water column is stratified. Increased oxygen consumption in bottom water is indicative of organic loading or respiring biomass and may or may not be sewage related. To confound matters the hypoxic episode of 1976 had already begun. The event was caused by a massive concentration of *Ceratium*, a phytoplankton dinoflagellate, in bottom water. It is obvious when examining oxygen concentrations in Figures 2, 3, 4, and 5 that the sludge tracking acoustical experiments were not in the hypoxic area at the time. However, increased concentrations of *Ceratium* may have been present to cause increased oxygen consumption in bottom waters. Stations K-10 (+371 minutes) and K-19 (+231 minutes) are spatially and temporally far from the dump locations (Figure 1). One would expect the heavier material to fall rapidly to the bottom in relatively close proximity to the dump. Station K-3 is closer to the disposal location, but the cause of the elevated oxygen consumption in bottom water still is unknown. Station K-18, even though occupied four hours eleven minutes after the spot dump, was physically close to the disposal area and may have been impacted. However, bottom water oxygen consumption at station K-18 was similar to that at pre-dump station K-15. Thus sewage sludge disposal probably has a minor impact on bottom water oxygen consumption.

CONCLUSION

Definable impacts of sewage sludge disposal on water column oxygen consumption in the New York Bight apex were observed. The initial effect of the dump was to stimulate oxygen consumption at the surface within minutes. This initial stimulation disappeared within an hour following the dump. The next observable effect was the stimulation of oxygen consumption at the pycnocline approximately 30 to 80 minutes after the dump. This influence subsided with time and resulted in background rates of oxygen consumption being measured at the pycnocline 3 to 6 hours after the dump. Less well documented and understood was an apparent secondary increase in oxygen consumption at the surface 3 to 6 hours following the dump. For the water column below the pycnocline, we were unable to document definable impacts of sewage sludge dumping on oxygen consumption. It appears that sewage sludge disposal in the New York Bight apex effects water column oxygen consumption chiefly above the pycnocline and not below it as one might expect.

