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# FIELD EVALUATION OF A NEW SURVEILLANCE TRAP IN SWEDEN

MARK S. BLACKMORE[1] AND CHRISTINE DAHL[2]

ABSTRACT. Field tests were conducted to assess the effectiveness of American Biophysics Counterflow 2000™ (CF2000) traps compared to $CO_2$-baited Centers for Disease Control (CDC) miniature traps at a site in central Sweden. Adult mosquitoes representing 17 species and 6 genera were collected in July and August 1998. Although the 2 trap types did not differ significantly in total number of adult female mosquitoes collected, CF2000 traps captured a greater diversity of mosquito species and significantly more adult males than did CDC traps. Interspecific differences in capture rates and interactions between trap type and location also were observed.

**KEY WORDS** Mosquitoes, traps, counterflow, Centers for Disease Control, Sweden

## INTRODUCTION

Sampling of adult mosquito populations provides important information for vector surveillance and abatement operations, as well as for ecological, taxonomic, and faunistic studies. Most methods for collecting adult mosquitoes use some form of attractant (e.g., light, chemicals, or bait animals) to lure the insects to a location where they can be captured either manually or by mechanical devices (traps). The efficacy of different mosquito trapping methods varies considerably depending on the target species, habitat type, geographic location, and trap design (Bidlingmayer 1967, Reisen et al. 1999). No device is universally effective for collecting all species in all situations. Therefore, traps should be evaluated under a variety of conditions to allow researchers and surveillance personnel to choose devices that best suit their particular needs.

Two basic trap designs have dominated the mosquito surveillance market for nearly half a century (Kline 1999). The New Jersey light trap (Mulhern 1942) uses light to lure mosquitoes into the vicinity of a large fan that draws them into a collecting jar. A major disadvantage of this trap is the difficulty of using it in remote locations because of its size, weight, and the necessity for a generator or other power source (Wilton 1975). The New Jersey light trap also lacks specificity, which increases the time required for sorting the collection (Reisen and Pfuntner 1987). The Centers for Disease Control (CDC) miniature light trap and analogs (e.g., American Biophysics Corporation's ABC Trap 1) function in a similar manner but are considerably smaller and more portable and usually are configured to use $CO_2$ as the primary attractant. The latter feature restricts the collection to host-seeking insects (mainly female mosquitoes) and thus reduces the time spent on postcapture sorting (Sudia and Chamberlain 1962).

Recently, traps have been developed that use dual flow systems that release a plume of chemical attractants from an emission port that is surrounded by an updraft current. This captures insects as they approach the attractant source. Prototype traps that used this counterflow configuration proved highly effective in field studies in central Florida (Kline 1999). The Counterflow 2000™ (CF2000) trap manufactured by American Biophysics Corporation (Jamestown, RI) is the 1st commercially available mosquito trap that incorporates this counterflow geometry in its design. The results of field studies conducted in Sweden that compared the efficacy of the CF2000 trap with that of a standard CDC miniature light trap baited with $CO_2$ are reported herein. The traps were evaluated on the basis of the total number of individuals collected, the total number of individuals of different species collected, and the diversity of mosquito species obtained during the trapping period.

## MATERIALS AND METHODS

*Study area:* The experiments were conducted in a region of central Sweden where high mosquito populations often cause economic losses associated with curtailment of recreational activities. Collections were made on a farm located approximately 2 km west of Österfärnebo (60°17′N, 16°46′E), Gävleborgs Län, Sweden. The study site is bordered on the south by a marsh that extends to the river Dalälven, and by forested areas to the north and east. Traps were positioned at 100-m intervals and were moved daily among the 4 positions in a randomized complete block design (Sokal and Rohlf 1981). Trap positions differed with respect to their distances from the marsh and woods (Fig. 1), and the degree of exposure to the prevailing wind.

