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Research Article

Leaching behavior of vitreous fertilizers for application as plant nutrients

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ABSTRACT

In view of the significant role of macro and micro nutrient elements for increasing food production to feed the growing population along with maintaining soil fertility, glassy fertilizers to supply the said need were prepared in the laboratory. The main objective of the present work is to study the role of different nutrient elements in the glass composition to be used as fertilizers. This has aimed to provide a better substitution of chemical fertilizers because of its specific nature of leachability in an aqueous medium. In the present research paper, the combined varying effect of different nutrient elements such as P, B, Zn, Fe, Cu, K and Si were analyzed using different experimental techniques.

Key words: Glass fertilizer, Leaching, Plant micro-nutrients, Controlled- released, Productivity

INTRODUCTION

In the present century, the world population so overloaded to reach eight billion coupled with increasing urbanization resulted in lack of cultivable land. The global food requirements can be fulfilled by crops with greater yield which also requires suitable nutrients inputs in the form of fertilizers. The chemical fertilizers which are in used presently have led to the problems of soil and groundwater contamination, mostly because of their water solubility. This not only contaminated the soil but also led to wastage of supplied nutrients. This can also lead to the rise in public scrutiny of the ill effects of agriculture (Varadachari, 1992)**.** Glass fertilizers are control released fertilizers, made in glass matrixes containing the most useful macro elements(P, K, Ca, Mg) and also incorporate some other micro elements (B, Fe, Zn, Cu, Mn, Mo, V, Si) required for the balance growth and development of crops and plants throughout their life cycle in maintaining physiological functioning (Chaturvedi *et al.,* 2014)**.** The researchers and technologists all around the world are much concentrated on the pollution of soil, ground water contamination and non-fertility of soil. The research works are also being carried out to determine the impact of nutrient elements for various types of crops and plants in different climatic conditions(Waclawska and Szumera, 2009; Torrisi *et al.,* 2013; Chaturvedi *et al.,* 2008; Javed *et al.,* 2013) but earlier made efforts in this area of research could not take a shape as a viable technology.

MATERIALS AND METHODS

Analytical and reagent grade chemicals as raw materials were used for the preparation of glass composition. The raw materials were weigh out as per calculations (mentioned in Tables 1 and 2) in an electronic balance and properly mix with acetone to get a homogeneity and further leave for overnight. Batches of glass compositions were melted in alumina crucibles of 100 ml. capacity in an electric furnace at 900 °C+5 °C. The melts were then poured on aluminum plate (as base) within a metal made mould. After getting it dried stored in a desiccator. The half of glass prepared was separated for getting powder with the help of a planetary ball milling. After ball milling the powder passed through sieves of 45μm particle size for agriculture application.

For leaching behavior experiments the solid samples were immersed in 100 ml distilled water for different period of time in a digital hot air chamber maintaining the temperature at 35 °C throughout the investigations. Glass specimens were tested for surface morphology and presence of nature of bond formation in prepared glass compositions and after leaching the related deficiencies of some species from glass matrix by using the techniques SEM and FTIR. The batch calculations for the samples are summarized in table 1 and 2.

RESULTS AND DISCUSSIONS

Leaching can be defined as loss or extraction of certain material or species from a carrier into a liquid. Another term for this is lixiviation, or the extraction of a soluble particle from its constituent parts. The release of species and other constituents from glasses in aqueous solution is due to the hydrolysis reaction (Bansal and Doremus, 1986). In the hydrolysis some bonds of glass network are broken which further leads to destruction of glass network if the medium is aggressive.

The leaching of the glass samples was studied using by immersion test method in different beaker of 250 ml. capacity containing 100 ml. water respectively at 35 °C for maximum 60 days. During this duration weight loss was measured after

15th day, 30th day, 45th day and 60th day and are summarized in Table 3. The weight of a sample before and after leaching can help in finding absolute weight loss of the samples and the rate of leaching were also calculated as their per day loss of species from glass network. This kind of leaching behavior investigated in laboratory has a direct significance with agricultural aspect i.e. the action of glass compositions with the soil in which the plants grow and complete their life- cycle.

It is evident from the Table 3 that leaching of species from the glass network is taking place for different duration of time which has a good resemblance with our motive of research. It is also clear here that in the beginning the leaching rate is high which becomes slower in later course of investigation and finally, better rate of leaching was observed for sample 1 consistently. This may be due the lowest density which indicates about the weak bond formation of glass network in this particular composition.

