TIME-RELATED CHANGES IN WATER QUALITY OF STOCK TANKS OF SOUTHEASTERN ARIZONA

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In semiarid rangelands, rainfall runoff can be trapped to provide drinking water for livestock. Stock tanks to store this water are made by constructing earthen dikes across small channels or swales. The Walnut Gulch Experimental Watershed, near Tombstone, Arizona, has a number of such tanks fed by watersheds of different sizes and soils (Fig. 1). The time that water is available for use in the tanks depends on the capacity of the tank, the amount and frequency of rainfall excess, and the porosity of the benthic sediment of the tanks. Water storage volume is continually being diminished by sediment deposition from the highly erosive rangeland watersheds contributing to a stock tank. The sediment also provides a nutrient base for algal growth in the ponds. The objectives of this study are to determine the water quality changes in stock tanks, what factors are instrumental in the changes, and to assess the effects of the changes.

At present, the study is more observational than experimental, in that a limited number of interactions or factors affecting water quality are examined. The tanks apparently never seal completely. If they did, salts left in the tanks after evaporation would cause a salinity buildup.

During the study period reported here, fall and spring rainfall was excessive; thus, water was present in some tanks longer than would normally be expected. Nonetheless, evaporation was quite high. The factors considered in this study were: DAYS (time since first sampling), INFLOW (a numerical ranking of the amount and type of runoff into the tanks), TOTAL N, K, pH, HCO_3, Fe, Mn, Ca, INORGANIC P, Mg, Na, Cu, Pb, Co, and Zn.

MATERIALS AND METHODS

Most of the chemical constituents were measured with a Perkins-Elmer 403 absorption spectrophotometer. Trace metals -- Co, Cu, Pb, Mn, and Fe -- were complexed using Na, diethyldithiocarbamate and concentrated with methyl isobutyl ketone by using a simplification of a technique given by Ted McCreary of the Soils, Water and Engineering Department, University of Arizona (personal communication). Phosphate was determined with the Murphy-Riley procedure (Watanabe and Olsen, 1965).

Two 1-pint samples were collected semimonthly at each of eight tanks, beginning September 15, 1972. Each time samples were collected, 10 ml of 0.5N HCl was added to one of the two samples to act as a preservative (pH2) and to prevent precipitation of the heavy metals. These samplings continued as long as the tanks had water or until the next summer's rains started.

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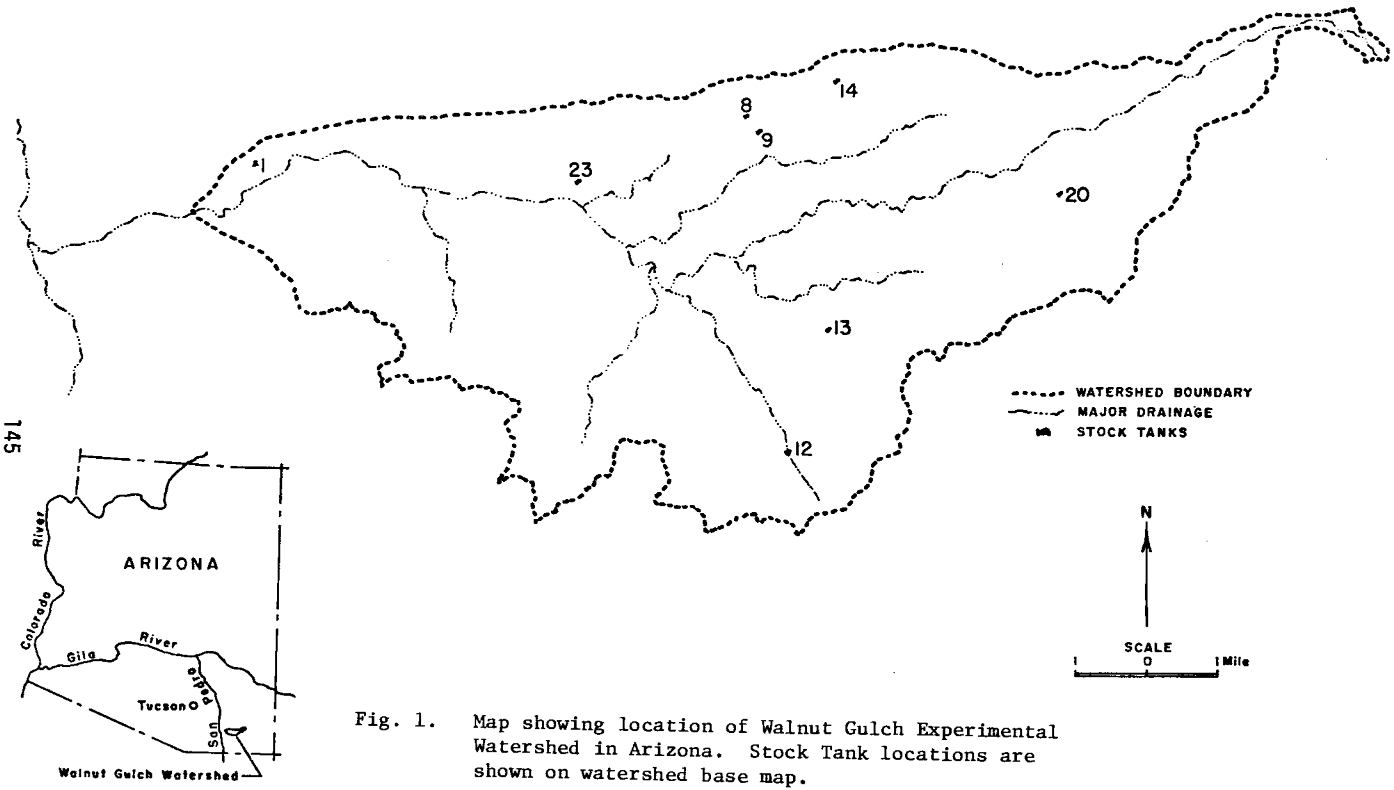