*Traps:* Adult mosquitoes were collected by using 2 CF2000 traps and 2 CDC Model 512 Miniature Light Traps™ (John W. Hock Company, Gainesville, FL). The CF2000 traps were configured and operated according to the manufacture's instructions with propane gas as fuel. Combustion of the propane supplied power for the intake fans and exhaust gases were vented to serve as an attractant. The CDC traps were powered by 6-V rechargeable batteries and were supplied with 2 kg

[1] Department of Biology, Valdosta State University, Valdosta, GA 31698.
[2] Department of Systematic Zoology, EBC, Uppsala University, 752 36 Uppsala, Sweden.

Table 1. Mosquito species collected at Österfärnebo, Sweden, between July 14 and August 5, 1998.

| |
|---|
| *Aedes (Aedes) cinereus* Meigen |
| *Aedes (Finlayia) geniculatus* (Olivier) |
| *Aedes (Aed.) rossicus* Dolbeskin, Gorickaja, and Mitrofanova |
| *Aedes (Aediomorphus) vexans* (Meigen) |
| *Anopheles (Anopheles) claviger* (Meigen) |
| *Anopheles (Ano.) maculipennis* Meigen |
| *Coquillettidia (Coquillettidia) richiardii* (Ficalbi) |
| *Culex (Culex) pipiens* s.l. Linnaeus |
| *Culiseta (Culiseta) alaskaensis* (Ludlow) |
| *Culiseta (Cus.) annulata* (Schrank) |
| *Culiseta (Culicella) morsitans* (Theobald) |
| *Ochlerotatus (Ochlerotatus) cantans* (Meigen) |
| *Ochlerotatus (Och.) communis* (De Geer) |
| *Ochlerotatus (Och.) euedes* (Howard, Dyar, and Knab) |
| *Ochlerotatus (Och.) excrucians* (Walker) "wide form" |
| *Ochlerotatus (Och.) intrudens* (Dyar) |
| *Ochlerotatus (Och.) sticticus* (Meigen) |

of dry ice per trap per day as an attractant. Because weak batteries could adversely affect trap performance and potentially reduce collection size, the batteries were replaced every 3rd day. The dry ice was placed in Styrofoam™ containers that had holes punched in the bottom to allow gaseous $CO_2$ to escape. These were suspended so that the container bottom was approximately 5–10 cm above the trap lids. The CDC traps were operated without lights.

*Procedure:* Traps were operated on a 23-h cycle and were serviced daily between 1500 and 1600 h. During servicing, collection bags were replaced, traps were moved, and dry ice was added to the CDC traps. All specimens collected were transported to Uppsala University where they were killed by freezing (−70°C), identified to species, and counted. Voucher specimens of the species collected are stored at the Zoological Museum, Uppsala University.

*Statistical analyses:* Analyses of variance were used to compare total numbers of mosquitoes caught by each trap type. Student's $t$-tests were used for species-specific comparisons. Species with a total collection of fewer than 20 individuals were not included in species-specific tests. Bonferroni–Dunn analyses were used to evaluate interactions between traps, trap type, and trap position (SuperANOVA, Abacus Concepts, Inc., Berkeley, CA). Post hoc comparisons between windy and protected sites used Mann–Whitney tests because of small sample sizes and unequal variance among groups. Species diversity was quantified by calculating Shannon indices (Smith 1992), which were compared by using unpaired $t$-tests.

