COLOR IT EVAPORATION

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INTRODUCTION

In the arid and semi-arid regions of the nation and the world, evaporation consumes vast quantities of the generally limited water supply within these areas. An estimated 17 million acre feet are lost annually within the 17 western states of the United States through this mechanism alone. Considering the demographic explosion occurring in this area, water and efficient water use is becoming more and more important. To attain an efficient utilization of current water resources, a thorough knowledge of evaporation must be known. More accurate and usable methods of determining evaporation are imperative in planning and operations of water resource systems.

Evaporation is determined by direct measurement or through the utilization of several empirical relationships which relate evaporation rate to some pertinent meteorological variables. This paper presents a rather unique parameter and its utilization in predicting evaporation or understanding evaporation phenomena from free water surface.

BRIEF REVIEW OF LITERATURE

Interest in evaporation is not new as early writings on the subject data back to 1798 when Dalton demonstrated that the rate of evaporation was proportional to the difference in vapor pressure between the evaporating surface and the atmosphere.

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The Dalton principle that evaporation is a function of vapor pressure differences is the basis for all vapor transfer methods developed since that time.

Since Dalton's work, much effort has been concentrated on evaporation phenomena with almost all meteorological parameters considered at one time or another. Abbe in 1905 reported the effect of sunshine and heat and further indicated that these parameters were studied in England as early as 1691. Meyer in 1915 developed one of the earlier evaporation formulas using vapor pressure deficit and wind velocity.

Cummings and Richardson in 1927 considered evaporation primarily a function of solar radiation and introduced the term insolation for this parameter. Richardson in 1931 introduced the term back radiation from the water and used same in the proposed empirical relation. Rohwer in 1931 developed a formula for estimation of evaporation based on the climatic factors, barometric pressure, wind velocity and vapor pressure deficit. Blaney and Morin in 1942 published an empirical formula using the parameters of mean monthly values of temperature, relative humidity and annual daytime hours. Hargreaves in 1956 developed a similar relationship using only the temperature and humidity relations.

Since Dalton's first thesis, one can see that extensive activity in determination, either directly or indirectly of evaporation has taken place and it continues to date. Most of the efforts are devoted to modification of existing methods, combination of presently studied parameters, or continuation of studies for purpose of verification of existing models. Thus, the parameter color is being added to the long list of parameters considered.

EXPERIMENTAL PROCEDURE

The need for evaporation data in the Lubbock, Texas region of the High Plains of Texas developed during a study relating to the use of playa lake water in artificial recharge operations. In order to determine subsidiary losses of water from the playa lake, evaporation was considered to be the primary loss. Much printed data exists for potential evaporation from free water surfaces exists but yet most do not specify the exact quality of water used in data determination. Since the waters used in the recharge study were a unique type - surface runoff with high sediment content - it was not clear that printed values for evaporation would be consistent with the actual values. The question of quality was the primary factor resulting in this study.

In order to determine evaporation rates, Class "A" U. S. Weather Bureau land pans were used. Since quality was the initial parameter of concern, three (3) waters, each with different quality characteristics were used during the initial phase. These waters were identified as clean (municipal water), sewage effluent (secondary treatment effluent), and surface runoff (collected in playa lakes). Major visible characteristic differences between the waters were in their color. The effluent possessed a dark-black-green color while the surface runoff was a reddish-brown color with evidence of suspended sediments. Two (2) additional waters were introduced after initial observations indicated their value. These waters were beef cattle feedlot runoff and artificially colored. The feedlot runoff possessed a higher density than municipal water as well as being dark-brown in color with evidence of suspended matter. The artificially colored water served primarily as a check as municipal water was used and was colored dark green using a dye. The chemical quality was not altered and the only difference was the color.

Measurements of ambient temperature, humidity, wind, barometric pressure, solar radiation, electrical conductivity and water temperature were made in addition to the direct measurement of evaporation. Evaporation data was obtained daily during select periods weather permitting and at 2-hour intervals periodically. The other measurements were made incidental to the evaporation data. Chemical analyses were performed periodically to ascertain the chemical quality of the waters.