Fig. 1. Map showing location of Walnut Gulch Experimental Watershed in Arizona. Stock Tank locations are shown on watershed base map.

A number from 0 to 3 was assigned to describe the visual impression of algal numbers in the samples. Near the end of the observations, some samples were fixed in Lugol's Solution and algae were counted and identified by Dr. E. Stahl of the biological Sciences Department, University of Arizona. There was little drift with time, and the concentrations of algae were represented as well by the counting system later, when obvious blooms occurred, as they were earlier in the study with the non-eutrophied waters (Fig. 2). Inflow to the various tanks since the last sampling was also recorded, by using an arbitrary numerical scale. Zero signified no inflow, 1 = rainfall on the tank, 2 = local runoff from immediate peripheral areas (runoff from tank sides where cattle concentration and resulting manure create a heavy nutrient supply), and 3 = runoff from the main drainage channels of the tank watershed.

DISCUSSION

Every tank had algal growth. All the essential nutrients and elements were present after the tanks were filled. In fact, the water quality was very similar in all tanks at the beginning of this study, regardless of where they were located. The uniform initial water quality probably resulted from several factors. The residual gravel pavement on the land surface is a heterogeneous mixture reflecting earlier climates and geology. Erosional processes have further reshaped and mixed the various rock types and soils of the area. The input to the tanks (i.e., ephemeral runoff from summer storms) was of short duration and violent in nature. Thus, the channel gravels were reworked time and time again during runoff, which thoroughly mixed the various rock types representative of the area.

The algal growth in the tanks is governed mainly by the time water is held in the tank and the amount of N present or added by livestock or microbial fixation. The tanks act as a storehouse for ions taken up for algal growth. The algae population withdraws nutrients from the tank as needed. This continues at an accelerating pace as long as the algal bloom increases. When algae ceases to grow, a release of ions (due to the dying algae) begins, and certain ionic concentrations increase in the tank water.

The sampling immediately before the tank dried up indicated that the concentrations of some elements rose many fold. This was true of several elements thought to be essential--Fe, Co, Mn, and sometimes Cu. The ion concentration graphs illustrate a "3-point moving average" of the concentration of each particular ion for all tanks sampled. Figures 7 and 8 show the variations in pH and bicarbonate concentration with time.

Inasmuch as most of these tanks have existed for several decades, the ionic concentrations are probably near equilibrium. Further decreases in concentrations, as were seen with several of the micronutrients, suggest that the biological system is using the particular elements, or that a slowly available nonbiologic sink is accepting the elements that decrease in concentration. In either or both events, the finite supply is insufficient to keep up with the two losses. Since it was not clear what elements participated in the growth process of the algae, a multiple component analysis (Huzar, 1966) was performed with the data (Figures 3-8).