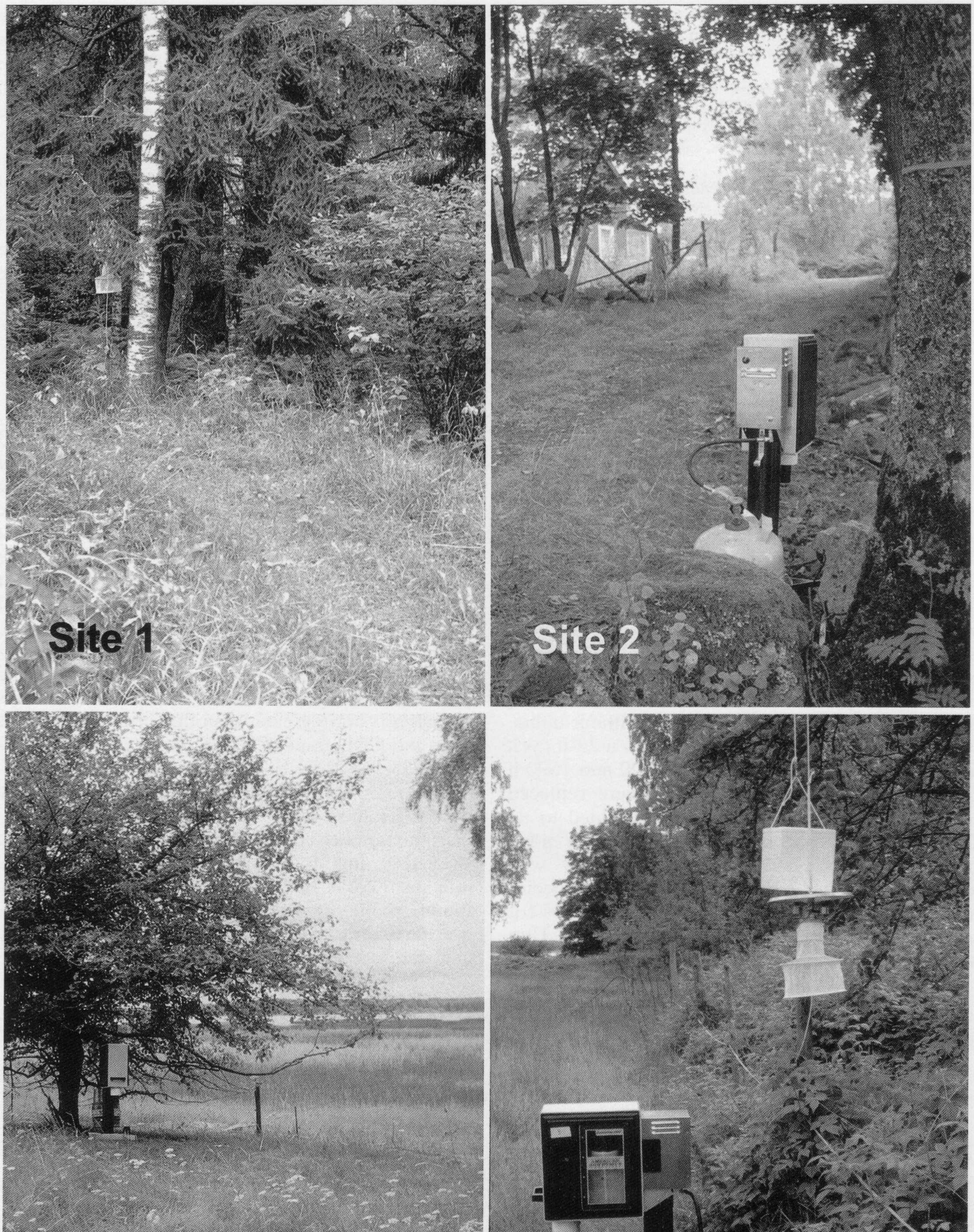
## RESULTS

A total of 12,726 mosquitoes was collected in 64 trap days (~200/trap/day). Of these, 12,649 (99.4%) were females. Seventeen species belonging to 6 genera (Reinert 2001) were collected (Table 1), but only 12 species were present in sufficient numbers for individual statistical analyses (Table 2). *Coquillettidia richiardii* (Ficalbi) was the most abundant species (39% of all mosquitoes collected) followed by *Ochlerotatus sticticus* (Meigen) (25%), *Aedes rossicus* Dolbeskin, Gorickaja, and Mitrofanova (19%), and *Aedes cinereus* Meigen (11%). The diversity of species collected by the CF2000 traps was significantly greater than that of the collections from the CDC traps (CF2000 $D = -1.67$; CDC $D = -1.33$, $t = 2.59$, $P < 0.05$).