Table 1: Calculation of the batch for glass composition

Sample 1: 55.0 P_2O_5+8.0 SiO_2+7.0 B_2O_3+15.0 K_2O+[6.0 ZnO+6.0 FeO+3.0 CuO]				
Compound	**Mole %**	**Molecular wt.**	**Weight**	**Weight %**
P_2O_5	55.0	142	7810	68.82
SiO_2	8.0	60	480	4.23
B_2O_3	7.0	70	490	4.31
K_2O	15.0	94	1410	12.42
ZnO	6.0	81	486	4.29
FeO	6.0	72	732	3.81
CuO	3.0	80	240	2.12
	100.0		11348	100

Table 2: Calculation of the batch for glass composition addition with MnO

Sample 2: 50.0P_2O_5 + 7.0 SiO_2 + 7.0 B_2O_3 +15.0 K_2O + [6.0 ZnO + 6.0 FeO + 3.0CuO + 6.0 MnO]				
Compound	**Mole %**	**Molecular Wt.**	**Total Wt.**	**Weight %**
P_2O_5	50	142	7100	64.5
SiO_2	7	60	420	3.81
B_2O_3	7	70	490	4.45
K_2O	15	94	1410	12.8
ZnO	6	81	486	4.4
FeO	6	72	432	3.9
CuO	3	80	240	2.18
MnO	6	71	426	3.87
	100		11004	99.9

The results obtained while studying the leaching behavior of the samples before and after leaching, FTIR analysis was carried out. It has been observed by doing a comparison between the plots received after FTIR analysis that around 600 wave number Si-O-Si bonds have taken place and around 1000 wave number there is Si-O stretch (Figure 1). We can clearly see this kind of deflection in the graphs. There is a clear evidence of peak at wave number 750(cm^{-1}) in Figure 2, which is actually before leaching, the same peak disappears after leaching indicates that the bond formed in the glass network broke due to leaching in water system resulting a nominal change in transmission value.

Figures 3 and 4 show the dissolution of some species from the glass network by the attack of water molecules. In aqueous media the dissolution may takes place by the following reaction due to breaking of silicon –oxygen network (Bansal and Doremus, 1986).

$$H_2O + \text{-Si-O-} \text{ -------> } \text{-SiOH. HOSi-}$$

Similar investigation have reported by other researchers (Cox and Khooli, 1992; Cox and Ford, 1989) when glass specimens were exposed in soil and water for a long duration of time initially, dissolution of glass will start(via ion exchange) of some weak bonded species from the glass network(Paul, 1990). Further, the monovalent cations present in network are more easily diffused because of their mobility in comparison doubly charged (divalent) and triply charged (trivalent cations) which are tightly bound with the glass network. In the similar way divalent and trivalent cations may migrate out from the glass network and finally tetravalent will be leached out with ultimate destruction of network (Chaturvedi *et al.,* 2014). Considering the surface morphology among the micrographs before and after leaching for exposure to water system for 60days, it is clear from the comparison of the micrographs that some species have migrated out from the glass network in the case of both samples of vitreous fertilizers. In addition to this, it is also evident while going through the micrographs that the greater destruction in the surface morphology was observed in case of sample 1 which has a almost good resemblance with the results obtained for rate of leaching.

Table 3: Absolute weight loss and rate of leaching for different duration of time

Sample no.& density	Immersion time (days)	Initial wt. (gm)	Final wt. (gm)	Weight loss (gm)	Rate of leaching (gm/day)
Sample 1	15	0.663	0.609	0.054	3.60×10^{-3}
Density-2.38	30	0.781	0.720	0.061	2.00×10^{-3}
	45	0.673	0.609	0.064	1.42×10^{-3}
	60	0.684	0.606	0.078	1.30×10^{-3}
Sample 2	15	0.923	0.903	0.020	1.33×10^{-3}
Density-2.82	30	1.796	1.765	0.031	1.03×10^{-3}
	45	1.776	1.741	0.035	0.77×10^{-3}
	60	1.654	1.615	0.039	0.65×10^{-3}