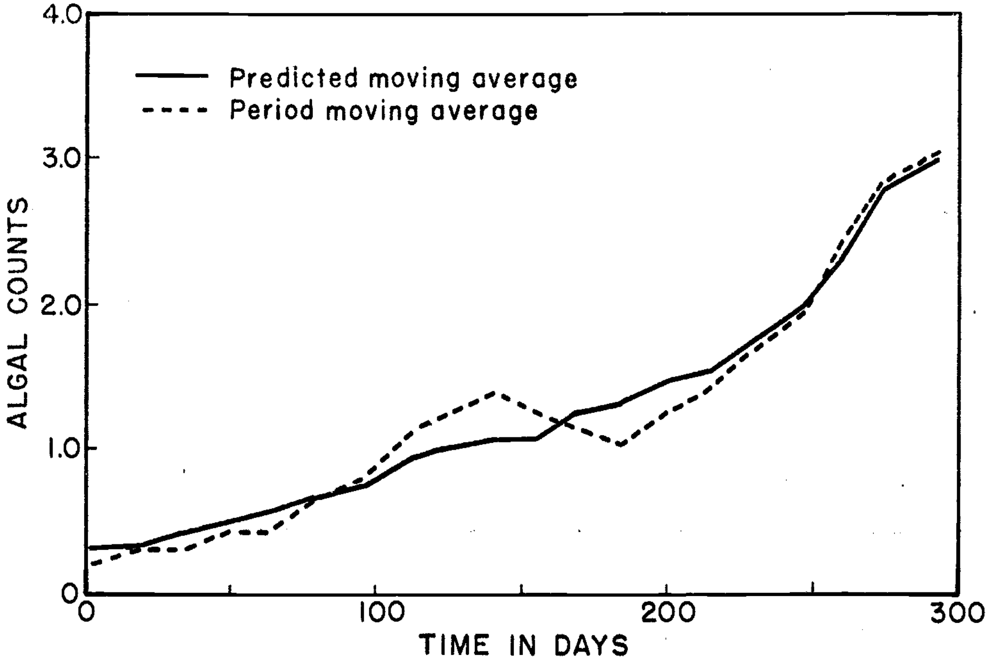

Fig. 2. Algal growth as a function of time. The time element was determined to be one of the most influential factors studied on algal growth in the tanks.