RESULTS AND DISCUSSION

Evaporation rate data dates back to 1966 and is available through the summer, 1970. After indications that differences in rates existed for the different colored waters, greater emphasis was placed on the color parameter. The results presented herein will be restricted to that which relates to this parameter.

Table 1 shows a typical chemical analysis of the three (3) waters - clean, effluent, and surface runoff. As can be seen from the table, chemical quality varied for the three waters but the difference was not significant to affect evaporation. The runoff water was extremely low in total dissolved solids yet had an observed evaporation rate greater than the clean and almost the same as the effluent.

TABLE 1

TYPICAL CHEMICAL ANALYSIS

Ions	Sewage	Runoff	Clean
Calcium	64 ppm	20 ppm	58 ppm
Magnesium	44	12	28
Sodium	420	3	60
Potassium	20	9	6
Bicarbonate	195	122	323
Chloride	560	20	69
Sulfate	600	40	80
Carbonates	36	0	0
TOTAL	2353	206	588
pH	8.8	7.3	7.5

Figure 1 shows the evaporation rates for runoff, clean, and effluent waters during six months in 1967. As can be seen from the figure, evaporation rates were highest during May and June with maximum rates of approximately 0.5 inches/ day from the darker colored waters - sewage effluent and surface runoff. As temperatures increase during July and August, the highest rates were observed for runoff and effluent whereas during the cooler months, the clear water had the higher rate. Salt content appeared to have no effect upon evaporation rate as was initially considered.

Similar evaporation rates were observed for four months in 1968. Figure 2 illustrates these rates and again the trend of higher rates for the darker waters and higher temperature months were noted. The maximum rate of evaporation was again approximately 0.5 inches per day.

Artificially colored green water was added to the waters observed in 1969. The purpose of its use was as a check to evaluate the effect of coloration on evaporation. The trend developed in 1967-1968 indicated that color may be a controlling parameter and the intent was to verify this trend. Figure 3 shows evaporation rates for clean, effluent, and green water. The highest rates for any of the years of record were observed during this time period. This was primarily due to the extremely hot dry weather during the study period. The figure again shows the evaporation rate increase during the hotter months for the colored waters. The artificially green water had a rate of evaporation equal or greater than the effluent with both having higher rates than the clean. Thus further substantiation of color as a parameter of influence.

A fifth category of water was used in the 1970 study. This water, beef-cattle feedlot runoff, possessed very dark color characteristics and was similar

