

LETTERS TO THE EDITOR

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THE EXTERNAL FIELD OF A RADIATING STAR IN GENERAL RELATIVITY

It is well known that the generalization of Schwarzschild's solution corresponding to the external field of a radiating star has not yet been obtained. The internal field describes a mixture of matter and radiation. In the outer field there is the expanding inner zone of pure radiation, with radius r_1 at time t_1 , beyond which the empty space is described by Schwarzschild's static solution. The zone of pure radiation is given by

$$ds^2 = \left(1 - \frac{2m}{r}\right)^2 dr^2 - r^2 (d\theta^2 + \sin^2\theta d\phi^2) - \frac{\dot{m}^2}{f^2} \left(1 - \frac{2m}{r}\right) dt^2, \quad (1)$$

$$f(m) = m \left(1 - \frac{2m}{r}\right). \quad (2)$$

[As usual an overhead dot denotes a differentiation with regard to t and an overhead dash a differentiation with regard to r . $f(m)$ is an arbitrary function of m .]

Since the lines of flow of radiation must be null geodesics the radiation tensor has to be

$$T^{\mu\nu} = \rho v^\mu v^\nu \quad (3)$$

with $\rho_{,\mu} v^\mu v^\nu = 0$ (4)

so that $(\rho v^\mu)_{,\mu} = 0$ and $(v^\mu)_{,\mu} v^\nu = 0$. (5)

The surviving components of the tensor are given by

$$-T_1^1 = T_4^4 = \frac{m'}{4\pi r^2}, T_1^4 = -\frac{m}{4\pi r^2}, T_4^1 = -\frac{\dot{m}}{4\pi r^2} \quad (6)$$

For differentiation along a line of flow we have the operator

$$\frac{d}{d\tau} = e^{-\lambda} \frac{\partial}{\partial r} + v^\nu \frac{\partial}{\partial t} \quad (7)$$

It is found that the field equations amount to

$$(i) \frac{dm}{d\tau} = 0, (ii) \frac{d}{d\tau} (r^2 e^{-\lambda} T_1^1) = 0,$$

$$(iii) \frac{d}{d\tau} (r^2 \rho) = 0, (iv) \frac{dv^1}{d\tau} = 0. \quad (8)$$

The equation that is most difficult to handle corresponds to $T_{,2}^2 = 0$. But it can be shown to be equivalent to (ii). The equation of continuity then leads to (iii) and (iv) readily. Thus, along the lines of flow of radiation m , v^1 and $r^2\rho$ are all conserved. It is worthy of notice that m' is positive while \dot{m} is negative. This as well as the results (6) and (8) are suggested by the Newtonian analogue.

The total energy of matter and radiation is conserved. m is the effective mass of the whole system at a point. The value of m at the boundary $r = r_1$ at $t = t_1$ is a constant, M . At time t_1 , for all values of r exceeding r_1 , the field is given by Schwarzschild's line-element corresponding to the value M . Also $\dot{m} = f(M)$ when $r = r_1$ and $t = t_1$.

The new results are (1), (2), (6), (8). Further details and astronomical applications are considered in a paper to be published elsewhere.

My thanks are due to Prof. V. V. Narlikar under whose guidance this work was done and who showed me the result 8 (i).

Benares Hindu University,
March 22, 1943. P. C. VAIDYA.

Einstein, Infeld and Hoffmann, *Annals of Mathematics*, 1938, p. 65; Narlikar, V. V., *Bombay Univ. J.*, 1939, 8, 37.

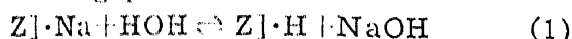
PERMEABILITY AND HYDROLYSIS OF SODIUM SOILS*

For many purposes a correct idea of the effectiveness of leaching an alkali soil is necessary. For instance, in reclamation work leaching is often practised though we do not know how long it will take to remove the evil influences

* This work was carried out under the auspices of the Irrigation Research Section, P.W.D., U.P. Government.

of exchangeable sodium. The futility of this process has been emphasised by various workers,¹ but few have attempted to study it mathematically. The following short note is meant to indicate the changes in permeability and its relation to the content of exchangeable sodium due to leaching a soil with water.

A sodium soil in contact with water undergoes hydrolysis, sodium hydroxide and hydrogen soil being produced.



Under leaching conditions, the exchangeable sodium is gradually replaced from the soil complex and its place is taken more and more by exchangeable hydrogen, with a consequent increase in the permeability of the soil.