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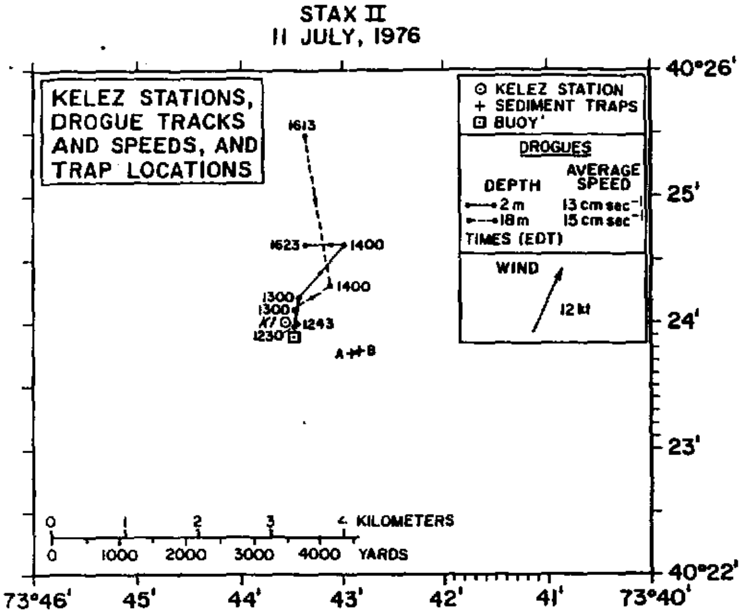
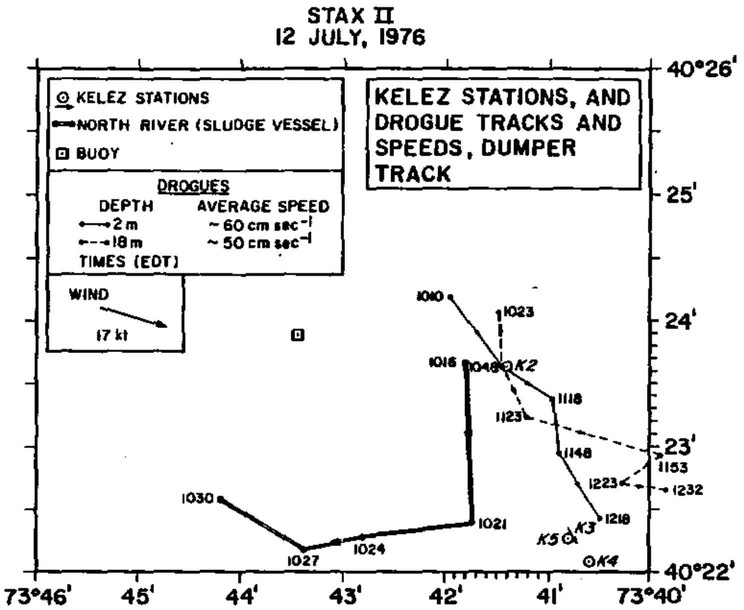
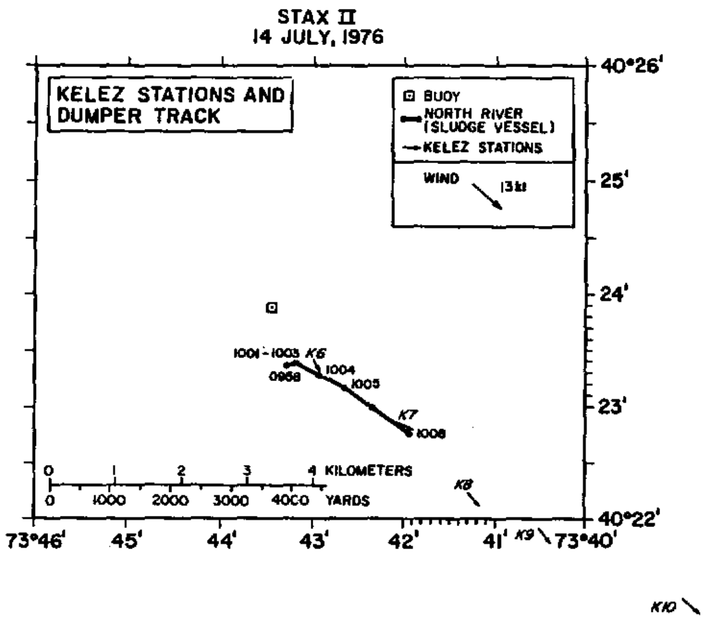
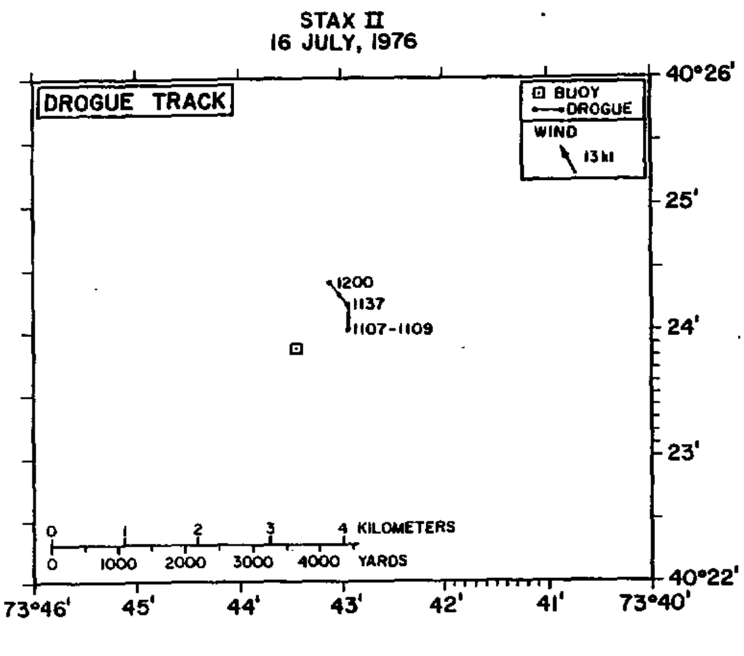
Figure 1. Station locations, dumper and drogue tracks, wind speed and direction and bottom sediment trap locations for STAX II.