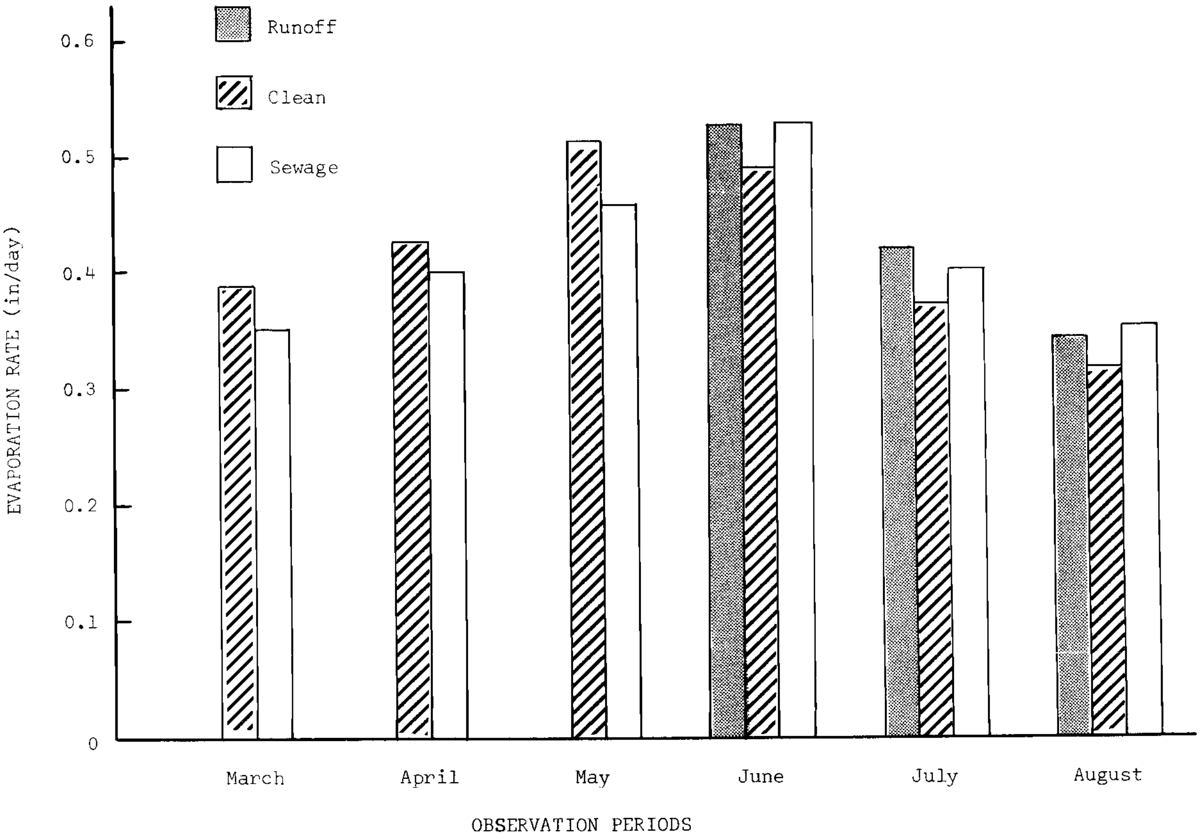

Figure 1. Average evaporation rates from free water surfaces of select waters in 1967.

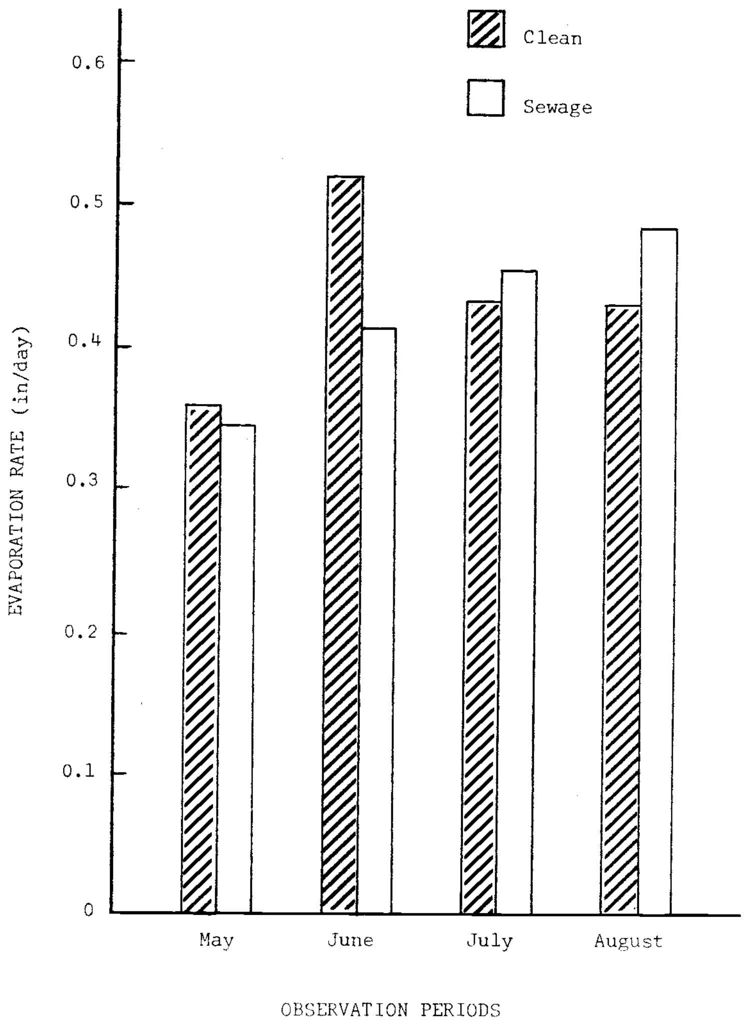

Figure 2. Average rate of evaporation from free water surfaces of sewage effluent and clean water in 1968.