Although the total number of females collected by the CF2000 traps was nearly 1.5 times higher than the number collected by the CDC traps (7,540 vs. 5,109), this difference was not statistically significant (Table 2). Significant differences were found among the 4 trap locations (Fig. 2) and significant interactions were found between trap type and trap location. These differences seem to be re-

Table 2. Comparison of the number of female mosquitoes collected by Centers for Disease Control miniature light traps (CDC) and Counterflow 2000 traps (CF2000) at Österfärnebo, Sweden, July 14–August 5, 1998. Includes only species with a total collection ≥20.

| | Total collected | | Mean no. collected/trap/day (SE) | | | |
|---|---|---|---|---|---|---|
| Species | CDC | CF2000 | CDC | CF2000 | $t$ | $P$ |
| All species | 5,109 | 7,540 | 159.7 (36.2) | 232.9 (41.5) | −1.33 | 0.19 |
| *Aedes cinereus* | 269 | 1,140 | 8.4 (2.5) | 32.8 (7.6) | −3.07 | <0.01 |
| *Ae. rossicus* | 243 | 2,207 | 7.6 (2.1) | 67.7 (17.1) | −3.54 | <0.001 |
| *Ae. vexans* | 11 | 29 | 0.34 (0.15) | 0.94 (0.03) | −1.77 | 0.08 |
| *Anopheles maculipennis* | 8 | 13 | 0.25 (0.11) | 0.42 (0.16) | −0.88 | 0.38 |
| *Coquillettidia richiardii* | 2,506 | 2,489 | 78.3 (21.2) | 77.8 (14.2) | −0.06 | 0.95 |
| *Culex pipiens* s.l. | 192 | 11 | 6.0 (1.4) | 0.3 (0.14) | 3.97 | <0.001 |
| *Culiseta alaskaensis* | 34 | 34 | 0.3 (0.3) | 1.10 (0.60) | −1.81 | 0.08 |
| *Cs. morsitans* | 41 | 9 | 1.3 (0.47) | 0.3 (0.09) | 2.05 | 0.45 |
| *Ochlerotatus cantans* | 22 | 23 | 0.69 (0.32) | 0.68 (0.21) | 0.03 | 0.98 |
| *Oc. communis* | 26 | 36 | 0.8 (0.36) | 1.2 (0.59) | −0.51 | 0.61 |
| *Oc. intrudens* | 41 | 115 | 1.3 (0.35) | 3.7 (1.2) | −1.95 | 0.06 |
| *Oc. sticticus* | 1,732 | 1,406 | 54.1 (20.0) | 43.1 (9.3) | 0.50 | 0.62 |


Site 1
Site 2
Site 3
Site 4

lated to variation in exposure to the wind among the trap sites. Although we did not have anemometers to quantify wind velocity, qualitative observations on relative windiness were recorded daily. Five dates (July 25, 30, and 31, and August 1 and 5) were noted as being particularly windy and trap positions 2 and 3 were consistently windier than the other trap locations. On windy days, the combined collections at sites 2 and 3 were significantly lower than at sites 1 and 4 (Fig. 3). At the 2 windy locations, the CF2000 traps captured significantly more mosquitoes than did the CDC traps (CF2000 mean = 263.6 mosquitoes/trap night, $n = 3$; CDC mean = 6.6 mosquitoes/trap night, $n = 7$; $P = 0.017$), but did not differ significantly from the CF2000 collections at sheltered locations (mean = 275.6, $n = 7$, $P = 0.83$).

Species-specific differences in capture rates between traps were observed for 5 of the 17 species at this site. The CF2000 traps collected significantly higher numbers of *Ae. cinereus*, *Ae. rossicus*, and *Ochlerotatus intrudens* (Dyar), but the CDC traps captured significantly more *Culex pipiens* s.l. Linnaeus and *Culiseta morsitans* (Theobald) (Table 2).

Although male mosquitoes comprised less than 1% of the total collection, virtually all of those that were collected (75 of 77) were captured by the CF2000 traps. Other species of Diptera that were collected in numbers included those in the families Simuliidae, Chironomidae, Psychodidae, and Mycetophilidae (Table 3). The number of black flies (simuliids) captured by the CDC traps was almost 7-fold greater than those collected by the CF2000 traps (CDC mean = 26.8/trap night, $n = 857$; CF2000 mean = 4.0/trap night, $n = 127$). Other nontarget species were collected more frequently by the CF2000 traps.