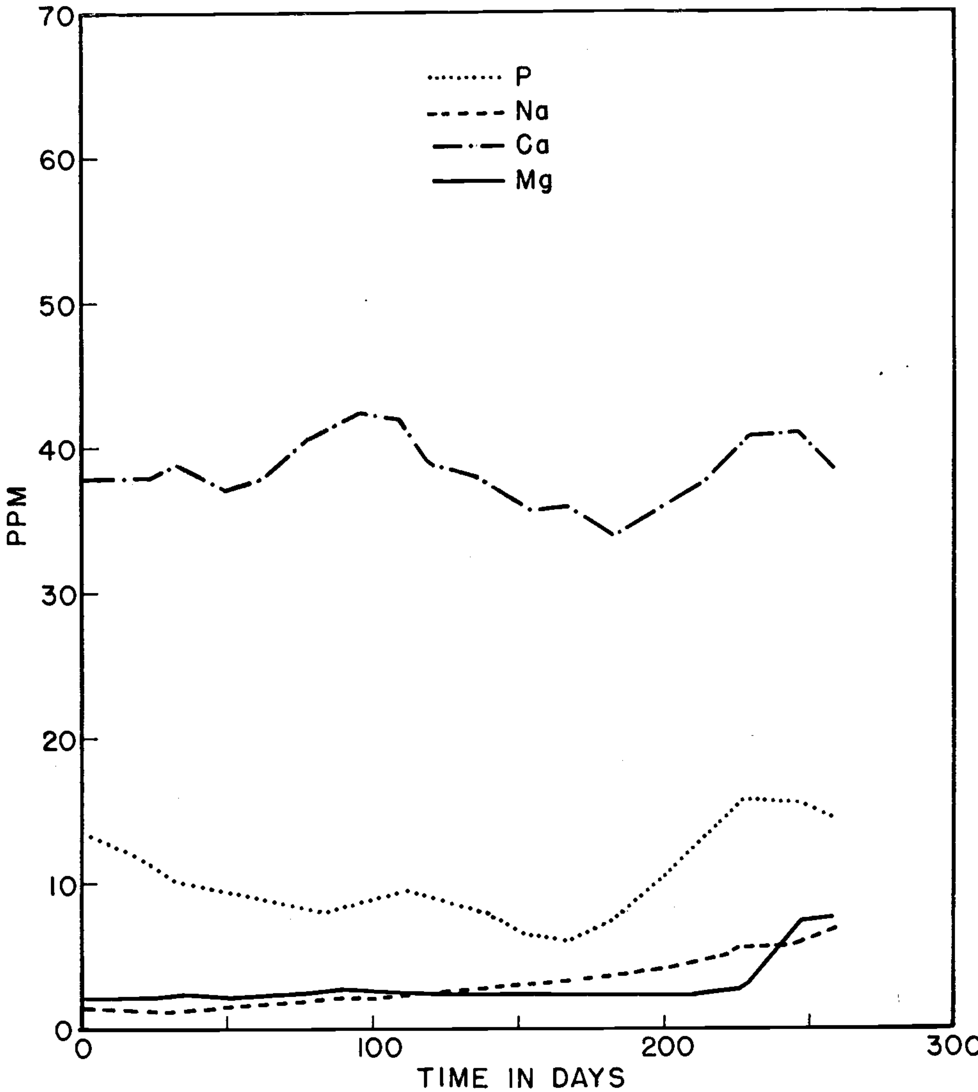

Fig. 3. Variations in P, Na, Ca, Mg concentration with time in water samples from stock tanks. The traces represent a moving average of the ionic concentration of each element in all the tanks sampled.

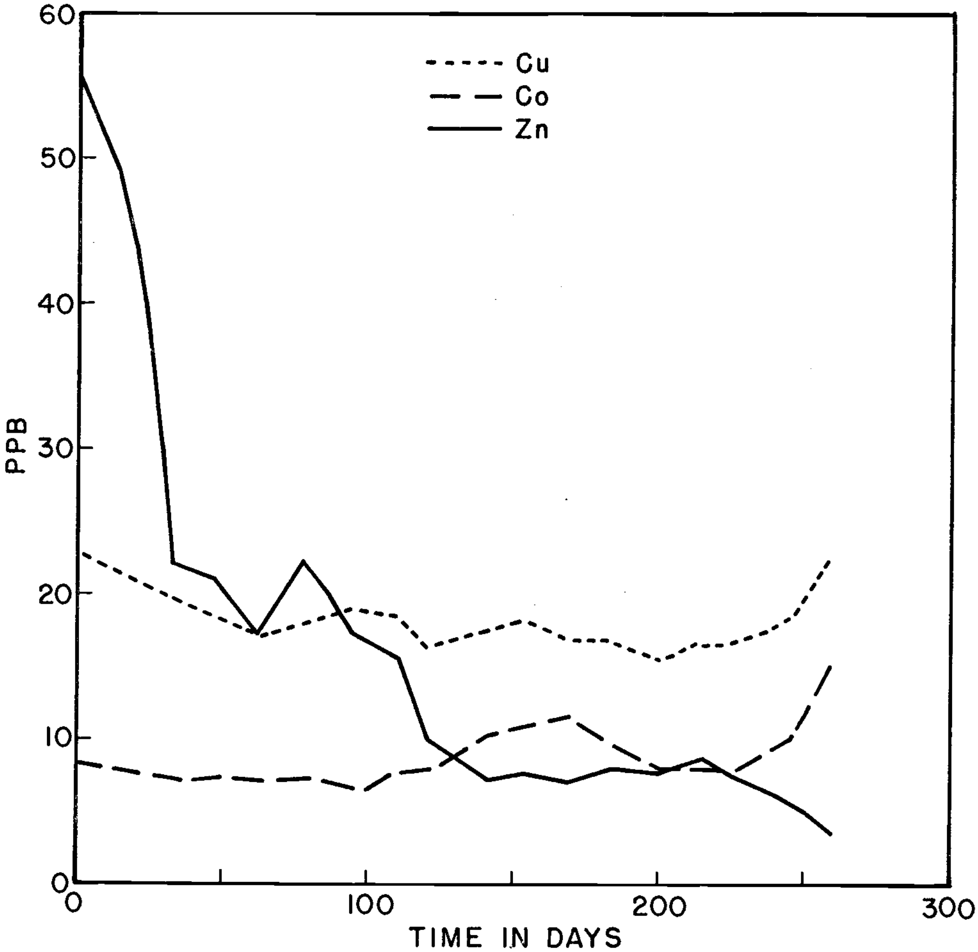

Fig. 4. Variations in Cu, Co, Zn concentration with time in water samples from stock tanks. The traces represent a moving average of the ionic concentration of each element in all the tanks sampled.