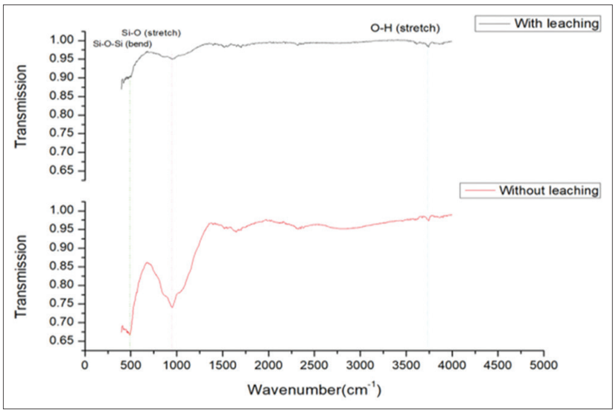

Figure 1: FTIR Spectra for Sample 1

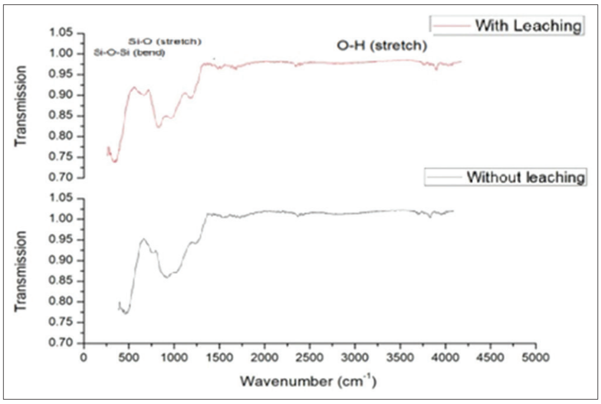

Figure 2: FTIR Spectra for Sample 2

A testing of soil has been carried out to know the existing nutrient position before application of glass compositions prepared in the agricultural research field. For this purpose, soil sample was taken randomly at a depth of 15 cm and get it air dried. There after the soil sample was sieved through 2.0mm sieve packed in polythene bags and stored. By using DTPA extractable method with AAS for Fe, Zn, Cu, Mn , colorimetric method for B, available N by Kjeldahl method, and available P by Olsen's method and available k by Flame photometric method have been employed for carrying out the macro and micro elements analysis for the soil of our research field and related results are summarized in Table 4.

The field trial has also been conducted during the spring season in small research field which has been developed for testing the prepared glass compositions and their related observations are illustrated in Table 5 and 6. The glass compositions [sample 1] was applied on ladyfinger and [sample 2] on tomato seeding and plantations.

By doing a comparative study among all the segments in terms of germination, plant height, plant branches and number of vegetative, it has been observed that both the compositions are giving better germinations (quick and more plants in numbers) rather than without ceramic and chemical nutrient segment. It is also evident from both the tables of agriculture parameters investigated that both the glass compositions show better and consistent results throughout the course of investigation and provide almost relatively similar and better response in comparison to chemical nutrients fertilizer used

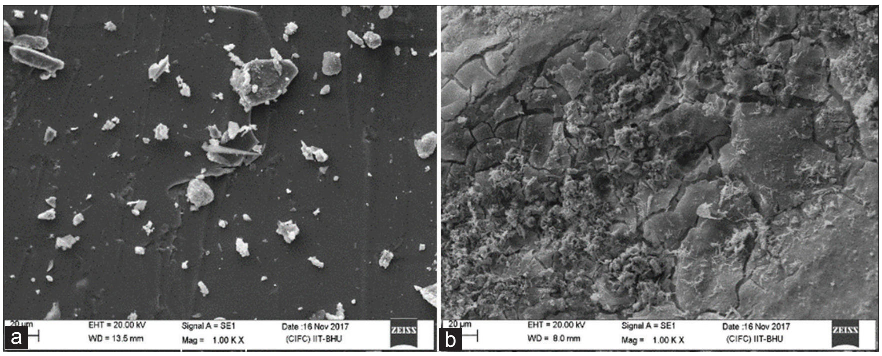

Figure 3: Surface Micrograph of Glass Specimen before (a) and after (b) leaching for sample 1 exposed to water system for 60 days duration at magnification 1.00kx