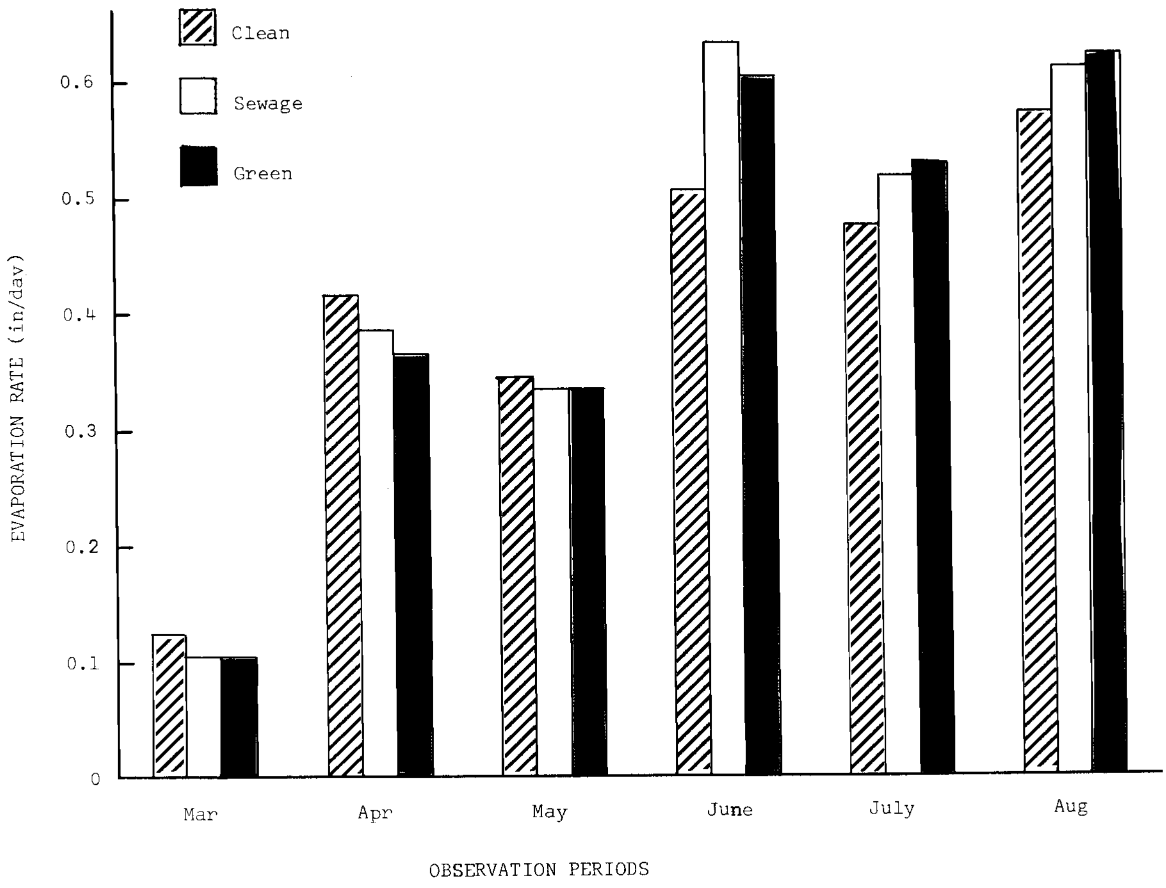

Figure 3. Evaporation rates for select waters and periods in 1969.

to the sewage effluent and green water in color. The rates observed are shown in Figure 4 and again indicate an increased rate for the darker colored waters especially during the hot summer months.

