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EVAPORATION OF WATER FROM RECLAIMED COPPER STAMP SANDS

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Evaporation of Water From Reclaimed Copper Stamp Sands[1]

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ABSTRACT - Potential water losses from porous, structureless, sandy copper stamp sands by evaporation averaged .41 of an inch per day in the surface six inches for June, July and August. Greatest potential loss was found to be a .78"/day and lowest loss was .04"/day. Incoming weekly solar radiation averaged .890 (Langleys). Available water (1/3-15 Bar) storage capacity of the stamp sands in the upper six inches amounts to 1.65 inches of water.

Introduction

Large quantities of raw ores must be processed to produce the necessary metals consumed by our present economic standard of living. It has been estimated that 1/2 million tons of copper and uranium tailings are deposited annually in the western states (Nielson and Peterson 1972. Unfortunately the location of these wastes near population centers constitute a real nuisance especially during periods of high winds when blowing dust becomes highly objectionable.

When plant growth fails to establish itself on mine wastes, lack of water or the fertility of the materials is generally responsible (Shetron and Duffek 1970). Abnormal losses of water from unprotected land surfaces is especially detrimental to the establishment and growth of plants, even though sufficient nutrients may be present to sustain growth.

Recent attempts to establish vegetation on reclaimed copper stamp sands, a non-sulfide mined mineral waste, have met with varying degrees of success. Intensive studies to quantify the stamp sands as a growth medium have brought to light the critical nature of these materials as a medium in which to grow plants.

Of particular interest are the physical properties of the stamp sands. They are medium to fine sand textured, (less than 10% silt plus clay), structureless (no organic matter present), 60% pore space with an average bulk density of 1.49 gms/ec. They will retain an average 1.6 inches of available water (1/3 - 15 bar) in the surface six inches. Furthermore, personal observations have noted removal of 2 to 3 inches of stamp sands by wind erosion under severe wind conditions (20 to 30 knots). Previous attempts to establish and grow vegetation (grass and legumes)

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with adequate fertilization and topdressing reveal that although excellent germination takes place, long term growth does not. Surviving seedlings are generally stunted, twisted and ragged in appearance.

The study site is a 120 acre deltaic deposit situated along the shores of Torch Lake in the Upper Peninsula of Michigan. The waste material is a very dark gray (5YR 3/1 moist)[3] finally crushed basalt and red conglomerate deposited from a water slurry after the extraction of copper. The position of the stamp sands in Torch Lake gives it no protection from wind. Up to one mile of open water abuts 70 percent of the deposit. The climate of the area is cool-humid with a mean annual temperature of 49°F and a precipitation of 32 inches in the form of snow and rain.

Methods

A temporary weather station was set up on the stamp sands to record the following: radiation, wind, temperature (air and soil), rainfall, and relative humidity. A factory calibrated solar radiation recorder (spectrum sensed .36 micron to 2.5 micron wave lengths) was used to measure sun and sky radiant energy. A contacting counter-totalizing anemometer, starting speed 2 m.p.h., was used to measure miles of wind at a height of four feet. A hygrothermograph, U.S.W.B. type with a sensitivity of 10/100°F and 0/100° Acc. of 3% relative humidity, was used to measure temperature and relative humidity. A general purpose rain gauge (forester type) with an 8 inch diameter and 7 inch capacity installed 30 inches above the ground was used to measure rainfall. Soil temperatures were obtained with factory calibrated nylon blocks burried at 1 inch and six inch depths in surface layer of the stamp sands. Daily and weekly data were collected for the period of June, July and August, the growing season at this latitude (47N).

Two methods were used to estimate evaporation: (1) free-water evaporation by the formula $E = (e_0-e_1)(0.068 + 0.00246V)$(Butler 1957), where e_0 is the saturation vapor pressure at the soil surface in inches of mercury, e_1 is the vapor pressure of the air at a height of two feet and V is the wind in miles per day at four feet above the surface; (2) Thornthwaite's potential evapotranspiration formula $E_{tp}=-1.6(10\bar{T}/I)^{a'}$. (Taylor 1972) where $\bar{T}$ is mean monthly temperature in degrees celcius, I is annual heat index (sum of twelve individual monthly heat indices), and a' is a parameter that varies from place to place depending on climate. Butler's equation was used because of a lack of vegetation, structure and the extreme porosity of the stamp sands. Data from Thornthwaite's method on the other hand should be meaningful with respect to potential water loss on the stamp sands when covered with vegetation. Kozlowski (1924) states that the evapotranspiration is primarily dependent on heat and theoretically independent of vegetation type as long as plant cover and available moisture is uniform.

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(3) Munsell soil color notation, Munsell Colors Co., Baltimore, Maryland.

Results and Discussion

The comparison of the two equations used in determining evaporation are not significantly different for the study period. But a large difference occurred for the month of July. Thornthwaite et. al. equation shows 0.6 of an inch/day for July whereas Butler's equation shows 0.42 inches/day. This was expected, as transpiration rates would be an additive factor to the loss of water during the warmer dryer summer months. The data do reveal the extremely high drying capacity of the stamp sands.