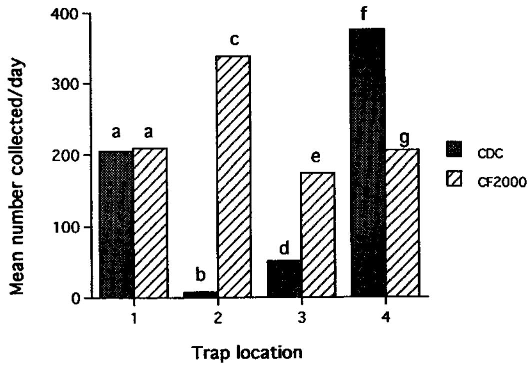



Fig. 2. Daily average number of mosquitoes collected by Centers for Disease Control miniature light traps (CDC) and Counterflow 2000 traps (CF2000) at 4 locations in Österfärnebo, Sweden, between July 14 and August 5, 1998. Different letters above bars denote significant differences ($P < 0.05$) between trap types at a given location.

## DISCUSSION

The 2 types of traps that were tested both rely on $CO_2$ for attracting mosquitoes and other blood-feeding insects. However, the way that this attractant is produced and presented, and the manner in which insects are captured after they arrive at the trap are entirely different. The CDC trap releases only $CO_2$ and does not present a warm target, but the CF2000 trap also produces heat, water vapor, and hydrocarbons, which may act as synergists in attracting mosquitoes (Gillies 1980). Despite this, no clear difference was found in the overall effectiveness of either trap at catching mosquitoes because of the strong interaction between trap type and trap location. Although the number and diversity of mosquitoes collected by each type of trap were not statistically different overall, significant site-specific and species-specific differences that likely resulted from the design of each trap were observed during this study.

The CF2000 trap clearly was more effective at the 2 locations that were more exposed to the wind. On days that were notably windy, the CF2000 traps located at positions 2 and 3 (the windy sites) captured about the same number of female mosquitoes as the traps in the more protected locations. In contrast, the CDC traps consistently caught few or no mosquitoes when located at positions 2 and 3 on windy days but remained quite effective at the other sites where the wind was less prominent.

One possible explanation for the poorer performance of the CDC traps under windy conditions may be the separation of the $CO_2$ source from the trap entrance. When the air is relatively calm, the $CO_2$ that sublimes from the dry ice container tends to fall around the trap body before it disperses. Concentrations remain high around the trap, including the area around the suction fan. Mosquitoes flying up the concentration gradient under these conditions can be captured as they pass through the intake current. Under windy conditions, the $CO_2$ may be blown away from the trap without falling to the level of the trap entrance. In this situation, mosquitoes flying toward the dry ice container suspended above the CDC trap would be less likely to encounter the suction from the intake fan on the opposite side of the rain shield, thereby greatly reducing the number captured. The design of the CF2000 trap circumvents this problem because any

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Fig. 1. Locations where mosquitoes were collected at Österfärnebo, Sweden, between July 14 and August 5, 1998. Inset site numbers correspond to position designations used in text. Photograph of position 4 provides comparison of relative heights of the Counterflow 2000 trap (left) and Centers for Disease Control miniature light trap (right).

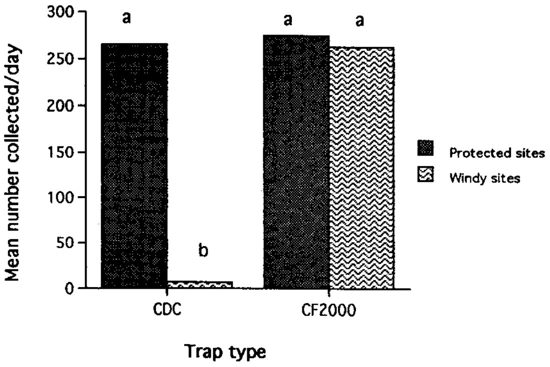


Fig. 3. Daily average number of mosquitoes captured by Centers for Disease Control miniature light traps (CDC) and Counterflow 2000 traps (CF2000) on windy days at locations that differed with regard to wind exposure. Different letters above bars denote significant differences ($P < 0.05$) between trap types at these locations.

mosquito following the attractant to its source must fly into the vicinity of the updraft. Thus, the counterflow geometry of the CF2000 trap capture mechanism seems better suited for use in windy conditions.