Since a trend appeared to correlate high evaporation rates with increasing ambient temperature, especially for the colored waters, rate measurements were made at 2-hour intervals. Figure 5 represents these observations during June, 1968 for clean and effluent water. Evaporation rates are higher for clean water during the evening and early morning hours but less during the daylight hours. Most significant differences occur during the mid-afternoon when air temperatures are the greatest. Water temperature measurements were made to determine if an increase in temperature could be detected. The effluent water temperature was approximately 2°F higher than for the clean. This indicates that back radiation probably was increased from this dark colored water and probably led to the increased rate of evaporation.

Figures 6 and 7 show the 2-hour relations for select waters but for different periods of the year - January, 1970 and July, 1969. The colored waters possessed higher rates during daylight hours in July, 1969 with the pattern very similar to that observed in June, 1968. However, in January, 1970, the colored waters possessed higher rates for all observations. This indicates that color is a parameter which influences both absorption of radiation and back radiation from the water and thus influences evaporation rates.

The measurements of humidity, temperature, wind, and radiation have not been analyzed to date to correlate their effect on the evaporation study as conducted. Indications are that no significant effects will be found within this analysis.

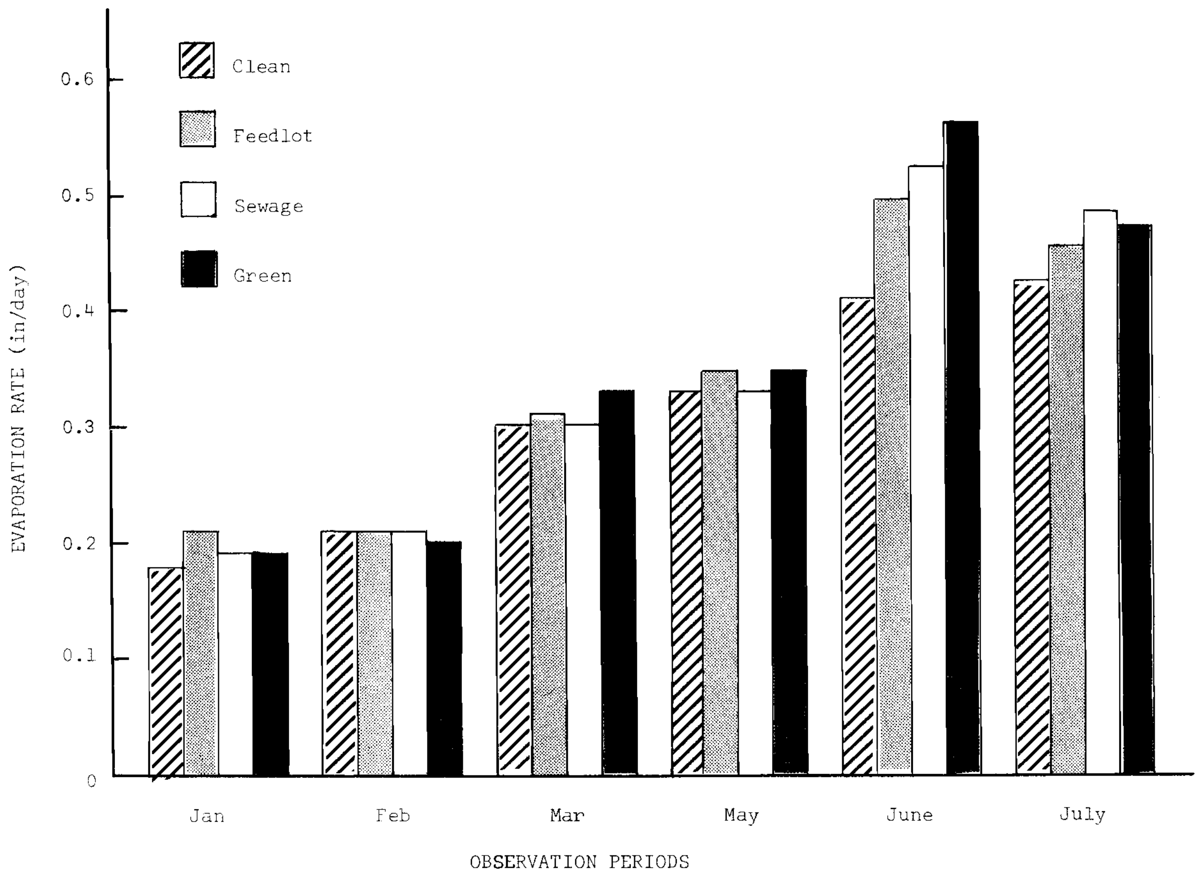

Figure 4. Evaporation rates for select waters and periods in 1970.

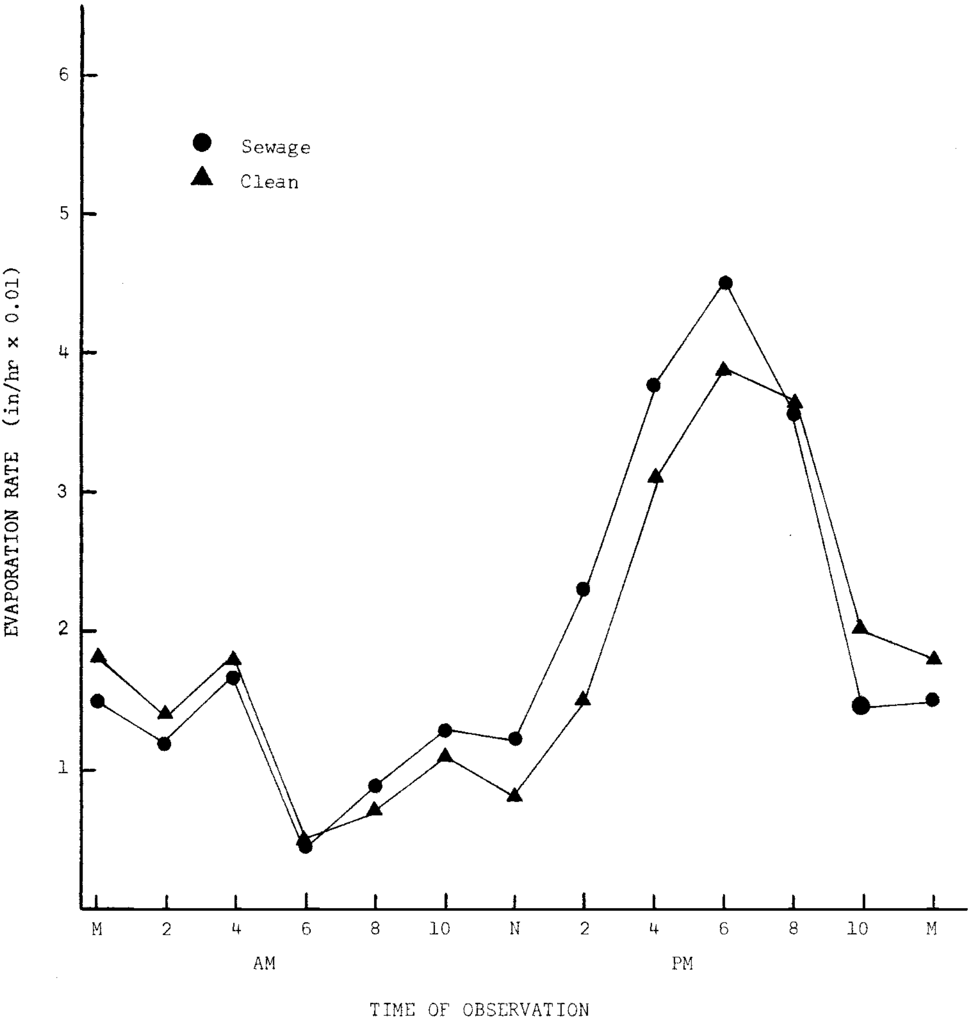

Figure 5. Evaporation rates for sewage effluent and clean water at 2-hour intervals in June, 1968.