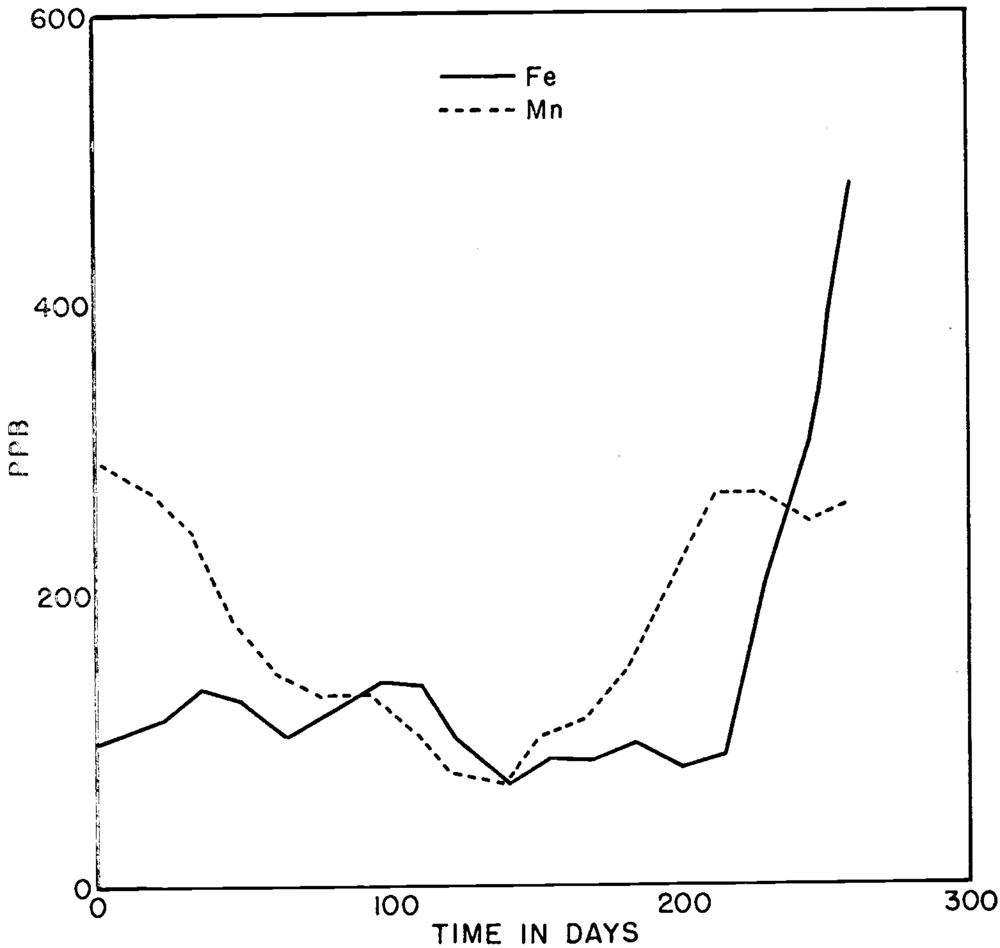

Fig. 5. Variations in Fe, Mn concentration with time in water samples from stock tanks. The traces represent a moving average of the ionic concentration of each element in all the tanks sampled.