According to Kozman (1965) this geographic area should have an average annual evaporation demand of 19 inches. The summary of data and amounts of water lost (Table 1) reveal that during the month of July alone the average potential loss can be as high as 13 inches of water. On a weekly basis, the per day rate of water loss varies from a low 0.04 inches per day to a high of 0.78 inches per day (Table 1). The daily rates correlate well with environmental factors. For example, the seventh week shows a high relative humidity, rainfall and low soil temperature, water loss per day was low. However, during the fifth week low relative humidities, high vapor pressure, and high soil temperatures with low rainfall occurred at the stamp sands. This week had the highest potential water loss. Mean weekly incoming radiation as measured at the temporary weather station was fairly constant for study period at .890 Langleys/min.

TABLE 1. Summary of Evaporation Data for Copper Stamp Sands For The Period of Mid June to Mid August. (Values are weekly averages)

Week	Relative Humidity %	Wind (m/day)	Vapor Pressure* Difference	Rain Inches	Soil Temp. 1-6"(F)	Potential Evap. in./day**	Available Water storage Capacity(in.)***
1	60	73.4	1.217	trace	95	.303	1.65
2	59	124.8	1.179	2.61	97	.441	1.65
3	53	142.3	1.200	.34	98	.502	1.65
4	62	151.6	1.300	.87	100	.572	1.65
5	58	133.5	1.389	.75	104	.776	1.65
6	66	130.3	.577	.37	84	.224	1.65
7	85	147.9	.090	2.44	69	.040	1.65
8	48	168.9	.885	.12	78	.331	1.65
two month Average	61	134.1	.980	.94	91	.410	1.65

*/ Vapor pressure = saturated vapor pressure at temperature of soil minus vapor pressure of air.

** Evaporation calculated as a free water surface.

*** Total amount of available water (1/3 - 15 bar or percent water at field capacity minus percent water at permanent wilting point in the surface six inches of stamp sands).

According to the Butler's equation, wind plays an important role. Table 1 reveals that air flow over the stamp sands is fairly high. This is believed to be the result of several factors. First, the unprotected nature of the site and lack of vegetation exposes the site to winds, particularly "eddy" currents along the surface. Secondly, persistent land-lake breezes occur day and night, but they do not usually blow at speeds over 5 miles per hour. According to Kozman (1965) wind speeds less than 2 miles per hour have a greater relative effect than speeds over 2 miles per hour. Percentage-wise, a 30% increase in evaporation will occur for winds up to 1 mile per hour and only a 50% increase for winds from 1 to 16 miles per hour (Pruit 1966). Thus, even with no winds in the surrounding area the land-lake breeze on the stamp sands will continue to evaporate moisture from the stamp sand. Furthermore, high winds passing over the hot, dark colored sands are heated quickly, thus relative humidity is lowered creating a steeper vapor pressure gradient between the soil surface and the flowing air.

Another important factor in the evaporation rate is the low albedo or reflective capacity of the soil surface (Ward 1967). Because of the very dark gray color of the sands, most of the insulation received is absorbed. During the summer months the stamp sands have reached a high temperature causing a higher vapor pressure gradient which will allow more soil moisture to be lost to the atmosphere. The highest surface layer temperature of $104^{o}F$ was recorded for the week with the greatest daily potential water loss.

Because of the sandy porous nature of the stamp sands, most of the water evaporated comes from precipitation. The surface layer of the sands dry down to permanent wilt level and beyond due to the poor capillary movement of water to the surface and low amounts of water stored. Table 1 reveals that the stamp sands can only store an average of 1.65 inches of available water (1/3 - 15 bar) in the upper six inches. On clear sunny days the surface of the stamp sands will dry out quickly. The sands immediately below the shallow, dry surface layer may be relatively moist. In weather such as the fifth week (Table 1) evaporation from the bare sands decreases rapidly to near zero within a few days. The reason for evaporation decrease is that the rate of evaporation exceeds the rate at which the stamp sands can transmit water to the surface. Nylon block observations on the drying time of the upper six inches reveal that the surface layer could potentially be at permanent wilting point in 1 to 2 days after recharge to field capacity (1/3 bar). Under these same conditions with plant cover transpiration may not be limited for a week. Thus, the water content of the stamp sands may be sufficient to maintain plant needs but not evaporation and evapotranspiration increases as plant cover increases (Taylor 1972).

Summary and Conclusions

This study shows that a high rate of evaporation occurs on these types of mine wastes stamp sands. This is important in future plannings of the site for vegetative stabilization. Although these data represent a possible upper bound for evaporation, they illustrate the severity of the site. Furthermore, drought conditions can develop quickly due to low storage capacity which is perhaps more important than evaporation (Alizai and Hulbert 1970). In order to maintain vegetation on the site, supplemental water will have to be added through irrigation.

On mine wastes such as these in a climatic region receiving adequate precipitation, desert like conditions could prevail limiting long term vegetative cover. Wind breaks, surface mulch, and irrigation will be needed to create more favorable plant-growth medium.

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