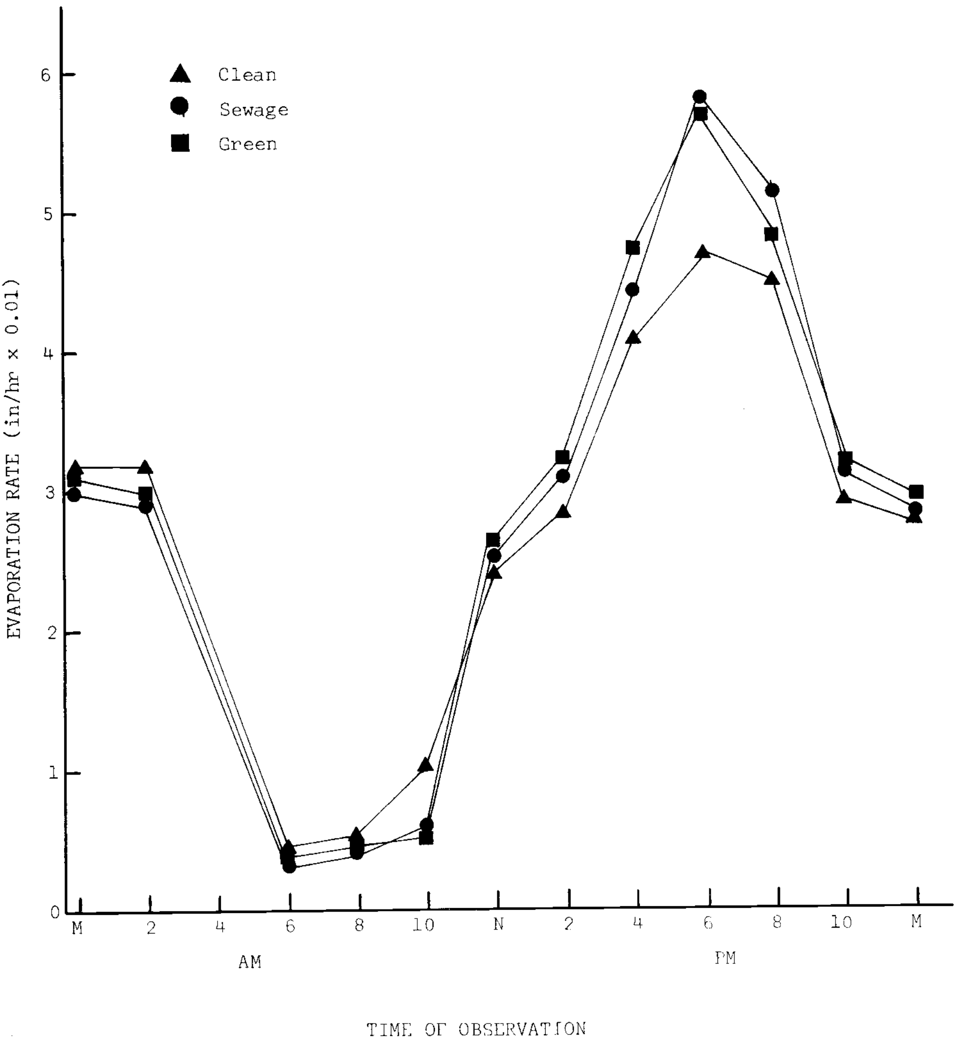

Figure 6. Evaporation rates for select waters at 2-hour intervals during July, 1969.