STAX II
11 JULY, 1976
KELEZ STATIONS, DROGUE TRACKS AND SPEEDS, AND TRAP LOCATIONS
KELEZ STATION
SEDIMENT TRAPS
BUOY
DROGUES
DEPTH
AVERAGE SPEED
2 m 13 cm sec⁻¹
18 m 15 cm sec⁻¹
TIMES (EDT)
WIND
12 kt
1613
1623
1400
1400
1300
1300
K1
1243
1230
A
B
KILOMETERS
YARDS
40°26'
25'
24'
23'
40°22'
73°46'
45'
44'
43'
42'
41'
73°40'


STAX II
12 JULY, 1976
KELEZ STATIONS
NORTH RIVER (SLUDGE VESSEL)
BUOY
KELEZ STATIONS, AND DROGUE TRACKS AND SPEEDS, DUMPER TRACK
DROGUES
DEPTH
AVERAGE SPEED
2 m ~60 cm sec⁻¹
18 m ~50 cm sec⁻¹
TIMES (EDT)
WIND
17 kt
1010
1023
1016
1048
K2
1118
1123
1148
1153
1223
1232
1218
K3
K5
K4
1030
1027
1024
1021
40°26'
25'
24'
23'
40°22'
73°46'
45'
44'
43'
42'
41'
73°40'


STAX II
14 JULY, 1976
KELEZ STATIONS AND DUMPER TRACK
BUOY
NORTH RIVER (SLUDGE VESSEL)
KELEZ STATIONS
WIND
13 kt
1001-1003
K6
0958
1004
1005
K7
1008
K8
K9
K10
KILOMETERS
YARDS
40°26'
25'
24'
23'
40°22'
73°46'
45'
44'
43'
42'
41'
73°40'


STAX II
16 JULY, 1976
DROGUE TRACK
BUOY
DROGUE
WIND
13 kt
1200
1137
1107-1109
KILOMETERS
YARDS
40°26'
25'
24'
23'
40°22'
73°46'
45'
44'
43'
42'
41'
73°40'

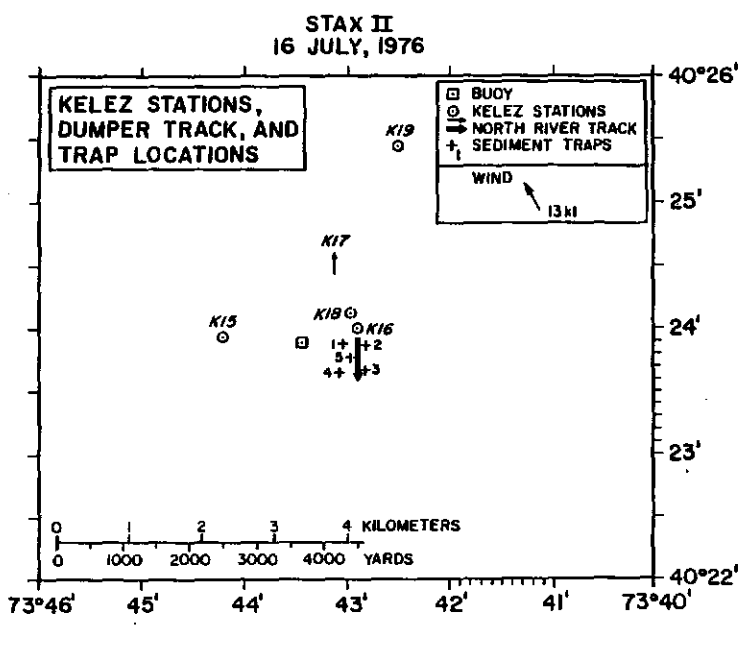

STAX II
16 JULY, 1976
KELEZ STATIONS, DUMPER TRACK, AND TRAP LOCATIONS
BUOY
KELEZ STATIONS
NORTH RIVER TRACK
SEDIMENT TRAPS
WIND
13 kt
K19
K17
K18
K16
K15
1
2
5
4
3
KILOMETERS
YARDS
40°26'
25'
24'
23'
40°22'
73°46'
45'
44'
43'
42'
41'
73°40'

Figure 2. Station K-1 was sampled 1322 EDT on 11 July 1976. This was a pre-experiment test station.