A 2nd factor that may have contributed to differences between the traps is the height of the trap entrance above the ground. Lundström et al. (1996) found that CDC traps caught significantly fewer mosquitoes when they were placed higher in the canopy (≥6 m) than when they were set relatively close to the ground (1.5 m). The lowest traps in their experiments were set at approximately the same height as the CDC traps used in the present study. Lundström et al. (1996) collected much higher numbers of *Ae. cinereus, Anopheles claviger* (Meigen), and *Cq. richiardii* in those traps than in the traps placed higher above the ground. A similar pattern was observed in the present study with *Ae. cinereus* and *Ae. rossicus,* which were collected in significantly higher numbers by the CF2000 traps, which have the capture mechanism located even closer to the ground. The only species collected in higher numbers in the CDC traps in the present study was *Culex pipiens* s.l. Linneaus, which is an ornithophilic species and perhaps more likely to seek hosts at greater heights.

Neither trap collected nontarget species in numbers sufficient to impede mosquito sorting or counting, but the CF2000 trap was more prone to collect other insects than the CDC trap. Most of the nontarget specimens collected were small species probably flying in the grass or ground vegetation. The majority of these were single occurrences, which suggests that the individuals were not attracted to the traps but probably encountered them at random. The lower position of the CF2000 intake fan probably predisposes this trap to these kind of accidental captures when tall grass or other vegetation is present.

Table 3. Nontarget species collected by Counterflow 2000 traps (CF2000) and Centers for Disease Control miniature light traps (CDC) at Österfärnebo, Sweden, July 14–August 5, 1998.

| Taxon | No. collected by CF2000 | No. collected by CDC |
|---|---|---|
| Diptera | | |
| Simuliidae | 127 | 1,117 |
| Chironomidae | ~3,000 | ~800 |
| Psychodidae | 128 | 4 |
| Ceratopogonidae | 95 | 0 |
| Mycetophilidae | ~250 | 0 |
| Tipulidae | 87 | 1 |
| Anisopodidae | 4 | 8 |
| Cecidomyiidae | 44 | 0 |
| Sciaridae | 17 | 1 |
| Unidentified dipteran | ~50 | ~10 |
| Suborder Nematocera | | |
| Unidentified | 19 | 0 |
| Suborder Brachycera | | |
| Unidentified | 9 | 3 |
| Psocoptera | 1 | 0 |
| Neuroptera | | |
| Chrysopidae | 1 | 0 |
| Homoptera | | |
| Aphididae | ~250 | 0 |
| Unidentified | 1 | 0 |
| Hymenoptera | | |
| Formicidae | 3 | 0 |
| Unidentified | 14 | 0 |
| Coleoptera | 1 | 1 |
| Trichoptera | 0 | 1 |
| Lepidoptera | 0 | 2 |
| Araneae | 2 | 2 |
| Pseudoscorpiones | 4 | 0 |

Two other families of biting flies that were collected, Simuliidae and Ceratopogonidae, differed in capture rate in the 2 traps. Black flies (simuliids) were captured in much higher numbers by the CDC traps, whereas ceratopogonids were only collected by the CF2000 trap. Why this was the case is not clear.

The results of this study do not warrant recommendation of the use of 1 trap type to the exclusion of the other. Each has advantages and disadvantages. For example, the CDC trap is compact and easily transported to remote field sites. It can be easily raised to different heights in the canopy, as was done in the experiments of Lundström et al. (1996). However, CDC traps are less effective under windy circumstances and require frequent maintenance. The CF2000 trap is more awkward to move but may be left for longer periods and requires less servicing. Another advantage is that propane is less expensive and, in many areas, is much easier to obtain than dry ice or gaseous $CO_2$.

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