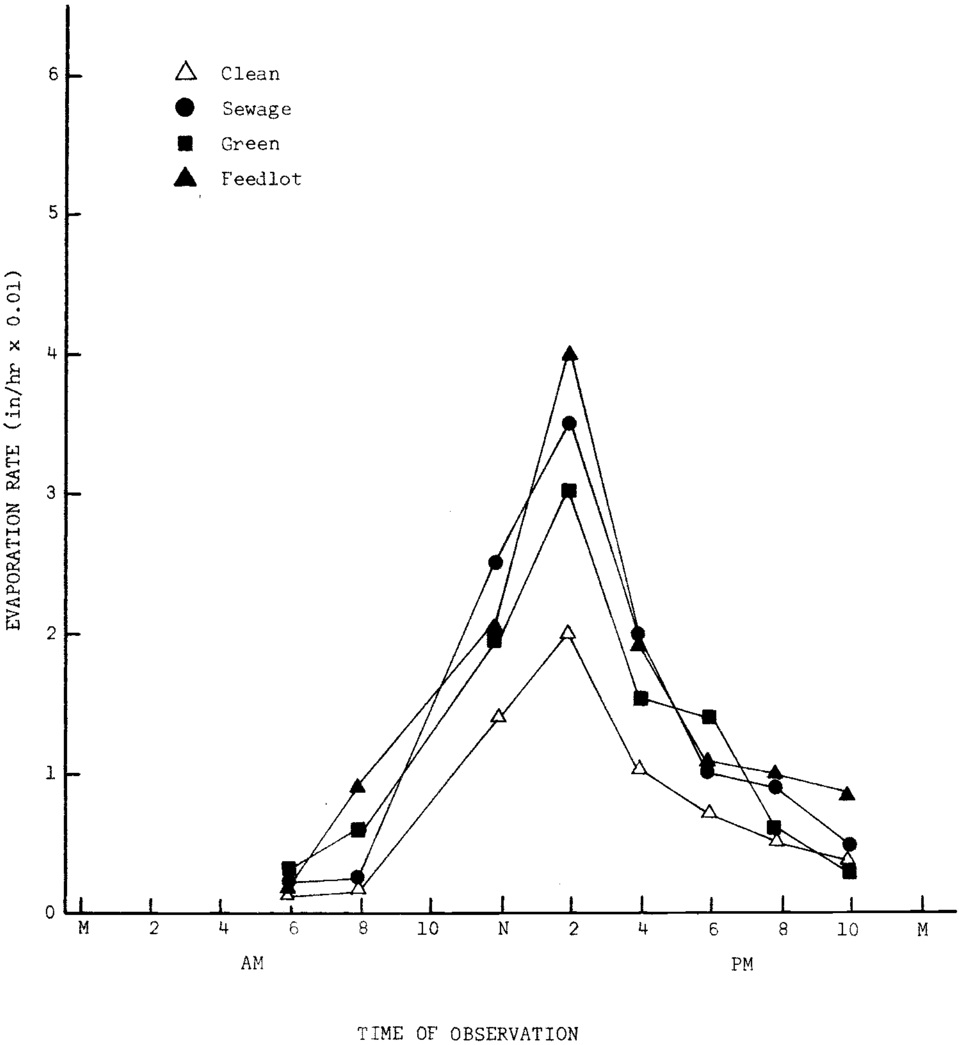

Figure 7. Evaporation rates for select waters at 2-hour intervals during January, 1970.

SUMMARY AND CONCLUSIONS

A total of five (5) different colored waters were studied during the period 1966 thorugh 1970 to determine their evaporation rates. Color was the one parameter which was significantly different for all waters as the color ranged from none or clear for the municipal water to a very dark brown for the beef cattle feedlot runoff. Other waters were surface runoff (reddish-brown), sewage effluent (dark-black-green) and colored municipal (dark green).

Observations indicate that different rates exist for the different waters with the darker or colored waters possessing the highest rates. This was consistent for all periods of observation leading one to the conclusion that color is a parameter of influence. The color seems to affect the amount of adsorbed radiation as well as the extent of back radiation.

The latter observation is supported when 2-hour interval evaporation rates are noted. The increasing rate during daylight hours for the colored waters and the reduced or lesser rate during hours of darkness leads one to conclude that back radiation might be significantly different. In all observations the trend for a higher daily rate of evaporation existed for the colored waters except during periods when air temperatures were low.

Additional study is required to firmly establish that color can be used in the development of an empirical relationship for estimation or prediction of evaporation from free water surfaces.

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