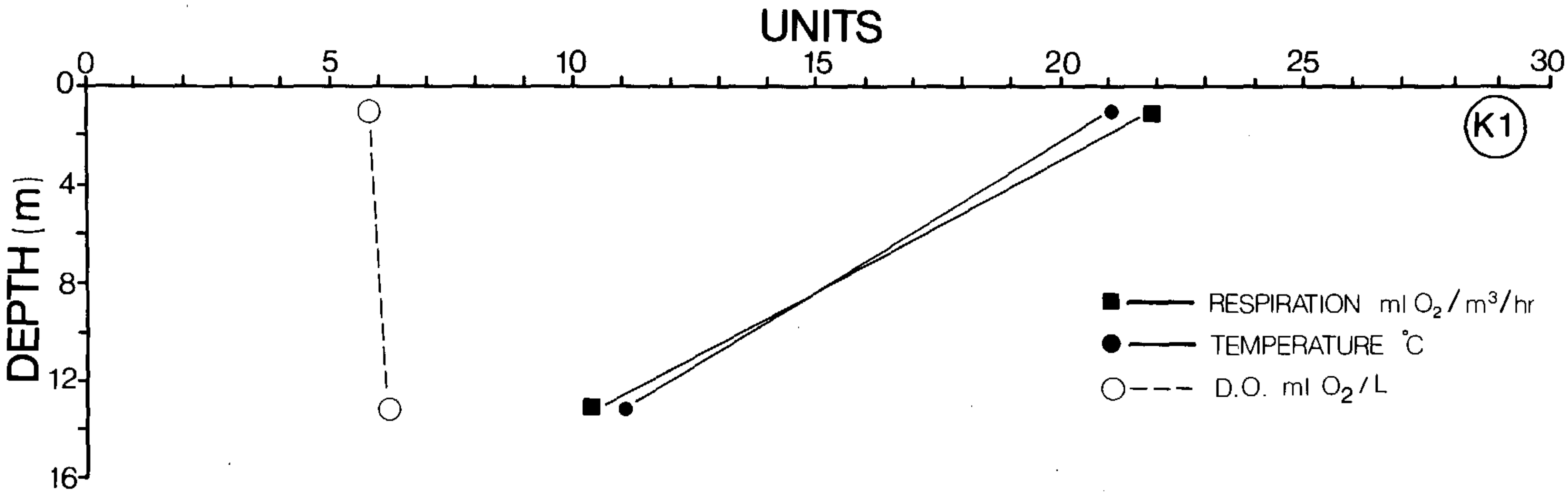
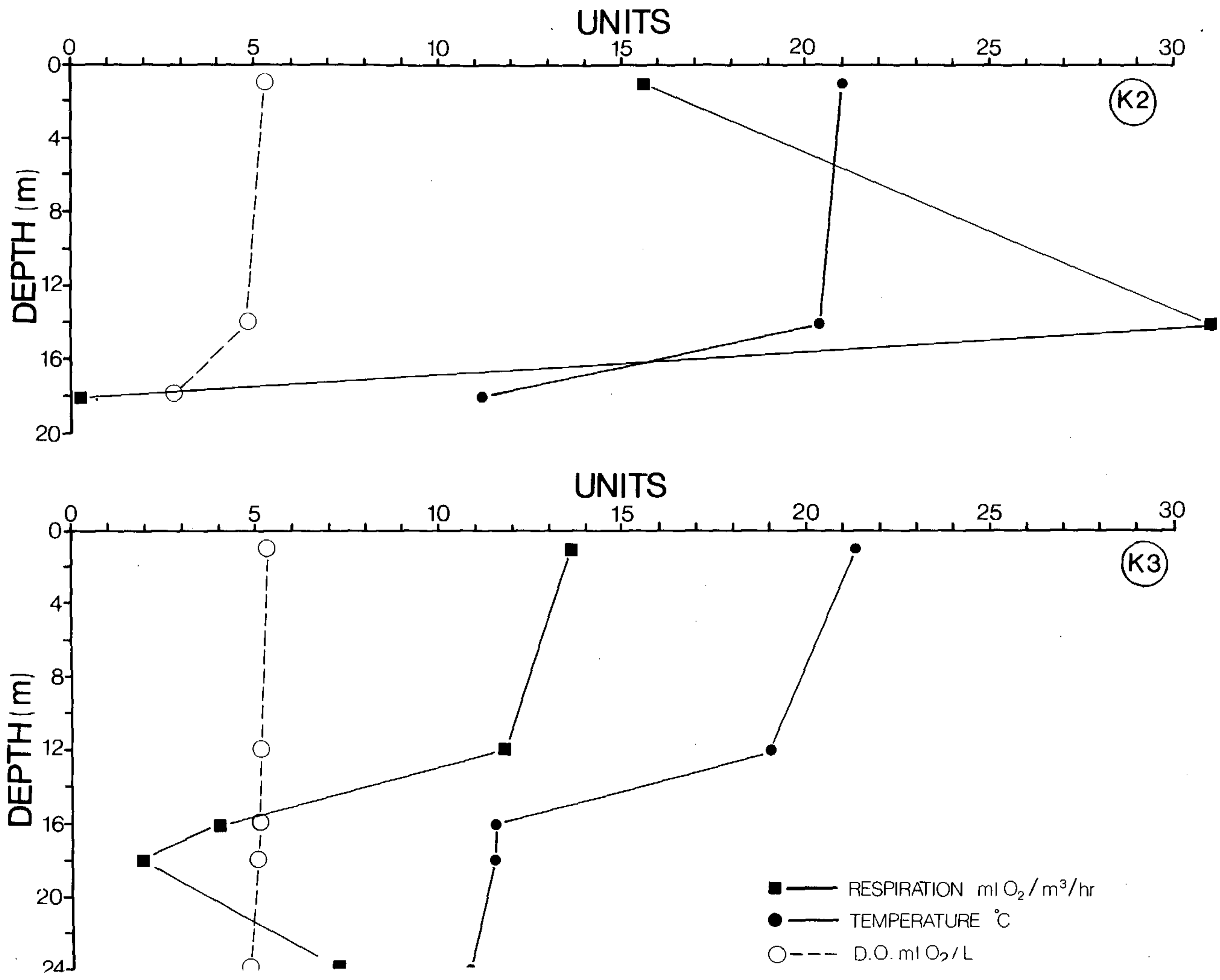