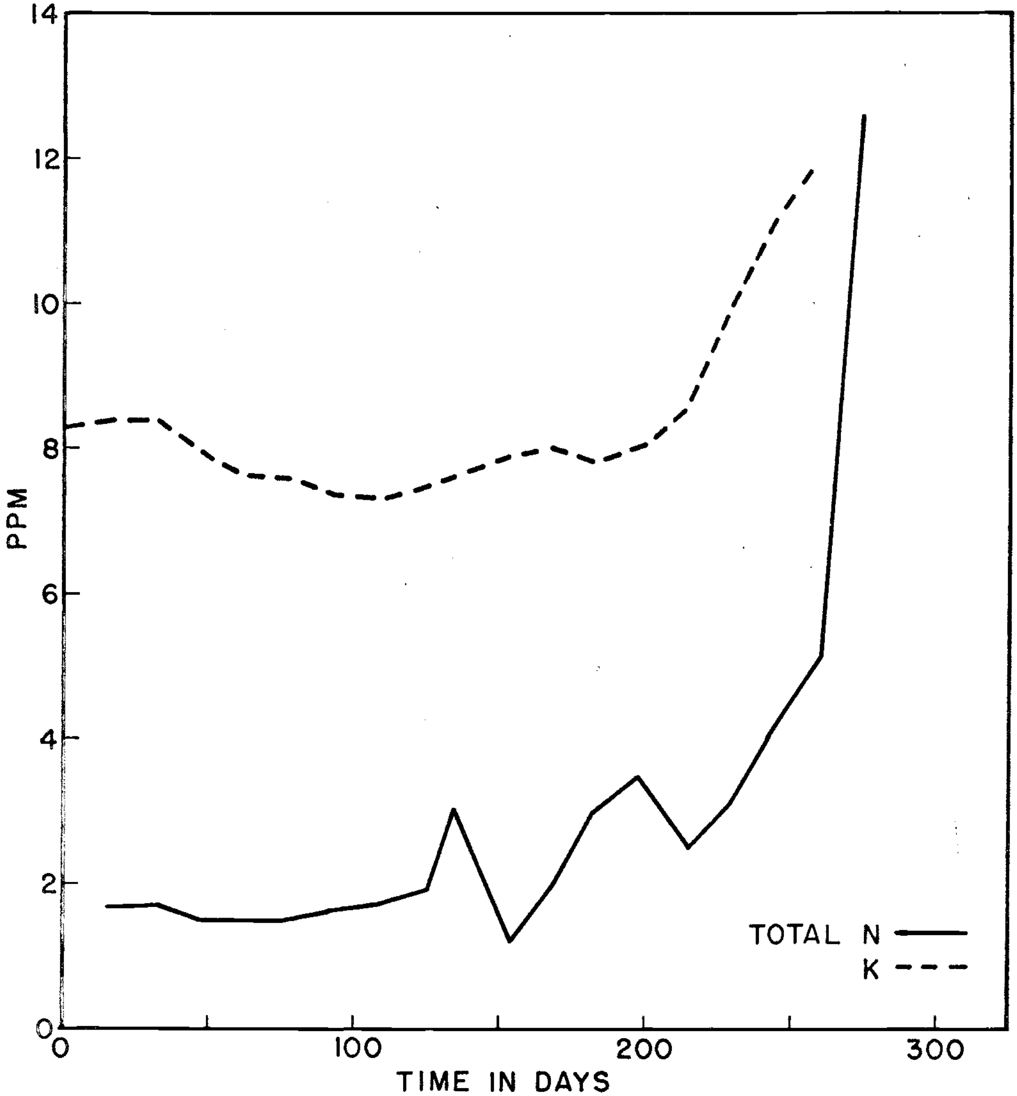

Fig. 6. Fluctuations in the K concentration and total nitrogen concentration of stock tank water sampled. The graph represents an average value for all eight tanks sampled.

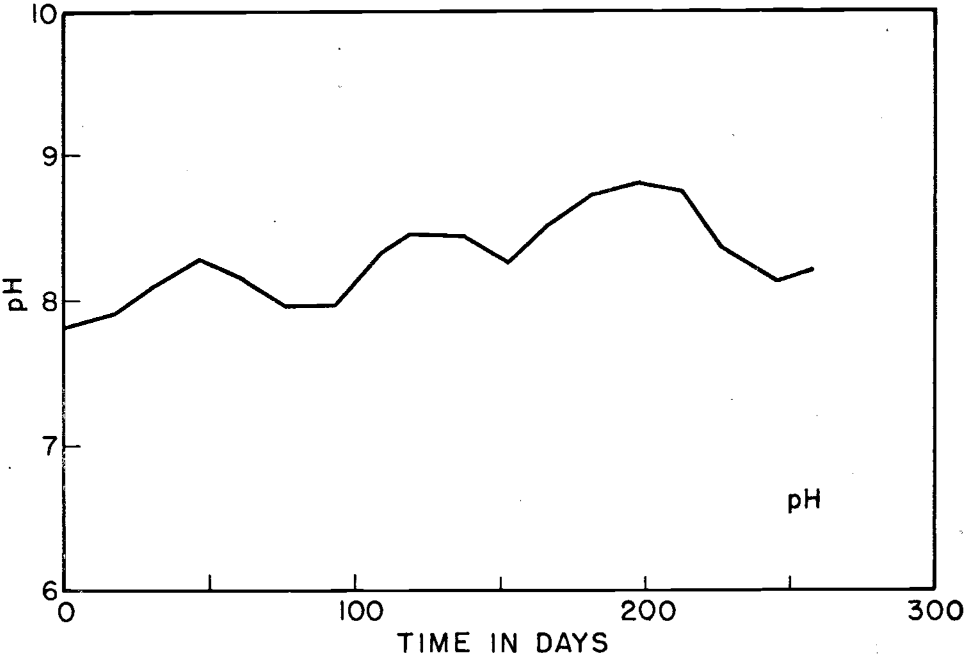

Fig. 7. Variations of pH level with time in stock tank water. The graph represents an average of the eight stock tanks monitored during the sampling period.