In order to see how the rate of percolation of water changes with gradual replacement of exchangeable sodium by hydrogen, pure sodium soil was prepared by leaching it first with 0.05N HCl and then with normal solution of sodium chloride. The excess reagents were removed by washing with water followed by washing with alcohol. The resulting sodium saturated soil was then treated with different amounts of dilute hydrochloric acid so as to introduce different quantities of exchangeable hydrogen in the exchange complex. The excess reagents again were removed by washing with water and finally with alcohol. These soils were analysed for the Na-content and then subjected to permeability tests. Three different soils were studied.

It is found that the permeability of hydrogen-sodium soils increases in a regular manner with the ratio of exchangeable hydrogen to base exchange capacity. If y is the rate of percolation of water in cms. per hour, H the quantity of exchangeable hydrogen in milliequivalents per 100 gms. of soil, and 'B' the base exchange capacity in m.e., then the following relation is found to hold good.

$$y = Ke^{nH/B} \quad (2)$$

K and n are constants. Table I refers to the results obtained in the case of one soil.

TABLE I

	H/B	y (observed) cms./hr.	y (calculated) cms./hr.
1	0.80	.064	.064
2	0.81	.060	.059
3	0.75	.055	.056
4	0.60	.070	.050
5	0.48	.045	.045
6	0.25	.038	.037
7	0.09	.036	.036
8	0.04	.032	.031
9	0.00	.032	.030

The observed rates of percolation agree with the calculated ones. In the case of fully saturated sodium soils the calculated rates are a little low. This is probably due to hydrolysis which a pure sodium soil undergoes, readily in contact with water. The end value of y

which is also the value for the constant K of equation (2) is obtained by extrapolation with the help of the equation. The values of the constants K and n together with other constants for three soils are given in Table II.

TABLE II

Soil No.	Clay content	B	K	n
13	21.85	10.0	.0300	0.84
12	27.44	14.8	.0095	1.22
5	27.60	20.5	.0024	2.60

The time required for a definite amount of exchangeable sodium to be released from the soil can be computed as follows.

The rate of loss of sodium from the exchange complex should depend on the quantity of exchangeable sodium and on the quantity of water, which in leaching conditions means the rate at which water percolates through the soil. The following differential equation is, therefore, necessary.

$$\frac{d(Na)}{dt} = -K_1(Na)y \quad (3)$$

In order to determine the integration constant K_1 , sets of percolation tubes were fitted in which pure sodium soil was kept in contact with water for months together. The rate of percolation and the content of exchangeable sodium were found out from time to time. The difference in the sodium content per hour approximates to the expression $\frac{d(Na)}{dt}$. Knowing the sodium content and corresponding rates of percolation, constant K_1 can be evaluated. Table III gives the value of the constants in the case of two soils.

TABLE III

Soil 13

Na (m.e./100 gms.)	Leaching period in hours	$\frac{d(Na)}{dt}$	y	K_1
10.00	0	—	.032	—
9.93	744	9.4×10^{-5}	.032	2.9×10^{-4}
9.80	1392	9.3×10^{-5}	.032	2.9×10^{-4}
9.70	1080	9.2×10^{-5}	.033	3.0×10^{-4}

Soil 12

Na (m.e./100 gms.)	Leaching period in hours	$\frac{d(Na)}{dt}$	y	K_1
14.80	0	—	.009	—
14.74	1560	3.84×10^{-5}	.009	2.9×10^{-4}
14.69	1344	3.72×10^{-5}	.011	2.8×10^{-4}
14.62	1464	4.78×10^{-5}	.011	3.0×10^{-4}
14.55	1488	4.70×10^{-5}	.011	2.9×10^{-4}

The values of K_1 are practically the same in the two cases.