UNITS
0
5
10
15
20
25
30
0
4
8
12
16
DEPTH (m)
K1
RESPIRATION ml O_2/m^3/hr
TEMPERATURE °C
D.O. ml O_2/L

Figure 3. Station K-2 was sampled at 1044 EDT and station K-3 at 1245 EDT on 12 July 1976. These stations were sampled 30 minutes and 2.5 hours, respectively, after a line dump of undigested sewage sludge.



UNITS
0
5
10
15
20
25
30
DEPTH (m)
0
4
8
12
16
20
K2
UNITS
0
5
10
15
20
25
30
DEPTH (m)
0
4
8
12
16
20
24
K3
RESPIRATION ml O_2 / m^3/hr
TEMPERATURE °C
D.O. ml O_2 / L

Figure 4. Stations K-6 through K-10 were sampled at 1013, 1115, 1303, 1426, and 1608 EDT, respectively, on 14 July 1976. The sampling times were +16 minutes, +78 minutes, +186 minutes, +270 minutes, and +371 minutes, respectively, after a line dump of digested sewage sludge.

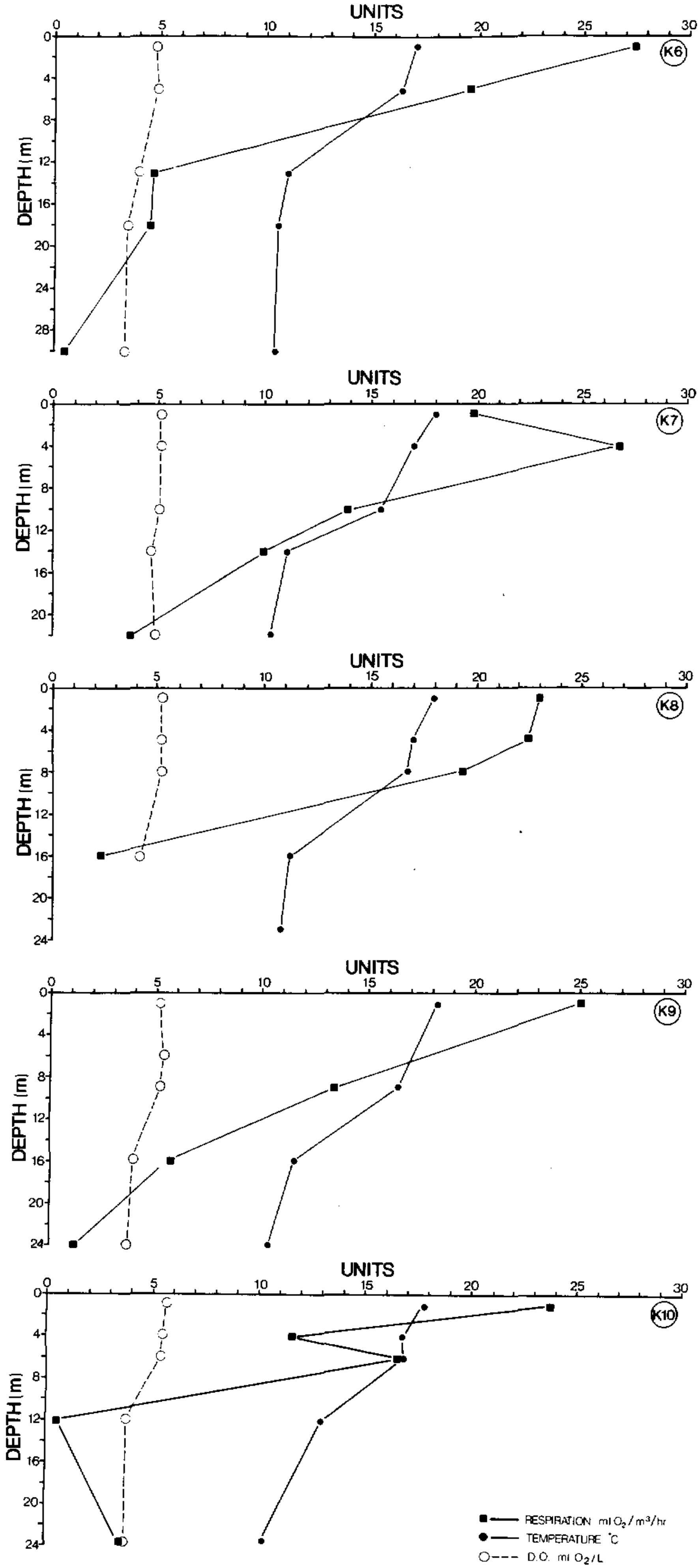
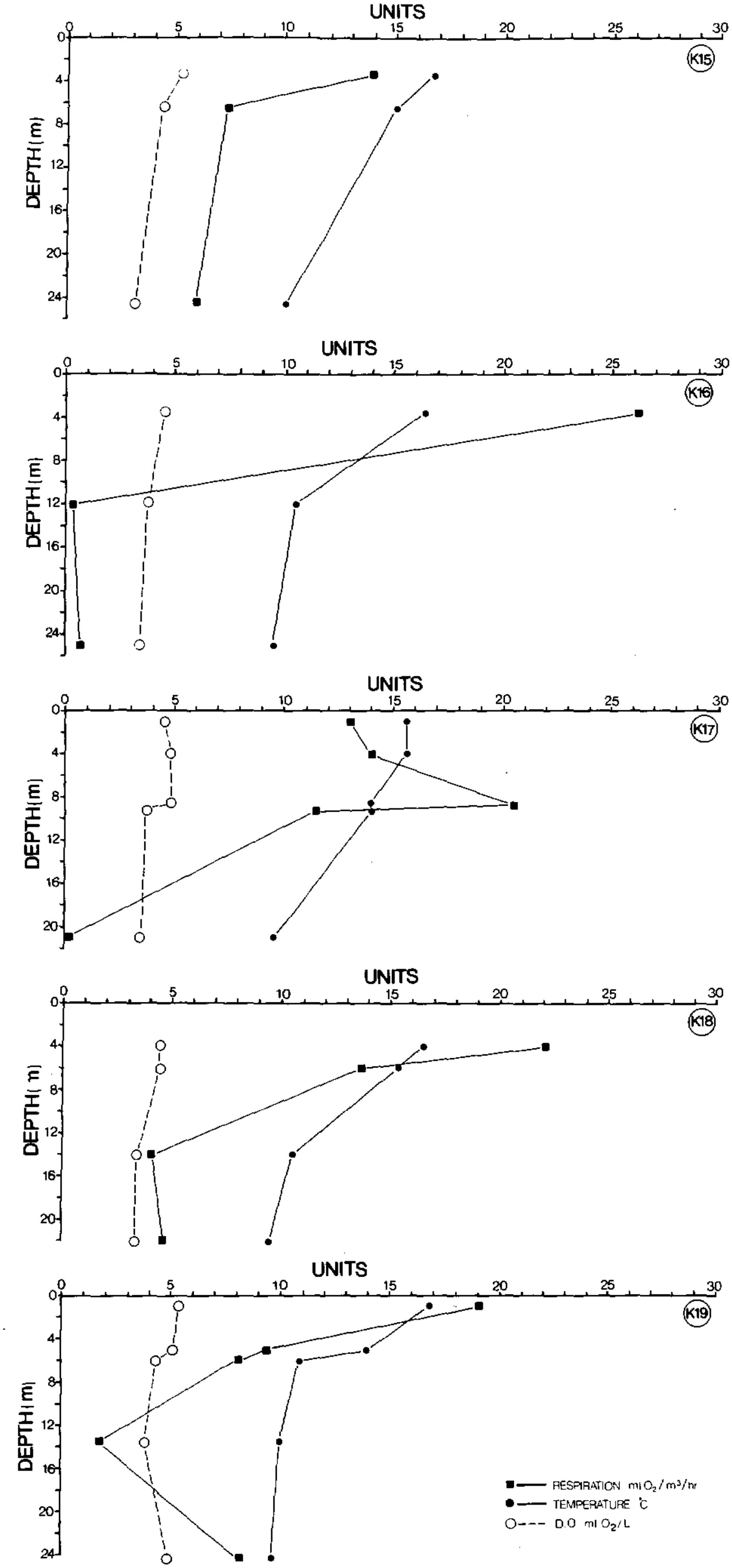

