tion (Cairns & Dickson, 1971). It would appear, therefore, that Station 2 was somewhat enriched but not seriously polluted. This assessment is further indicated by the presence of elmid (riffle) beetles and heptageniid mayflies, both of which are sensitive generally to extreme pollution (Cairns & Dickson, 1971). A similar condition apparently was present at Station 7, but it may have been slightly more enriched than 2, since percentage of chironomids was higher, Simulidae increased in percentage, and hydropsychiids and heptageniids decreased considerably. The effluent from the new wastewater treatment plant seemed to have a pronounced enrichment effect at Station 8, where chironomids dominated the samplers and number of families was lower than at either Station 2 or 7. The sampler at Station 4 collected far fewer organisms than did the samplers at Station 7 or 8, but the number of families at 4 was only one less than that at 7 and chironomids were dominant, which indicates some enrichment. The effluent from the old wastewater treatment plant at Station 5 apparently produced environmental stress, since only three families were present and chironomids made up about 95% of all organisms.

Stations 3 and 6, in pooled areas, were less productive than most riffle stations. Station 3, above the old treatment plant, yielded a lower percentage of chironomids and more diversity and organisms than Station 6, below the old plant. In addition, Station 3 had a high percentage of heptageniid mayflies, but none was present at Station 6. These conditions indicate that Station 6 had not recovered from the effects of the old wastewater treatment plant.

ACKNOWLEDGMENTS

Messrs. Ron Merville and Tom Woods provided valuable assistance with the field and laboratory work. This study was financed by a grant from the Faculty Research Committee of Middle Tennessee State University and from the Environmental Protection Agency (Construction Grant WRC-Tenn-244 Murfreesboro).

LITERATURE CITED

ous media. Consequently, the literature provides little
guidance for determining if electrical considerations
pertain to these coal-derived colloids. Thus, the be-

behavior in an electric field of the particles in the coal-
derived liquid was observed to determine if these
particles carry a net charge and, if so, of what sign.
The observations are reported here.

Similar investigations have been carried out by
Reising (1937) for paint pigments and by Hedrick
et al. (1941) for pulverized coal particles in gas oil.
Hedrick et al. found that in an electric field, coal
particles in oil assume a lines-of-force arrangement; it
was concluded that both positive and negative charges
exist not only on different particles but on different
areas of the same particle. They also found that sur-
face-active agents prevent agglomeration. Soyenko-
ff (1931) concluded that electrostatic charges are un-
important as stability factors in nonaqueous media.

**EXPERIMENTAL APPARATUS AND PROCEDURE**

A special microscope slide and slide holder similar to Reising's
apparatus was fabricated. A diagram of the slide with the
attached electrodes is shown in Fig. 1. A slide holder (not
shown) was made of nonconductive Bakelite plastic with a
recessed area to hold a standard microscope slide and a hole
for transmitted light observation. At opposite ends were two
binding posts with steel clamps. The dc-power supply (Model
D6, Oregon Electronics) was connected to the binding posts,
and the steel clamps secured the slide and provided electrical
contact with the aluminum electrodes. The holder was clamped
to the microscope stand (Microstar 10 Series Microscope) be-
neath the objective lens. For safety reasons, the cathode was
connected directly to ground, the microscope was grounded
between the electrodes and the eyepieces, the supply circuit
was equipped with a 0.1-A fuse, and the lower part of the micro-
scope was covered with a Plexiglas box (leaving only the eye-
pieces exposed for viewing). The power supply, high-voltage
leads passed through a safety-interlock switch so that no volt-
age could be applied to the electrodes unless the Plexiglas box
was in place.

A drop of oil was placed on the electrode gap and spread
to a fairly uniform thickness. After securing the special micro-
scope slide in the holder, the microscope slide was positioned
and brought into focus before the Plexiglas cover was put in
place. Once the cover was in place, the voltage was applied to
the electrodes and the subsequent behavior of the particles was
observed (usually at 100X). Unfiltered and filtered oil, which
were obtained from the Solvent Refined Coal (SRC) process
pilot plant at Wilsonville, Alabama, were used in these studies.

**RESULTS**

Because the solids concentration in the unfiltered
oil was too high for convenient observation, the un-
filtered oil was diluted with the filtered oil by a factor
2:1, 4:1, and 8:1. It should be noted that the filtered
oil also contained a significant concentration of small
particles.

The variable power supply was equipped with both a
voltmeter (0 to 600 V) and ammeter (0 to 500 mA).
Because of the low conductivity of the nonaqueous
media (\(\sim 2 \times 10^{-8} \text{ mho/cm} \)), the ammeter never
indicated a readable current.

The coal-derived oil was quite dark and the oil film
had to be spread quite thin on the microscope slide in
order to have sufficient light transmitted for observa-
tion. In initial experiments no slide cover was used,
and oil film depth was uniquely determined by the
dimensions of the aluminum electrodes and the surface
tension of the oil. Without the cover, the microscope
image darkened noticeably when voltage was applied
across the electrodes. This darkening is attributed to
an increase in oil film depth brought on because of
changes in surface tension with the electrolytic heating
of the oil. Using a slide cover in subsequent experi-
ments both eliminated the image darkening and cut
off the available surface for evaporation.

With the electric field turned off, the particles were
relatively stationary, although very slow movement of
the liquid was sometimes observed. When the full 500 V
was applied to the electrodes in the experiments with
no slide cover, very rapid movement of the liquid and
the particles was seen. Particles were observed to move
toward the anode and toward the cathode. Particles
were also observed moving into the gap from sur-
rounding liquid and in the gap normal to the electric
field (i.e., not toward either electrode). Time lapse pho-
tographs of several seconds showed circular patterns of
movement within the electric field.

Over a period of about 25 min, a layer of particles
collected on both the cathode and the anode; the layer
on the anode was the larger. In addition, short spikes
which pointed toward the cathode appeared on the
anode. These spikes grew until, after 30 to 45 minutes,
they formed filaments that bridged the gap between the
anode and cathode.

Small particles moving in both directions parallel to
the electric field were observed between the filaments.
One large oblong particle (0.3 mm long) revolved 90\(^\circ\)
to align itself with the electric field when the field was
turned on. When the field was turned off, it reverted
to its original position.

Some of the observations discussed above are prob-
dably due to thermal effects. With the electric fields
employed here (500 V per 0.05 cm, assumed to be
uniform) and the estimated liquid conductivity of
\(2 \times 10^{-8} \text{ mho/cm} \), the volumetric heat generation
was estimated to be about 2.0 W/cm\(^3\). This heat generation
rate is sufficiently high so that strong thermal convec-
tion currents could be expected.

The thermal effects were reduced and the problems
due to thick liquid films were eliminated by using thin-