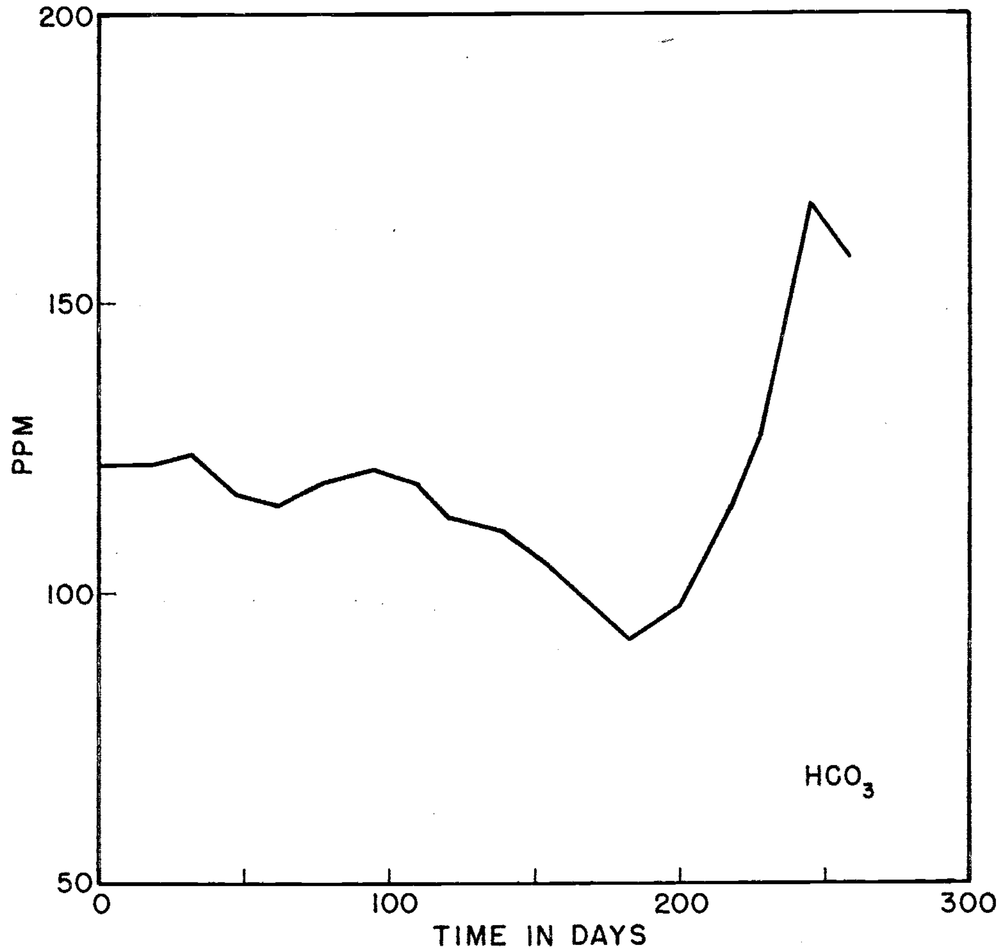

Fig. 8. The average variation in bicarbonate concentration with time in the eight stock tanks tested. The dramatic rise in HCO_3 concentration starting at 180 days is due to the evaporation and concentration of the tank waters as the tanks approach dryness.

Factors that affect eight different tanks were examined collectively, which resulted in 135 observations, with up to 20 observations at one tank. A computer analysis of this data using Huzar's multiple linear regression program disclosed that six variables were associated with 56.3% of the variance (Table 1). With the multiple regression technique, one assumes that all variables are independent, so that the results are as certain as possible. However, such independence was not always present in this study. The first variable was the time of sample collection, called DAY. Obviously, many things affect an algal population with time, so this parameter is related to many other variables; but, no factor was more important than time alone.