UNITS
0 5 10 15 20 25 30
DEPTH (m)
0 4 8 12 16 20 24 28
K6
UNITS
0 5 10 15 20 25 30
DEPTH (m)
0 4 8 12 16 20
K7
UNITS
0 5 10 15 20 25 30
DEPTH (m)
0 4 8 12 16 20 24
K8
UNITS
0 5 10 15 20 25 30
DEPTH (m)
0 4 8 12 16 20 24
K9
UNITS
0 5 10 15 20 25 30
DEPTH (m)
0 4 8 12 16 20 24
K10
RESPIRATION ml O2/m³/hr
TEMPERATURE °C
D.O. ml O2/L

Figure 5. Stations K-15 through K-19 were sampled at 0941, 1105, 1208, 1336, and 1507 EDT, respectively, on 16 July 1976. The sampling times were -75 minutes before a spot dump of undigested sewage sludge and +9 minutes, +72 minutes, +160 minutes, and +251 minutes after the spot dump.



UNITS
DEPTH (m)
K15
K16
K17
K18
K19
0 5 10 15 20 25 30
0 4 8 12 16 20 24
RESPIRATION ml O_2/m³/hr
TEMPERATURE °C
D.O ml O_2/L

Table 1. KELEZ station locations and times for STAX II.

Sta.	Date	Time(EDT)	Approximate Location	
			Latitude	Longitude
K-1	7/11/76	1430-1322	40°24.0'N	73°43.45'W
K-2	7/12/76	1044-1051	40°23.60'N	73°41.40'W
K-3	7/12/76	1245	40°22.29'N	73°41.73'W
K-4	7/12/76	1330	40°22.06'N	73°40.62'W
K-5	7/12/76	1527	40°22.26'N	73°40.77'W
K-6	7/14/76	1013-1023	40°23.33'N	73°42.93'W
K-7	7/14/76	1115-1127	40°22.82'N	73°42.03'W
K-8	7/14/76	1303-1311	40°22.15'N	73°41.20'W
K-9	7/14/76	1426-1442	40°21.83'N	73°40.45'W
K-10	7/14/76	1608-1620	40°21.24'N	73°38.82'W
K-15	7/16/76	0941-0947	40,23.90'N	73°44.21'W
K-16	7/16/76	1105-1107	40°24.02'N	73°42.86'W
K-17	7/16/76	1208-1218	40°24.48'N	73°43.09'W
K-18	7/16/76	1336-1344	40°24.10'N	73°42.95'W
K-19	7/16/76	1507-1519	40°25.45'N	73°42.5'W