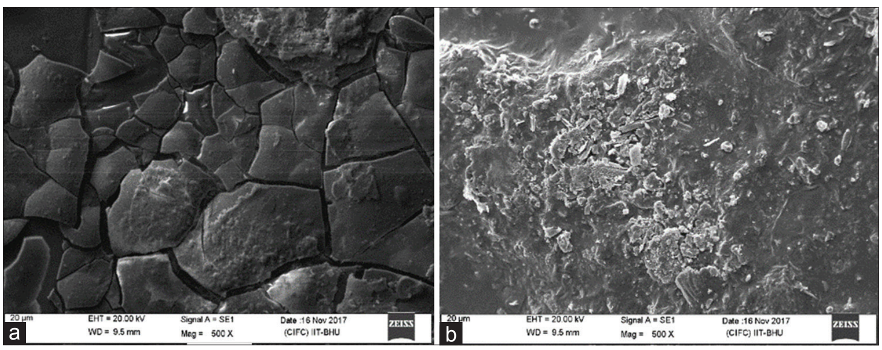

Figure 4: Surface Micrograph of Glass Specimen before (a) and after (b) leaching for sample 2 exposed to water system for 60 days duration at magnification 500x

Table 4: Macro and micro- nutrient elements concentration in (ppm) of the soil observed along with pH and TDS

pH 7.94	TDS 390	Organic carbon %	N (kg/ha)	P (kg/ha)	K (kg/ha)	B (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	S (ppm)
Observed Values		0.41	140.0	34.28	189.17	0.62	12.11	1.56	0.79	7.32	12.36
Std. Range		0.10-1.11	40-245	3-90	70-600	0.10-11.5	2-80	1-6.50	0.10-5.37	2-28	2-59

Table 5: Effect of ceramic fertilizer (sample 1) along with chemical fertilizer on ladyfinger seeding and plants

Testing Period (in days)	Agriculture Observations	Without fertilizer	Chemical fertilizer	Ceramic Fertilizer
10	Germination	slow	good	good
20	Plant Height (cm)	1	3	4
	No. of plant branches	4	6	8
30	Plant Height (cm)	8	12	12
	No. of plant branches	6	9	10
	No. of flowers appearance	2	4	7
40	Plant Height (cm)	16	21	22
	No. of plant branches	8	11	12
	No. of flowers/ vegetative	5	7	10
	Vegetative size(cm)	2	3	5
50	Plant Height (cm)	24	29	32
	No. of plant branches	10	14	14
	No. of flowers/ vegetative	10	14	14
	Vegetative size (cm)	4	5	6
60	Plant Height (cm)	32	36	42
	No. of plant branches	10	14	14
	No. of flowers/ vegetative	10	15	15
	Vegetative size(cm)	5	6	6.5

Table 6: Effect of Ceramic fertilizer (sample 2) along with chemical fertilizer on tomato seeding and plants

Testing Period (in days)	Agriculture Observations	Without fertilizer	Chemical fertilizer	Ceramic Fertilizer
10	Germination	good	Very good	Very good
20	Plant Height (cm)	6	8	8
	No. of plant branches	4	4	4
30	Plant Height(cm)	14	17	17
	No. of plant branches	6	7	7
	No. of Flowers appearance	3	6	7
40	Plant Height(cm)	22	26	26
	No. of plant branches	9	11	11
	No. of flowers/ vegetative	3	6	7
50	Plant height (cm)	49	55	59
	No. of plant branches	10	15	15
	no. of flowers/vegetative	4	8	8
60	Plant Height (cm)	59	65	70
	No. of plant branches	14	16	20
	No. of flowers/vegetative	6	8	9

for study. While studying the experimental data observed from table 5&6, the effect of the vitreous fertilizer [sample 1 for ladyfinger and sample 2 for tomato] show an evident influence along with maintaining their physiological functioning and nutrients deficiencies occur from time to time in agriculture fields.

CONCLUSIONS

Various glass compositions having different micronutrients and macronutrients were successfully prepared in the laboratory. The leachability of the glasses was obtained in adoptable release of nutrients for longer periods. The present work was successful in the preparation of glass powders to be used for enhancing food production and in maintaining soil fertility. Immersion test method showed that the leaching rate was higher in the beginning and became slower in later course of investigation. Finally, a better rate of leaching was observed for sample 1 and its rate of leaching was consistent throughout the course of study. Surface morphology of the glass samples also confirmed the results obtained during leaching experiments. The prepared glass compositions were successfully applied [sample 1] on the ladyfinger and [sample 2] tomato seeding/ plants which provided a better germination along with other agriculture parameters investigated throughout the course of study. It is important to mention that both the tested glass compositions may be a better substitution of chemical fertilizers for enhancing the production as well as removal of non- fertility in Indian agricultural situations.

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