USE OF RICE HULL ASH IN WATER TREATMENT

by

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This thesis has not been previously presented in whole or part, to any University or Institution for a higher degree.

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Dedicated to

MY PARENTS

ABSTRACT

Rice hulls, the largest milling byproduct of rice, constitute one fifth of the paddy by weight. The hulls which can be obtained at relatively low cost, are in abundant supply in most developing countries, particularly in the Asian region. Hull contains approximately 20% silica by weight and, on combustion, yields a porous ash having a silica content of approximately 90 percent. This thesis investigates the following two possible applications of rice hull ash in water treatment processes:

(i) the use of rice hull ash as a filter medium;

(ii) the use of rice hull ash as a coagulant aid.

Rice hull ash comprising amorphous silica was produced from locally available rice hulls, using a specially constructed incinerator. Scanning electron microscopic studies were conducted to evaluate the microstructure of this ash as well as diatomaceous earth and filter sand. The laboratory filtration experiments were conducted at slow to semi-rapid filtration rates in order to investigate the effectiveness of rice hull ash medium in removing turbidity, bacteria and colour from water, and to compare its performance with a conventional sand filter. Synthetic water was made by adding suitable amounts of kaolin clay, *Escherichia coli* suspension, coffee/leaf extract, to laboratory tap water. Filtrate quality and head loss were considered as the major parameters in assessing the performance of these filters. A number of thin layer filter experiments were conducted to obtain the variation of turbidity with depth in rice hull

ash filters, under selected operating conditions. Solubility studies of rice hull ash at various strengths of sodium hydroxide and for various steeping periods were made to evaluate the optimum conditions for silica solubilisation. A dilution procedure including partial neutralization and subsequent aging prior to further dilution was adopted to convert alkali soluble rice hull ash into activated silica. Coagulation of dilute clay suspensions ($\leq$ 40 mg/L), using alum, activated silica and selected polyelectrolytes were conducted with the aid of a jar test apparatus.

The filtrate turbidity for approximately 750 mm depth of rice hull ash medium was equal to or less than that of a sand medium, at rates of filtration 0.25 to 2.0 m^3/m^2h and a turbidity range of 20 to 60 FTU. The rate of head loss in the sand medium was 1.5 to 5 times more than in an ash filter. The optimum rate of filtration for the ash filter occurred at 1.0 m^3/m^2h, with a rate of head loss of 52 mm/d. At filtration rates of 0.5 and 1.0 m^3/m^2h, for an influent *Escherichia coli* concentration of 100 - 2000 no/mL, approximately 70% to 90% reductions in bacterial numbers were achieved by 750 mm depths of rice hull ash media. Colour removal of at least 30% was achieved by shallow depths ($\leq$ 320 mm) of ash media, at slow rates of filtration ($\leq$ 0.25 m^3/m^2h).

The results obtained from thin layer filtration experiments were analysed using a statistical filtration model known as the chi-square distribution analogy. This technique was successful in predicting the performance of rice hull ash filters at specific operating conditions.

The optimum removal of silica from rice hull ash occurred when ash was steeped in 5% NaOH solution for a period of 24 h. A procedure for the preparation of activated silica from rice hull ash was developed. The addition of 5 mg/L of activated silica as a coagulant aid during the coagulation of turbid water (40 mg/L of kaolin clay) with 50 mg/L of alum at pH value of 6, was sufficient to achieve a residual turbidity of 1.2 FTU. The coagulation of the same water with alum or alum-polyelectrolyte at similar conditions led to higher residual turbidity.

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A	Filter constant
A_o	Area of the filter
B	Filter constant
B_1	Constant
C	Concentration of suspension
C_o	Concentration of suspension at the inlet
C_g	Concentration of suspension mass/unit volume
$C_1(T)$	Concentration of suspension entering the layer at filtration time T
$C_2(T)$	Concentration of suspension leaving the layer at filtration time T
$\bar{C}(T)$	Average suspended solid concentration in layer ΔL
F	Theoretical filter capacity
H_o	Head loss in the clean filter medium
H_L	Total head loss
H_T	Head loss
J	Hydraulic conductivity
J_o	Hydraulic conductivity of clean medium
L	Depth measured from the surface
L_{min}	Minimum depth
P_c	Cumulative probability
Pe	Peclet number
$Q(T)$	Amount of material collected in the layer ΔL up to time T
T	Filtration time
T_1	Absolute temperature

T_2	Temperature
U	Variate
V	Volume
a_o	Constant
a_1	Constant
b	Filter constant
d_f	Fibre diameter
d_g	Collector or grain diameter
d_p	Particle diameter
f_o	Porosity of the clean filter medium
g_o	gravitational acceleration
h_K	Kozeny constant
i	Hydraulic gradient of the closed filter medium
i_o	Hydraulic gradient of the clean filter medium
k	Filter constant
k_1	Filter constant
k_2	Filter constant
k_3	Boltzmann's constant
k_4	Constant
k_5	Accumulation coefficient
k_6	Detachment coefficient
m	Constant
r	Constant
s_o	Specific area of the filter pores at $t = 0$
t	Filtration time
t_H	Time

u	Interstitial velocity
u_c	Interstitial velocity at which no deposition would take place in an initially clean medium
u_o	Initial interstitial velocity
v	Rate of filtration
x, y, z	exponents
α	Self porosity of deposited material
α_o	Collision efficiency
α_1	Scour coefficient
β	Bulking factor
η	Single collector efficiency
η_D	Collector efficiency for diffusion
η_G	Collector efficiency for gravitational settling
η_I	Collector efficiency for interception
η_T	Overall efficiency
λ	Filter coefficient
λ_o	Initial filter coefficient (clean filter)
λ_T	Filter coefficient
μ	Coefficient of viscosity
ν	Degrees of freedom
ρ	Density of fluid
ρ_p	Density of particles
ρ_s	Density of deposited material
σ	Volume of deposited particles/until filter volume
σ_g	Specific deposit mass/unit volume
σ_T	Specific deposit at time T

σ_u	Maximum specific deposit (saturation or ultimate specific deposit)
ϕ	Filter constant
FTU	Formazin turbidity units
J.T.U.	Jackson turbidity units
R.H.A.	Rice hull ash