Substituting the value of y from (2), Equation (3) can be rewritten as:

$$\frac{d(\text{Na})}{dt} = -K_1 (\text{Na}) Ke^{n(\text{H})/B} \quad (4)$$

Since $(\text{H}) = B - (\text{Na})$,

$$\frac{d(\text{Na})}{dt} = -K_1 (\text{Na}) Ke^{n(\text{NA})/B} \quad (5)$$

or
$$\frac{d(\text{Na})}{dt} = K_2 (\text{Na}) e^{-n(\text{NA})/B} \quad (6)$$

The equation (6) can now be integrated (equation 7) and the approximate time for a definite stage of hydrolysis can be calculated.

$$K_2 t = \frac{\text{Na}_{(0)}}{\text{Na}_{(t)}} \left[\log(\text{Na}) + \frac{n(\text{Na})}{B} + \frac{n^2(\text{Na})^2}{B^2 2} + \frac{n^3(\text{Na})^3}{B^3 3!} + \dots \right] \quad (7)$$

$\text{Na}_{(0)}$ and $\text{Na}_{(t)}$ represent sodium contents at the beginning and at the end of time t .

The series on the right is convergent. Making use of the first five terms only and substituting for different constants for two soils we get the following values:

	Time for 50% hydrolysis	Time for total hydrolysis
Soil 13	4.23 years	11.63 years
Soil 12	12.40 years	49.62 years

It should be noted that the rate of hydrolysis increases with the rate at which products of reaction are removed. In other words hydrolysis will be faster the greater the rate of percolation. It has also been observed that the rate of percolation is inversely proportional to the clay content and the base exchange capacity.² Hence the hydrolysis will be more pronounced in soils which are poor in clay content and of low exchange capacity.

Under field conditions a number of exchange reactions may take part along with those contemplated above. For instance, many alkali soils have a reserve of CaCO_3 , and the process of 'hydrolysis' is usually combined with the process of 'calcification'. The natural conditions in the field present a variety of such combinations. Further the greater compactness of the soil in the fields will tend to make the process of hydrolysis much slower than under laboratory conditions.

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April 6, 1943.

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THE NATURE OF THE TEA OXIDASE SYSTEM

THE cytochrome theory of tea fermentation advanced by Roberts^{1,2} has not been substantiated so far by any direct evidence for the presence of cytochrome and cytochrome oxidase in tea leaf. A closer investigation of this aspect of the problem based on spectroscopic and manometric determinations has recently given results quite contrary to those of Roberts.

Cytochrome.—Spectroscopically cytochrome is easily detected in the reduced state by its characteristic absorption spectrum. In tea, by observing the cytochrome 'b' band, Roberts claims to have demonstrated the presence of cytochrome, not in the leaf, but in the basal portions of the stem. In choosing this tissue for observation his object was probably to exclude any interference from chlorophyll. In my examination of this tissue in finely ground suspensions and with added succinate or $\text{Na}_2\text{S}_2\text{O}_4$ I could obtain no indication whatever for the presence of cytochrome. Similarly when other tissues of the tea plant were separately collected and tested none of them displayed any specific cytochrome bands.

Extraction of chlorophyll and tannin from leaf by acetone would eliminate their interference with the detection of cytochrome. Thus Yakushiji³ has reported the presence of α -bands of cytochromes b and c in acetone-extracted spinach leaves. No cytochrome could, however, be detected in the acetone-extracted tea leaves and attempts to prepare cytochrome C from such material by the method of Keilin and Hartree⁴ yielded only negative results.

There was again no spectroscopic evidence for the presence of cytochrome in highly active and concentrated solutions of tea enzyme in which cytochrome must be expected if the observed activity were due to the cytochrome system. Selective absorption was absent both in the ultraviolet and the visible regions of the spectrum.

Cytochrome Oxidase.—Preparations of cytochrome oxidase from goat heart muscle readily oxidised cytochrome C, such oxidation being denoted by the disappearance of the reduced cytochrome C spectrum. But a tea oxidase preparation which was highly active on catechol ($-\text{Qo}_2 = 170$) failed to oxidise cytochrome, reduced by Pd and H_2 , and its spectral characteristics persisted for a considerable period in presence of the enzyme. In the preparation of this enzyme our earlier method was further refined so as to minimise the inactivating effect of acetone on cytochrome oxidase, the acetone extraction being carried out rapidly at -20°C . The leaf powder was then extracted with buffer at pH 7.0 and purified by fractional saturation with $(\text{NH}_4)_2\text{SO}_4$ and dialysis. A suspension of the insoluble leaf residue gave results similar to those of soluble enzyme and it is clear that cytochrome oxidase is completely absent in both.

Corroborative evidence against the cytochrome theory was further obtained by O_2 uptake measurements as given below.

1. I. Leather, Report of Usar Land Reclamation in U.P., 1914. 2. Nayar and Shukla, *Proc. Indian Sc. Congress*, 42, p. 74.