The next factor to enter the regression was total N (Fig. 6), determined with an autoanalyzer. Analysis of nitrogen in this manner breaks down all fixed forms of N; thus, we could determine the total amount of nitrogen in the samples. Total N in the tanks comes from two major sources--waste products from the higher animals (livestock) and algal fixation of N during the growth process. The N parameter decreased the unexplained variance by 13%; i.e., the coefficient of determination (R^2) increased by 13%.

Two other variables, potassium (Fig. 6) and pH (Fig. 7), enter next and explain small, but significant increases in R^2. Potassium concentration in the tanks reacted like most of the other ions present, by increasing in concentration with time and with diminishing water storage. However, the concentration did not approach the 17-ppm level, above which the growth of blue-green algae is no longer limited (Eyster, 1964). Thus, the 8- to 12-ppm range of K concentration in the tanks sampled was a major control on algal growth (Fig. 6). The K concentration decreased slightly until near the 200th day, then increased suddenly as four of the tanks completely dried up. Other factors are naturally involved in these fluctuations, but the K concentration must be considered one of the most influential on algal growth patterns in these tanks.

The pH level in the tanks behaved predictably, with a general rising trend (Fig. 7). The several major fluctuations in pH did not correlate well with any other trends in the ionic concentrations monitored. As algal growth progresses, Ca is precipitated and the pH rises. However, other unexplained factors presumably have damped this rise, as indicated by the several fluctuations during the monitoring period. The relative positions of DAY and Total N were reversed at this time in the regression, and Total N became dominant.

At this point, all variables have been positively correlated with an increase in algal numbers. The next two entering variables, INFLOW and bicarbonate ion concentration (Fig. 8), are negatively associated with increasing algal numbers. The relative positions of the two most important variables (Total N and DAY) remained stable in their ranking as the last two factors entered the regression.

Inflow runoff affects algal growth also, as evidenced by decreases in algal population of the individual tanks, after each significant flow into them. We have not yet attempted to analyze the interactions of multiple factors responsible for changes in the algal growth pattern. Neither have we determined the ionic concentration change in the tanks caused by dilution and changes in light intensity with the stirring of

Variable	Relative position or rank at each step 1	2	3	4	5	6	Coefficient in polynomial
DAY	1	1	1	2	2	2	0.3338×10^{-2}
Total N		2	2	1	1	1	0.9492×10^{-1}
K			3	3	3	3	0.6332×10^{-1}
pH				4	4	5	0.1870×10^{0}
Inflow					5	4	-0.1335×10^{0}
HCO_3						6	-0.2961×10^{-2}
R^2	38.1	51.3	52.8	54.3	55.5	56.3	

(F ratio to stop = 1.5)

Table 1. Stepwise analysis of data from eight stock tanks, using a multiple linear regression program.

sediment from inflow. However, our first impressions are that the ionic concentrations are lowered by an amount disproportionate to the amount of inflow received. Presently, we can only say that the inflow parameter is responsible for significant changes in the algal growth pattern of the tanks. Concentration of HCO_3 was essentially an indicator of evaporation and increased greatly as the water stored in a tank decreased.

Since an assumption of the multiple regression technique is that all variables are independent, the question arises as to the independence of the factors considered in this study. Because the biological processes associated with the stock tanks were uncontrolled and complex, such independence was not always present. Some factors may actually be influenced by the algae or may influence other factors, or observed influences could be due to random chance.

CONCLUSIONS

Algal growth was the most prominent change taking place in stock watering tanks with time. The chemical makeup of the waters varied little during the sampling period, except just before the tanks dried up. As algae died, ions tied up by the algae were released to the water, causing an increase in concentration of many of the nutrients. Since graphical analysis of the time change in ionic concentrations of the tanks was inconclusive in determining the impact of each factor on algal growth, the data from eight stock tanks were analyzed by stepwise linear regression.

Six variables were associated with 56.3% of the variance, although 20 variables were used in the complete analysis. The six variables were DAY (time since first sampling), total N concentration (a measure of all fixed forms of N in the samples), K concentration of the tank water, pH of the tank water, INFLOW (recharge to the tanks), and HCO_3 concentration of the tank water samples. The first two variables, DAY and Total N explained 51.3% of the variance. Then K entered, not changing the positioning of the first two variables, and R^2 increased to 52.8%. The pH factor was next to enter the regression and at this time the relative positions of DAY and Total N were reversed, with Total N becoming dominant. The last two factors, INFLOW and HCO_3, were negative (an increase in INFLOW or HCO_3 concentration resulted in a decrease in algal population) and increased the coefficient of variance to 56.3%

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